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Etiology and Ureteral Reconstruction Strategy for Iatrogenic Ureteral Injuries: A Retrospective Single-Center Experience

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Keywords
Ureter · Iatrogenic ureteric injury · Ureteral strictures · Surgical management · Ureteral reconstruction

Abstract
Objective: To analyze the etiology, characteristics, and ureteral reconstruction strategies of iatrogenic ureteric injuries in a high-volume center. ***Methods:*** Between September 2010 and August 2019, we retrospectively collected patients who underwent ureteral reconstruction due to iatrogenic ureteric injuries. Patient profiles, laboratory data, imaging studies, perioperative data, and complications were recorded. ***Results:*** Sixty-eight patients were enrolled in this study. The upper, middle, and lower thirds of the ureter were affected in 30, 2, and 36 cases, respectively. Of the 68 ureteric injuries, 69.1% occurred during urological procedures, followed by gynecological procedures, general surgery, radiotherapy, and orthopedic surgery. The majority of urological injuries (41, 87.2%) occurred due to stone removal. There was a significant difference in the age, sex, and location of ureteric injuries between the urological and nonurological groups. The median follow-up time was 17.9 months. The overall symptom remission rate was 91.2% and ranged from 87.5 to 100% for different reconstructive surgeries. ***Conclusions:*** Urological procedures were the most common cause of iatrogenic ureteric injury; thus, extra care should be taken. Timely detection and appropriate treatment of the ureteric injuries are necessary. Treatment strategies should be depended on the location and length of injury.

Introduction

Iatrogenic injury is the most common cause of ureteric injury [1–3]. This type of injury occurs during gynecological, urological, and general surgery and other pelvic medical treatments. Based on previous research, gynecological surgery is the most common cause of iatrogenic injury, and the distal ureter is the most vulnerable part [1, 2]. Currently, the increasing use of endourological and laparoscopic surgery has resulted in changes in the frequency and etiology of iatrogenic ureteric injuries [4, 5].

Iatrogenic ureteric injuries lead to ureteral strictures, flank pain, dilation of the upper ureter, loss of renal function, or even death [3]. Ureteral reconstruction surgery is

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Table 1. Clinical characteristics and preoperative data of patients

	N (%)
Sex	
Male	33 (48.5)
Female	35 (51.5)
Age, years	44.6±11.7
BMI, kg/m^2	25.0±3.8
Side	
Right	32 (47.1)
Left	33 (48.5)
Bilateral	3 (4.4)
Location	
Upper 1/3	30 (44.12)
Middle 1/3	2 (2.94)
Lower 1/3	36 (52.94)
Symptoms	
Abdominal and/or flank pain	37 (54.4)
Fever	19 (27.9)
Urine leak	4 (5.9)
Vaginal drainage	3 (4.4)
Oliguria or anuria	2 (2.9)
No symptoms	23 (33.8)
Diagnostic examination	
CTU	24 (35.3)
Ultrasound	15 (22.1)
MRU	6 (8.8)
CT	4 (5.9)
Retrograde pyelography	4 (5.9)
Antegrade pyelography	4 (5.9)
Ureteroscopy	3 (4.4)
Enhanced CT	2 (2.9)
Intraoperative immediate	6 (8.8)
Diagnostic time	
Immediate	6 (8.8)
<3 days	9 (13.2)
>3 days	53 (77.9)
Etiology	
Urological	47 (69.1)
Gynecological	11 (16.2)
Radiotherapy	5 (7.4)
General	4 (5.9)
Orthopedic	1 (1.5)
Urine drainage before surgery	
Nephrostomy	43 (63.2)
Double “J” tube	14 (20.6)
No	11 (16.2)
Preoperative serum creatinine, μmol/L	94.0±28.3
Postoperative serum creatinine, μmol/L	88.5±26.1

CTU, computed tomography urography; MRU, magnetic resonance urography; CT, computed tomography.

necessary to prevent further consequences. Successful ureteral reconstruction must include a tension-free, watertight anastomosis that is adequately spatulated, with a good remaining blood supply, and the use of absorbable, fine sutures [6, 7]. The strategy of ureteral reconstruction depends on the etiology, location, and length of the ureteric strictures. Ureteroureterostomy and ureteroneocystostomy can be performed safely for short-length ureteric defects [8, 9]. For long and complex ureteric defects, a Boari flap, psoas hitch, or even an ileal ureter and autotransplantation should be considered [8]. In recent years, new tissue ureteral replacements have been developed with a good prognosis; such replacements include buccal/lingual mucosal grafts and appendiceal onlay flaps [10, 11]. Because of their good prognoses, these new techniques will reduce the use of long ileal replacement in some situations.

