Original Article

Long-Term Outcomes of Laparoscopic Repair of Complex Ureteral Injuries: A Single-Center Experience

Kenneth Cintrón-Cartagena[1,2*], Amanda Torres-Arroyo[2], Emil Varas-Rodríguez[2], Gustavo Colón[2], Rodrigo Ortiz[2], Gilberto Ruiz Deyá[1,2]

[1]Department of Urology, St. Luke's Episcopal Medical Center, Ponce, PR
[2]School of Medicine, Ponce Health Sciences University, Ponce, PR
*Correspondence: kcintron19@stu.psm.edu
DOI: 10.71332/283bzy33

Abstract: Ureteral injuries, often iatrogenic during gynecological or endo-urological procedures, can severely impact quality of life and renal function, potentially causing sepsis or renal failure. The distal ureter is most vulnerable, and resulting strictures require management based on their cause, location, and length. Short distal strictures are treated with ureteroureterostomy or ureteroneocystostomy, while longer ones may require a Boari flap with psoas hitch or ileal ureter replacement. This study evaluates postoperative renal function and symptoms recurrence in patients treated with these techniques for complex ureteral injuries. A retrospective review of 14 patients treated between 2007 and 2017 was conducted. Nine underwent laparoscopic Boari flap and five ileal loop interposition, with at least five years of follow-up. Intraoperative and postoperative outcomes were analyzed. Indications included endoscopic surgery strictures (3), radiation-induced strictures (2), and non-urological iatrogenic injuries (7). Two patients had primary ureteral cancer. Mean operative time was 158 minutes, and hospital stay averaged 2.1 days. Preoperative creatinine was 1.3 mg/dL, increasing to 1.4 mg/dL and 1.5 mg/dL at one and three months postoperatively. CT cystogram showed vesicoureteral reflux in all Boari flap patients. At five years, all patients were symptom-free with unobstructed ureters. Complications included one ileus and one anastomotic stricture. Boari flap and ileal ureter replacement are effective alternatives for complex ureteral strictures, preserving renal function. Larger studies are needed to validate these findings against standard open techniques.

Keywords: Ureteral injuries; Ureteral strictures; Boari flap; Ileal ureter replacement.

Academic Editor: Karla Santiago-Soltero, MD

Received: 2/3/2025
Revised: 5/20/2025
Accepted: 5/30/2025

1. Introduction

Ureteral injuries adversely impact both patient quality of life and renal function. Although ureteral injury is uncommon, it can lead to sepsis and renal failure [1]. Iatrogenic injury, particularly following gynecological or endourological surgeries, has emerged as the primary cause of such injuries, with the distal ureter being the most vulnerable region [1]. This susceptibility is compounded in scenarios involving radiation-induced injuries, malignancy, which, along with iatrogenic causes, contribute significantly to the prevalence of ureteral strictures. Therapeutic management for ureteral strictures is tailored based on the cause, location, and length of the stricture. Short distal ureteral strictures, generally up to 4–5 cm, are often effectively managed with ureteroureterostomy or ureteroneocystostomy [2]. Although these techniques are used for shorter ureteral strictures, they might induce tension at the anastomosis site for ureteral strictures of 12-15 cm, which compromise surgical outcomes.

Regarding longer distal and middle ureteral strictures and how to address them, the Boari flap, supplemented by a psoas hitch, presents a robust solution. This technique, capable of bridging defects up to 12 to 15 cm, leverages the rich vascular supply from adjacent ureteral tissue and depends on sufficient preoperative bladder capacity [3]. In addition to facilitating anatomical continuity, the Boari flap combined with a psoas hitch has been shown to evade the risk of recurrent urinary tract infections and prevent electrolyte derangements in patients with long segmental ureteral strictures [3]. This technique involves vesicular mobilization to the affected side and pulling superiorly to ensure a tension-free connection, usage of a submucosal conduit to decrease the risk of ureteral reflux for the re-anastomosis and securing the suture to the ipsilateral psoas tendon to evade coiling of the ureter [3]. However, because this technique depends on bladder capacity, Boari flap supplemented by psoas hitch may not be sufficient for more complicated cases, such as retroperitoneal fibrosis or total ureteral avulsion.

