REVIEW PAPER

TRAUMA AND RECONSTRUCTIVE UROLOGY

Multi-institutional data analysis and literature review of comparative outcomes of autologous ureteral substitution techniques

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Introduction Complex ureteral strictures often require substitution techniques to preserve renal function. Multiple autologous reconstruction options exist, yet comparative outcome data across techniques remain limited.

Material and methods This multicenter retrospective cohort study included 168 patients who underwent ureteral reconstruction using ileal interposition, Yang–Monti tabularization, appendiceal interposition, or fallopian tube substitution. Preoperative, intraoperative, and postoperative variables were analyzed. Renal function outcomes were assessed using serum creatinine and estimated glomerular filtration rate (GFR). Complications were classified according to the Clavien–Dindo system.

Results Postoperative renal function improved significantly across the cohort, with mean creatinine decreasing from 2.19 ±1.35 mg/dl to 1.68 ±0.93 mg/dl ($p < 0.001$) and mean GFR increasing from 58.3 ±17.4 ml/min to 65.6 ±15.0 ml/min ($p < 0.001$). No statistically significant differences were observed among reconstruction techniques in renal outcomes, complication rates, or operative variables ($p > 0.05$). Electrolyte disturbances (12%) and infections (11%) were the most common complications.

Conclusions Ileal, Yang–Monti, appendiceal, and fallopian tube ureteral substitutions demonstrate comparable outcomes in renal preservation and complication profiles. These findings support individualized surgical decision-making based on patient-specific factors rather than inherent superiority of a specific technique.

Key Words: ureteral substitution ‹› reconstructive urology ‹› renal preservation ‹› bowel interposition ‹› Yang–Monti technique

INTRODUCTION

Complex ureteral stricture formation often results from iatrogenic, malignant, infectious, traumatic, or radiation-induced origins frequently necessitating substitution reconstruction to preserve renal function. Operative approaches that originated in 1906 have developed alongside technological advancements broadening patient eligibility and physiological benefits [1]. However, each technique accompanies unique anatomical challenges, risks, and complications including stricture recurrence, metabolic disturbances, mucus production, and ureteral leaks [1–3].

Literature reviews containing each of these techniques independently were found to be single-institutional with small patient sizes. Our study provides a multi-institutional retrospective analysis of 168 patients undergoing ileal interposition, Yang–Monti tabularization, appendiceal interposition, and

fallopian tube substitution due to ureteral stricture formation. Our study compared each technique with perioperative and postoperative data to assess renal outcomes, complications rates, and further stratify with demographic variables. Results of our study concluded that these autological techniques provide comparative outcomes with each other despite stratification of perioperative and postoperative variables, complications, and patient demographics.

MATERIAL AND METHODS

This retrospective cohort study analyzed patients who underwent ureteral repair using one of four reconstructive techniques: Yang–Monti, ileal substitution, appendiceal substitution, or fallopian tube substitution (Figure 1, Tables 1, 2). Data were collected from multicenter institutional surgical records and included preoperative, intraoperative, and postoperative variables. The dataset comprised 168 patients with complete data available for core variables. This was a retrospective, multi-institutional cohort study conducted across tertiary referral centers with expertise in complex ureteral reconstruction. Due to the retrospective and multicenter nature of the study, follow-up duration was heterogeneous and not standardized across institutions. Clinical, laboratory, and imaging data were collected based on the most recent available postoperative evaluation documented in the medical record. Renal function outcomes and complication data were analyzed using the last available postoperative follow-up for each patient. Durable success parameters such as need for reoperation, requirement for chronic ureteral stenting, and late complications were captured throughout the available follow-up period.