Although iatrogenic ureteric injury is uncommon, increased attention should be paid to this condition. Once ureteric injury occurs, it can be a great challenge for urologists. In this paper, we analyze the etiology of iatrogenic ureteric injury and report experiences regarding complex ureteral reconstruction for treating iatrogenic ureteric injuries.

Materials and Methods

From September 2010 to August 2019, 68 ureteral injuries were treated by a single surgeon at Peking University First Hospital. We retrospectively collected information regarding patient characteristics, etiology, laboratory data, imaging studies, operative data, perioperative data, and complications from our Reconstruction of Urinary Tract: Technology, Epidemiology and Result (RECUTTER) database.

Iatrogenic ureteric injury was classified as immediate diagnosis, which was defined as any laceration, avulsion, or transection identified during the surgery, and delayed diagnosis, which was defined as postoperative ureteral stricture identified on imaging studies. Failure of ureteral reconstruction surgery was excluded because it was a treatment outcome instead of an accidental injury. Patients were diagnosed by history, physical examination, laboratory tests, and radiological examinations, including antegrade and retrograde pyelography, nuclear renography, computed tomography urography (CTU), and magnetic resonance urography. The location of ureteric injury was verified by intravenous pyelography, retrograde pyelography, and enhanced urinary CT examination. For complicated ureteric injuries, a 3-dimensional CT reconstruction was performed. Complications were evaluated by the Clavien-Dindo classification system [12]. Surgical success was defined as improved/stabilized hydronephrosis or relief of symptoms.

Patients were followed up at 1 and 6 months after surgery and at least once a year thereafter. A physical examination, blood serum creatinine, urine routine tests, and urinary ultrasound were performed at each visit. Enhanced CTU was performed every year. However, for ileal ureters, patient follow-ups were complicated and frequent. In the first 2 years, patients visited the clinic every 3 months. The patients routinely received a physical examination, blood tests (including a blood gas analysis, serum creatinine test, and electrolyte test), urine routine test, and urinary ultrasound at each visit. Enhanced CTU was performed every 6 months.

All analyses were performed with SPSS® Statistics, version 20.0. The Kolmogorov-Smirnov test was used to determine whether the data were normally distributed. Differences between 2 groups were compared using the independent-sample *t* test for continuous variables and χ^2 test or Fisher's exact test for categorical variables. The rank-sum test was used for nonnormal distributions. A two-sided value of $p < 0.05$ was considered to indicate statistical significance.

Results

A total of 68 patients, including 35 women and 33 men, experienced iatrogenic ureteric injuries and were managed (Table 1). The mean age was 44.6 (range from 18 to 71) years. Complaints included abdominal and flank pain in 37 cases, fever in 19 cases, urine leakage in 4 cases, vaginal drainage in 3 cases, oliguria or anuria in 2 cases, and no symptoms in 23 cases. The injuries were located on the right side in 32 patients, on the left side in 33 patients, and bilaterally in 3 patients. The upper, middle, and lower thirds of the ureter were affected in 30, 2, and 36 cases, respectively. Only 6 patients were found to have a ureteral injury immediately during the initial surgery, 9 patients were diagnosed within 3 days after surgery, and 53 patients received a diagnosis >3 days after surgery. CTU was the most common imaging examination used for diagnosis. The mean preoperative serum creatinine level among all patients with ureteral injury was 94.0 μmol/L.