Other studies have shown that for longer and more complex ureteral strictures, where ureterolysis fails, intestinal substitution emerges as a suitable alternative [4–6]. This method, although used sparingly, helps avert nephrectomy by replacing the ureter with intestinal segments, thus preserving renal function [5–7]. The technique of ileal ureter entails medialization of the colon and subsequent Gerota Fascia incision with the purpose of both visualizing anatomy and exposure of the renal pelvis [5,8]. After excision of the superior ureteral portion, the ileal segment is measured and isolated at 20 cm from the ileocecal valve and bowel continuity is re-established by an endostapler [5]. Transverse holes are then sealed with continuous suture for further configuration of the bowel segment with the purpose of ileal placement completion by both pyelo-ileal and ileovesical anastomoses [5]. This streamlined approach to addressing ureteral injuries underscores the necessity of a tailored surgical strategy that adapts to the unique challenges posed by the nature and extent of the ureteral damage. Recent studies have demonstrated that this surgical technique, when performed laparoscopically, results in shorter operative times when compared to robotic alternatives [9, 10]. In contrast, other authors have suggested that, while traditional open surgery is vital for reconstructive procedures, minimally invasive techniques, like laparoscopic and robotically-assisted procedures, represent a compelling alternative associated with less morbidity and mortality [11].

An essential component of the population our center serves is the fact that it is not only underserved, but also that there is an ever-increasing demand for specialized surgical practitioners. Hence, providing accessibility for patients in need and training for those who will be performing these interventions on their own in the near future is of the utmost importance. In this study, we aim to present these surgical approaches to complex ureteral strictures stemming from previous radiation, trauma, iatrogenic injury, or idiopathic retroperitoneal fibrosis and evaluate for any changes in renal function and recurrence of symptoms postoperatively.

2. Methodology

Study population: Retrospectively acquired data of fourteen patients that underwent surgical correction of ureteral stricture from 2007-2017 by an experienced surgeon at St. Luke's Episcopal Medical Center in Ponce, Puerto Rico was evaluated. All methods were carried out in accordance with relevant guidelines and regulations. Informed consent was obtained from all subjects as per institutional protocol. The cohort of patients (n=14) included in this study was stratified into two groups: one group underwent Boari flap with psoas hitch (n=9) and the other group underwent ileal ureteral substitution (n=5). All procedures were performed by a single surgeon using a laparoscopic approach. Epidemiological and clinical data were extracted for each patient. Variables such as age, sex, body mass index (BMI), and stricture etiology (endoscopic surgery, radiation-induced, non-urological surgery, iatrogenic injury, and primary ureteral cancer) were evaluated in the study. Patients (n=14) with radiologic imaging results showing ureteral strictures at 10 cm or more and patients (n=2) with underlying malignancies localized in the mid and distal ureter from the aforementioned etiologies were included in this study.

Operative technique: The patients were placed in a supine position. Trocar placement was arranged in a fan-like configuration approximately 2 cm above the umbilicus. One is in the midline, and the other two trocars are on each side. In cases involving ileal loop anastomosis, an additional trocar was placed between the xiphoid process and the trocar above the umbilicus. The ileum was the segment used in all cases, with the proximal end anastomosed to the renal pelvis and the distal portion to the bladder. The segment of the ileum was harvested using an endoscopic stapler.

Evaluation of clinical outcomes: Parameters for intraoperative analysis were divided in operative time and intraoperative complications. Perioperative outcomes were compared between the groups. Creatinine was assessed preoperatively and, at one and three months postoperatively. Average hospital length of stay and operating time were calculated for both cohorts. Post-op CT Cystogram was performed to evaluate for vesicoureteral reflux. Follow-up at five years was performed to evaluate for symptoms and ureteral obstruction via CT Urogram.

Statistical analysis: Central tendency measurements were used to describe the sample distribution. The distribution of clinical variables was analyzed using contingency tables and Fisher's or Chi-squared (X2) tests. To assess the statistical significance of mean differences in continuous variables, the Mann–Whitney U test was used.

3. Results

As summarized in Table 1, our study cohort consisted of eight female and six male patients. A total of nine cases underwent the Boari flap procedure after having a stricture as a result from an endoscopic surgery or a non-urological surgery iatrogenic injury. From that group, three cases had

a stricture from an endoscopic surgery (21.4%) and six cases (42.9%) from a non-urological surgery iatrogenic injury. There were no cases involving any radiation or malignancies. The mean age for the Boari flap group was 61 years old, and seven female patients underwent this procedure, which notably accounted for 50% of our total cohort. A total of five cases were included in the Ileal ureter procedure group. The causes for strictures in this group of patients were varied, including radiation-induced strictures, non-urological surgery iatrogenic injury, and a stricture followed by a primary ureteral cancer. From this group, two cases (14.3%) presented with a radiation-induced stricture, one case (7.1%) had a non-urological surgery iatrogenic injury (multiple endoscopic and reconstructive procedures), and two cases (14.3%) had a stricture followed by a primary ureteral cancer. There was no case involving endoscopic surgery stricture under this group. The mean age for this group was 60 years of age, from which 28.6 % of the whole cohort involved male patients.

Table 1. Description of the study cohort, including cases that underwent Boari flap and Ileal loop interposition procedures.