Regarding etiology, urological injuries accounted for 69.1% (47 cases) of the total cases and the nonurological injury group consisted of 11 gynecologic (16.2%), 4 general surgical (5.9%), 1 orthopedic surgery (1.5%), and 5 radiotherapy (7.4%) cases (online suppl. Table 1; see www.karger.com/doi/10.1159/000511141 for all online suppl. material). The majority of urological injuries (41, 87.2%) occurred due to stone removal, and most were in the upper third of the ureter (28, 41.2%). An endoscopic procedure was performed for a large proportion (30 cases, 73.2%) of patients with ureteric injury caused by stone removal. In detail, holmium laser lithotripsy was performed in 17 cases and pneumatic lithotripsy was performed in 3 cases. The details of endoscopic lithotripsy for the other 10 patients were not available at that time. Hysterectomy (5, 45.5%) was the most common cause of gynecological injuries, followed by hysterectomy plus bilateral salpingo-oophorectomy (4, 36.4%). Five radioactive ureteral injuries occurred after radiotherapy, 4 of which were due to treatment for gynecological tumors. All 3 bilateral ureteral injuries were caused by radiotherapy. All gynecological and radioactive ureteral injuries were in the lower third of the ureter. Among the ureteric injuries caused by general surgery, 2 occurred during radical resection of rectal carcinoma, 1 occurred during anal prolapse surgery, and 1 occurred after laparoscopic cholecystectomy. Three injuries occurred in the lower third of the ureter, while 1 occurred in the upper third. Furthermore, it should be noted that we found an upper ureteral injury caused by L_{3-4} lumbar tuberculosis surgery.

To compare the characteristics of different etiologies, we divided patients into 2 groups: urological and nonurological (Table 2). Patients in the urological group were younger than those in the nonurological group (p = 0.014). Significant differences were found in the sex and injury location between the urological and nonurological groups ($p < 0.001$). There was no difference in BMI, preoperative creatinine, postoperative creatinine, or complications between groups. In the urological group, an immediate diagnosis occurred more often, and the time to intervention with a delayed diagnosis of urological injuries was shorter than that for other etiologies, but without statistical significance.

According to the location and length of injury, we adopted different procedures (online suppl. Table 2). Multiple repair methods were used for upper ureteral injuries, and ileal ureter replacement (10, 33.3%) and pyeloplasty (7, 23.3%) were the most common procedures for management. A majority of lower ureteral injuries were repaired with a Boari flap (12, 33.3%) and ureteroneocystostomy (8, 22.2%). The ileal ureter replacement also played an important role in lower segment of the injuries (9, 25.0%). The number of injuries in the middle part was relatively small, and the management was mainly based on conventional repair (ureteroureterostomy and Boari flap). The median follow-up duration was 17.9 months (0.4–106.5 months). The symptom remission rate was 91.2% overall, ranging from 87.5 to 100% for different reconstructive surgeries. Postoperative ultrasound showed that all hydronephrosis had been improved by appropriate intervention, except for 1 case of aggravation after ureteroneocystostomy. Balloon dilation and endoureterotomy were performed to relieve moderate hydronephrosis. A total of 20 complications occurred in 15 cases. Intestinal obstruction (6 patients, Grade 2) and urinary tract infection (4 patients, Grade 1) were the most common complications, and 3 patients who underwent ileal ureter reconstruction presented metabolic acidosis (Grade 1). One patient with an anastomotic fistula recovered after conservative treatment (Grade 2). The major postoperative complications are shown in Table 3.

Table 2. Comparison of different etiologies of ureteral injuries

	Urological	Nonurological	p value
Age, years	42.3±10.9	49.8±11.9	0.014
Gender			
Male	30	3	<0.001
Female	17	18	
BMI, kg/m^2	25.4±3.9	24.1±3.4	0.191
Location			
Upper	28	2	
Middle	2	0	<0.001
Lower	17	19	
Preoperative creatinine, μmol/L	98.1±28.6	84.9±25.9	0.075
Postoperative creatinine, μmol/L	91.7±25.8	81.3±26.0	0.130
Diagnostic time			
Immediate	4	2	
<3 days	3	6	0.108
≥3 days	40	13	
Time to intervention in delayed diagnosis, months	6.5 (1–108)	6.0 (0.5–216)	0.906
Complications	9	6	0.528

Table 3. Major complications after reconstruction

Reconstruction strategy	Complication	Management
Grade III A		
Boari flap	Reflux after extubation	A secondary stent was placed
Appendiceal onlay	Double J tube shedding	The position of the D-J tube was adjusted under cystoscopy
Grade III B		
Bilateral ileal ureter with bladder augmentation	Intraoperative injury to the colon	Colostomy
Ileal ureter replacement	Incisional hernia	Hernia repair
Ureteroneocystostomy	Stone formation	Lithotripsy
Ureteroneocystostomy	Renal insufficiency	Balloon dilation combined with endoureterotomy

Discussion

The ureter is a moveable and flexible retroperitoneal organ that extends from the renal pelvis to the bladder, lies on the anterior surface of the psoas muscle, and is surrounded by muscle and abdominal organs. Because of the mobility, narrow diameter, and retroperitoneal position of the ureters, as well as the protection provided by overlying peritoneal contents, ureteric injury is a rare condition. Iatrogenic ureteric injuries account for 75% of ureteric injuries [2]. Among iatrogenic etiologies, gynecologic procedures are the most common, causing 52–82% of ureteric injuries, followed by general surgery and urological surgery [1, 13]. With the increasing use of endoscopic surgery, the etiology of ureteric injuries and the incidence of urological injuries have changed [5].

In our single-center experience, we found that urological surgery was the most common cause of iatrogenic ureteric injuries, followed by gynecological, radiological, general, and orthotopic surgery. A high rate of urological injuries was associated with the aggressive use of endoscopy, occurring in ureteroscopic lithotripsy and percutaneous nephroscopic lithotripsy. Notably, upper ureteral injuries accounted for a considerable percentage of endoscopic injuries. Therefore, when managing stones with endoscopy, especially stones in the upper ureter, extra care should be taken. Furthermore, holmium laser lithotripsy causes far more ureteric injuries than pneumatic lithotripsy. Li et al. [14] reported a significantly higher postoperative stricture occurrence rate for a Ho:YAG laser lithotripsy group than for a pneumatic lithotripsy group. A recent meta-analysis verified that laser lithotripsy resulted in more postoperative ureteral stricture than pneumatic lithotripsy (OR = 3.38) [15]. The laser power and irrigation rate are considered together to determine safe laser lithotripsy parameters. Aldoukhi et al. [16] performed an in vitro study to explore parameter safety boundaries and offer reference for selection of safe laser and irrigation settings. Proper selection of thermally safe laser settings and irrigation rates during ureteroscopy with laser lithotripsy may help reduce the risk of endourological ureteric injury.

Several strategies can be used to decrease complications during ureteroscopy procedures. Before ureteroscopy, double-J stent placement is preferred. Multicenter research has shown that preoperative double-J stent is an effective way to reduce intraoperative complications and improve the stone-free rate [17, 18]. During ureteroscopy, creation of ureteral access sheaths (UASs) is an alternative. It has been shown that UASs have a number of potential advantages, including facilitation of ureteroscope access, reduction of intrarenal pressure, and improved visibility [19]. Snow-Lisy et al. [20] recommend the routine placement of UASs for flexible ureteroscopy unless small stones (≤4 mm) are easily basketable. In addition, an UAS is not recommended for the semirigid ureteroscope [20]. However, there are some other voices concerning UASs are associated with an increased risk of ureteral injury is controversial [19, 21]. Thus, further investigation is needed. Meanwhile, managing impacted ureteral calculi with ureteroscopy requires more consideration due to failure of retrograde passage of a guidewire beyond the stone. In instances of severe ureteral stone impaction, it is often difficult to determine the edge of the stone from the edematous ureteral wall [22]. Prior series have suggested a synergistic increase in the risk of ureteral stricture with stone impaction [23–25].

Patient characteristics differed based on etiologies. Patients in the urological injury group were younger than patients in the nonurological group because of the large number of stone patients in the urological group. According to previous studies, the peak incidence of urinary stone disease occurs between 20 and 50 years of age [26]. However, tumors are more common in the older adults. Thus, we suggest that the age difference in susceptibility to the initial disease related to the ureteral injury was the primary cause of the age differences between groups. A previous study showed that urological ureteric injuries, especially those caused by endoscopic surgery, were found more frequently in the urological surgery group than in the nonurological group [5]. Although an immediate diagnosis occurred more often in the urological group, we found no significant difference between the urological and nonurological groups. This may be associated with the sample size and bias. Urological injuries occurred most often in the upper ureter and were significantly different from nonurological injuries. Notably, long upper ureteric injuries are more difficult to repair than long distal ureteric injuries; therefore, most ileal ureter surgeries were performed for urological injuries in our study. This result suggests that although urological ureteric injuries were found earlier and more easily, reconstruction of the ureter was sometimes more difficult than that for nonurological ureteric injuries.