Variables	Boari flap (n=9)	Ileal ureter (n=5)	p-value
Age mean (SD)	61.3 (12.3)	60.0 (6.3)	1.000
Sex			
Female	7 (50.0)	1 (7.1)	0.1261
Male	2 (14.3)	4 (28.6)	
BMI			
<25 kg/m^2	4 (28.6)	0 (0)	0.2516
≥25 kg/m^2	5 (35.7)	5 (35.7)	
Stricture Etiology			
Endoscopic Surgery	3 (21.4)	0 (0)	
Radiation Induced	0 (0)	2 (14.3)	
Non-Urological Surgery Iatrogenic Injury	6 (42.9)	1 (7.1)	
Primary Ureteral Cancer	0 (0)	2 (14.3)	
Stricture Etiology			0.0050
Surgery-related	9 (64.3)	1 (7.1)	
Radiation-induced	0 (0)	2 (14.3)	
Primary ureteral cancer	0 (0)	2 (14.3)	

Table 1. *p*-value was obtained from Mann-Whitney test, Chi-square or Fisher's exact test. SD: standard deviation; BMI: body mass index

Perioperative results are summarized in Table 2. Mean creatinine levels from the Ileal ureter procedure were higher compared to the Boari flap procedure. In both groups, levels increased from preoperative to postoperative (one and three months), respectively. The average preoperative creatinine was 1.3 mg/dL and postoperative 1.4 mg/dL and 1.5 mg/dL in one and three months, respectively. Same results appear in operating time with 162.02 ± 91.56 minutes and the hospital length of stay with 4.00 ± 1.73 days (p =0.0005) from the Ileal ureter group compared with the Boari flap group. Mean operative time for both groups was 158 minutes with a mean hospital stay of 2.5 days.

Table 2. Description of the perioperative variables in cases that underwent Boari flap (n=9) and ileal loop interposition (n=5).

Perioperative variables	Boari flap (n=9)	Ileal ureter (n=5)	p-value
Creatinine (mg/dL)			
Pre-op mean ± SD	1.16 ± 0.36	1.50 ± 0.21	0.0629
Post-op (1 month) mean ± SD	1.27 ± 0.42	1.62 ± 0.19	0.1374
Post-op (3 months) mean ± SD	1.42 ± 0.47	1.77 ± 0.24	0.2542
Operating time (min) mean ± SD	155.50 ± 8.28	162.02 ± 91.56	0.0784
Hospital length of stay (days) mean ± SD	1.11 ± 0.33	4.00 ± 1.73	0.0005

Table 2. *p*-value was obtained from Mann-Whitney test. SD: standard deviation.

Follow-ups at a mean of five years with CT Urogram after the surgical operation from both groups were assessed. All patients in the Boari flap cohort (n=9) that underwent a postoperative CT Cystogram presented with vesicoureteral reflux. All patients from Boari flap (n=9) and Ileal ureter groups (n=5) showed no symptoms with unobstructed ureters. One patient developed a postoperative ileus, and another presented with a uretero-vesical anastomosis stricture 16 months after the procedure, which was treated with an endoureterotomy.

4. Discussion

The present study emphasizes the importance of employing a tailored approach in managing ureteral strictures while weighing the effectiveness of the Boari flap with psoas hitch compared to the ileal ureteral substitution procedure. The Boari flap has been demonstrated to be a successful procedure for managing short to medium-length ureteral strictures. This procedure relies heavily on the leveraging of the rich vascular supply from the adjacent ureteral tissue and appropriate bladder capacity to support the implantation of the ureter [3]. Our results indicate that the Boari flap with psoas hitch procedure provides patients with favorable outcomes in the form of absent postoperative symptoms and lack of obstruction in the ureter [3]. In addition, there is a minuscule risk for recurrent urinary tract infections, stable levels of creatinine, shorter operative time, and shorter length of hospital stay. Nonetheless, the dependence of this procedure on bladder capacity may limit its

applicability in more complex cases, such as those with total ureteral avulsion of retroperitoneal fibrosis [3].

In contrast, the ileal ureteral substitution procedure has been proposed as an alternative solution for managing longer and more complex ureteral strictures [5–7]. In essence, this technique aims to preserve renal function and avoid a total nephrectomy by replacing the damaged ureter with an intestinal segment [5,6]. In this cohort, the patients in the ileal group had higher average creatinine levels at all time points, a difference which may be reflective of baseline differences rather than a disproportionate impact of the operation itself. Most notably, the preoperative creatinine in this group was elevated at baseline compared to the Boari group, while the observed postoperative rise was smaller. Furthermore, the ileal group consisted of 80% males, while the Boari group consisted of 22% males. The disproportionate presence of males in the ileal group may partially explain the higher baseline creatinine levels, as males typically have higher serum creatinine, especially in old age [5,6]. In addition, patients who underwent this procedure had longer operative times and hospital stays, likely reflecting the complexity and degree of underlying pathology. Despite these challenges, the long-term follow-up data is promising, as none of the patients reported any postoperative symptoms, and no signs of ureteral obstruction were present [5,6]. These signs are a testament to the durability and effectiveness of this approach.