The strategies of ureteral reconstructions were varied depending on the locations and lengths of the ureteric injuries. According to previous research, ureteric injuries mostly occur in the distal ureteral ureter [1, 2, 5]. Short distal ureteral defects can be managed by ureteroneocystostomy or ureteroureterostomy. For longer ureteric strictures, psoas hitches and Boari flaps can create a tension-free anastomosis. Sometimes the flap can even be used to reconstruct full-length ureteral defects [27]. However, for middle and upper ureteric injuries, the type of ureteral reconstruction was limited. Ureteroureterostomy and pyeloplasty were the preferred surgical method for short strictures. For wider upper and middle ureteral reconstruction, urinary tissue could not achieve a tension-free anastomosis. Combining our experience and previous reports, we found that the appendiceal onlay flap was a viable treatment option with satisfying result for patients with complex right proximal and midureteric strictures [11]. In addition, lingual mucosal graft ureteroplasty also presented a good prognosis in upper ureter stricture repair in our study.

Regarding long ureteral injuries, ileal ureter replacement and autotransplantation should be the final techniques considered. With long-term follow-up, ileal ureter replacement could resolve both long unilateral and bilateral ureteric defects with a good prognosis [28, 29]. On the basis of our findings, we advocate that strict selection of patients based on preoperative renal function is indispensable. Patients with significant renal insufficiency should be excluded, and patients with borderline creatinine should undergo combined ileal replacement and Boari flap-psoas hitch procedures to shorten the length of the ileal graft [30]. However, postoperative complications, including urinary infection, lithiasis, metabolic acidosis, mucus obstruction, or stenosis of the ileal ureter, must be taken into account. In addition, we did not perform autotransplantation due to the risk of vascular complications.

To the best of our knowledge, this is the largest single-center report of iatrogenic ureteric injury in our country. We reported our 9-year experience of iatrogenic ureteric injuries in patients, and our success rate was 91.2%. Our experience follows the "TB" principles described in previous research, which included a tension-free, watertight, thin suture, no touching of the key area, and protecting the blood supply [31]. These principles helped to improve the surgical success rate. Second, we suggest that urologists should have several alternative strategies. The initial determination of the location and the length of the ureteric strictures was performed by a preoperative radiology examination. The reconstruction strategy was finally devised according to the perioperative measurement. Third, we preferred using an omental wrap to preserve the blood supply of the anastomosis. Fourth, postoperative management of the patients was also necessary, especially for long ileal ureter replacement. Iatrogenic ureteric injuries were difficult to repair, and the surgery could easily fail. Patient compliance was increased with standardized postoperative management. If the surgery failed or complications occurred, medical treatment could be performed in a timely manner.

There are several limitations of our research. First, our hospital is a tertiary center. Our sample only included patients in our center, which might have influenced the outcomes. We have treated several complicated long iatrogenic ureteric defects in the last 5 years that resulted in a good prognosis. However, short-length iatrogenic ureteric injury cases were lacking. Second, most patients were referred to our hospital for ureteral reconstruction, and it was difficult to accurately identify the primary operation that led to the ureteric injury. The detailed processes of lithotripsy such as the diameter of the device, energy, frequency, whether to use a ureter access sheath, and whether to present a double-J stent before operation were unavailable. In addition, our research was retrospective and information on the exact length of the ureteral strictures was missing. At last, our criteria of success were not functionally assessed via renal scintigraphy. Therefore, multicenter prospective studies with large sample sizes and long follow-up periods need to be performed in the future.

In conclusion, urological procedures were the most common cause of iatrogenic ureteric injury, due primarily to the aggressive use of endourological techniques. Extra care should be taken when managing stones with endoscopy. Timely detection and appropriate treatment of the ureteric injuries are necessary. Depending on the location and length of the iatrogenic injury, different ureteral reconstructions must be performed. Nonetheless, despite the difficult treatment of iatrogenic ureteric injury, the procedure can be carried out effectively and safely by skilled surgeons with good surgical principles and postoperative management.

Statement of Ethics

This article is a retrospective study that contains data from human participants. This article does not contain any studies with animals performed by any of the authors. Informed consent was obtained from all individual participants.

Conflict of Interest Statement

The authors declare that they have no conflicts of interest.

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Author Contributions

G.P. Ding and X.F. Li: data collection, data analysis, and manuscript writing. D. Fang: manuscript editing and proof. H. Hao: project development. X.S. Li: surgery and study design. L.Q. Zhou: quality monitoring.

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