Operative time and hospital stay were markedly varied between our groups. Patients undergoing ileal ureteral substitution had longer operative times (162.02 ± 91.56 minutes) and hospital stays (4.00 ± 1.73 days) compared to those who underwent Boari flap with psoas hitch (155.50 ± 8.28 minutes and 1.11 ± 0.33 days, respectively; $p = 0.0784$ and $p = 0.0005$). Despite these differences, neither procedure showed significant intraoperative complications, indicating that both are safe alternatives when performed by experienced surgeons. With regards to the creatinine levels, while absolute values were higher in the ileal ureter group at all time points, the relative rise during the postoperative period was greater in the Boari flap group. This finding suggests that renal function remained stable overall, with no disproportionate impact with either surgical approach. It is worthwhile to note that both techniques are directed towards preserving renal function and preventing further deterioration, which was successfully achieved in both groups. Long-term follow-up of these patients reveals the success of both procedures. At five-years postoperatively, no patients reported any symptoms, and imaging confirmed that no ureteral obstruction was present. These findings evidence the efficacy of both approaches and their ability to provide long-term relief from ureteral obstructions and associated symptoms.

The results of this study align with those reported by Benson et al., who described their institutional experiences with Boari flap, ileal interposition, and autotransplantation of the kidney in a cohort of 18 patients [12]. This study reports a high success rate of all techniques, with more

than 90% of patients preserving renal function and having positive radiographic outcomes at the latest follow-up. Similarly, no difference in outcomes between the Boari or ileal groups were observed, reinforcing the importance of a patient-specific tailored approach to addressing these pathologies, accounting for patient anatomy and case complexity. Our findings expand on this earlier work by reporting on long-term follow-up in the complex of new laparoscopic techniques. As a whole, the results from both studies highlight the need for prospective, multicenter trials to evaluate patient selection and long-term outcomes of these procedures.

Nonetheless, the current study is not without limitations. The small sample size of our cohort and the retrospective nature of the design can limit the generalizability of our findings. While the single-surgeon component can be beneficial for outcome consistency, it may not fully reflect the outcome diversity that could occur in larger centers and practices. Finally, the lack of radiation or malignancy-induced strictures in the groups can be a potential source of bias and may also limit the applicability of our findings. Future research should focus on conducting larger, multicenter studies that validate these findings and further explore additional techniques that can offer patients improved outcomes. Additionally, further study of the cost-effectiveness and accessibility of these procedures is needed, especially in the context of underserved populations.

5. Conclusions

The laparoscopic Boari flap with psoas hitch and ileal loop ureteral substitution are both feasible alternative surgical techniques for patients with complex ureteral strictures. They provide long-term relief and preserve renal function without any reported symptoms and with no evidence of ureteral obstruction after a five-year follow-up. Ileal loop ureteral substitution can be considered for the management of longer and more complex cases of ureteral strictures. However, more extensive studies are needed to validate these results compared to traditional open technique and to the level of complexity of strictures.

Author Contributions: Conceptualization, K. Cintrón-Cartagena and G. Ruiz Deyá; methodology, K. Cintrón-Cartagena and R. Ortiz; validation, K. Cintrón-Cartagena, A. Torres-Arroyo, E. Varas-Rodríguez, and G. Colón; formal analysis, K. Cintrón-Cartagena; investigation, K. Cintrón-Cartagena, A. Torres-Arroyo, E. Varas-Rodríguez, R. Ortiz, and G. Colón; resources, G. Ruiz Deyá; data curation, K. Cintrón-Cartagena; writing—original draft preparation, K. Cintrón-Cartagena, A. Torres-Arroyo, E. Varas-Rodríguez, R. Ortiz, and G. Colón; writing—review and editing, all authors; supervision, G. Ruiz Deyá; project administration, G. Ruiz Deyá; funding acquisition, G. Ruiz Deyá. All authors have read and agreed to the published version of the manuscript.

Funding: No funding was received for this study.

Institutional Review Board Statement: The study was approved by the Institutional Review Board (IRB) of Ponce Health Sciences University (IRB 2407210320).

Informed Consent Statement: Informed consent was obtained from all subjects involved in the study.

Data Availability Statement: The datasets used and/or analyzed during the current study available from the corresponding author upon reasonable request.

Acknowledgments: In this section, you can acknowledge any support given which is not covered by the author contribution or funding sections. This may include administrative and technical support, or donations in kind (e.g., materials used for experiments).

Conflicts of Interest: The authors declare no conflicts of interest.

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