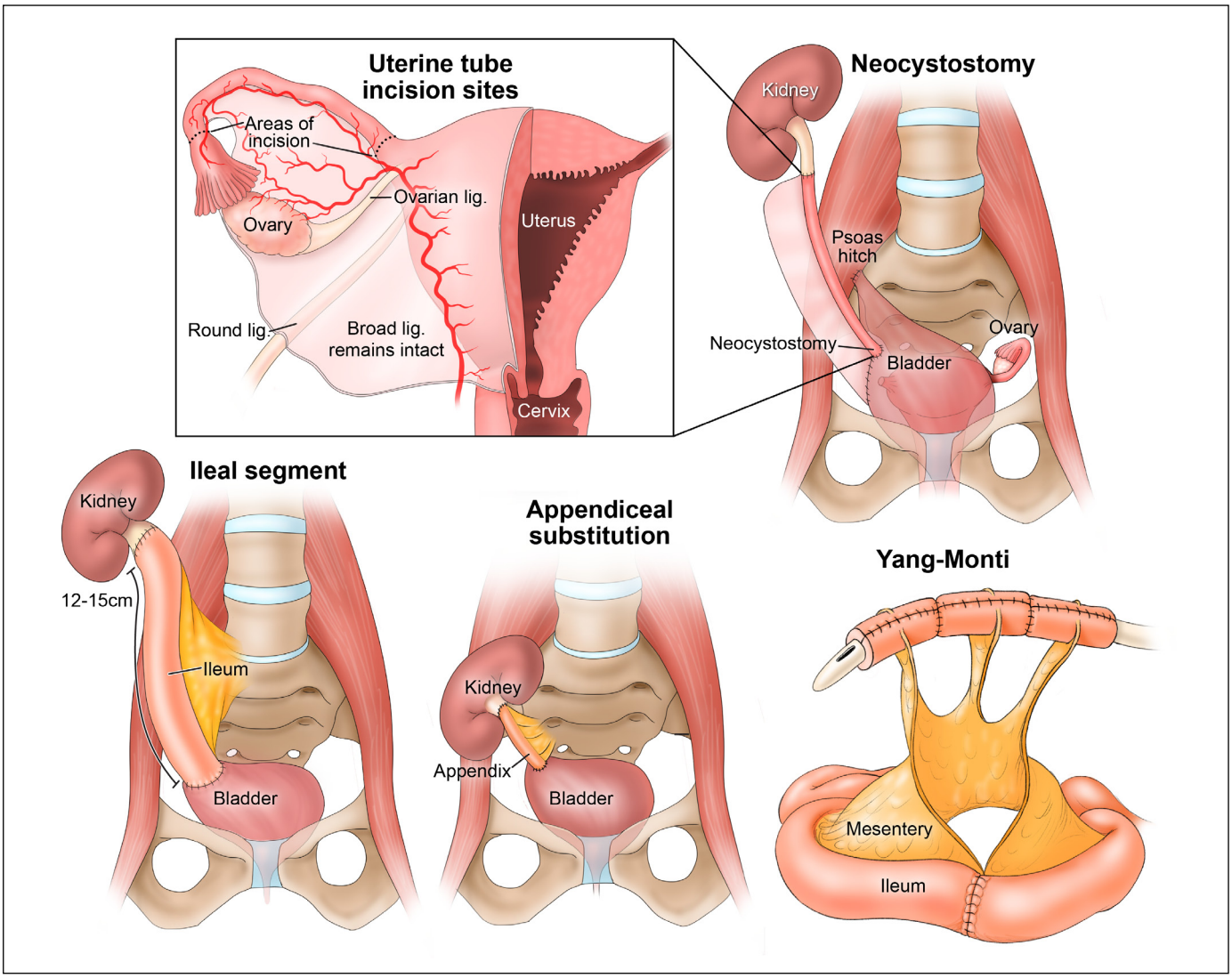

Figure 1. *Substitution techniques.*

Demographic variables included age, gender, and body mass index (BMI). Preoperative clinical factors analyzed consisted of preoperative stenting, exposure to radiation, baseline creatinine, and grade of hydronephrosis. Intraoperative variables considered were surgical approach, procedure length (in minutes), and estimated blood loss (EBL, in ml). Surgical success was primarily assessed using changes in serum creatinine and estimated GFR as global markers of renal preservation. Secondary outcomes included postoperative complications – categorized using the Clavien–Dindo Scale [4–6] – need for reoperation, requirement for chronic ureteral stenting, and radiographic or functional evidence of patency when available.

Statistical analysis included means, standard deviations, counts, and percentages. Paired t-tests compared pre- and postoperative creatinine and GFR values. χ^2 tests were used for categorical associations. Independent t-tests and one-way ANOVA evaluated differences across subgroups. Patients with incomplete creatinine or GFR values were excluded from any paired analyses but were included in descriptive summaries where applicable, and missing values were not imputed. All statistical tests were two-tailed, with p-values <0.05 considered statistically significant.

Table 1. *Repair technique*

Repair technique	Number of procedures
Yang–Monti	58
Ileal substitution	48
Appendix substitution	44
Fallopian tube	18
Grand total	168

Table 2. *Surgical approach*

Approach	Total	Percent
Open	74	44.047619
Laparoscopic	27	16.0714286
Robotic	67	39.8809524

Bioethical standards

The study was approved by Institutional Review Boards Italy (Ospedale Cristo Re, Ospedale San Filippo Neri and Ospedale Sant'Eugenio Rome, Policlinico Campus Biomedico; No. approval: ITEUAI 233976655-21.1.2.3.4; date: 11.2.2025); Institutional Review Board Spain (Uros Associates, Clinica Sagrada Familia; No. approval: EUES 0288679_11, date: 10.12.2025); United States Institutional Review Board (Mount Sinai) of Icahn School of Medicine at Mount Sinai (No. approval: 8554223/22A; date: 3.4.2025).

RESULTS

A total of 168 patients were included in the analysis, with a mean age of 50.9 years (range 18–82). Reconstruction techniques included Yang–Monti ileal reconstruction in 58 patients (34.5%), ileal interposition in 48 patients (28.6%), appendiceal interposition in 44 patients (26.2%), and fallopian tube substitution in 18 patients (10.7%). Preoperative radiation exposure was present in 51.2% of patients, and 58.9% had preoperative ureteral stents in place.

Renal function outcomes

Postoperative renal function improved significantly across the entire cohort. Mean serum creatinine decreased from 2.19 ±1.35 mg/dl preoperatively to 1.68 ±0.93 mg/dl postoperatively (p <0.001). Similarly, mean estimated GFR increased from 58.3 ±17.4 ml/min to 65.6 ±15.0 ml/min (p <0.001), with a mean ΔGFR of +7.3 ml/min.

When stratified by reconstruction technique, no statistically significant differences were observed in the degree of renal function improvement among groups (ANOVA: p = 0.87 for creatinine change, p = 0.16 for GFR change).

Table 3. *Minor and major complications early and late per repair type*

Repair	Sum of minor late complications	Sum of major early complications	Sum of major late complications	Sum of minor early complications
Montie	49	29	9	29
Ureteral substitution	34	22	14	26
Appendix	31	16	13	28
Fallopian tube	14	4	4	14
Total	128	71	40	97

Operative characteristics

The mean operative time across all procedures was 131.1 minutes. Mean estimated blood loss was 383.4 ml and did not correlate significantly with body mass index ($r = -0.14$) or procedure duration ($r = -0.02$). No significant associations were identified between reconstruction technique or surgical approach (open, laparoscopic, or robotic) and estimated blood loss or overall complication rates (ANOVA: $p = 0.91$ and $p = 0.36$, respectively). Blood transfusion requirements were uncommon, with 22.0% of patients receiving at least one unit of packed red blood cells.

Complications and reoperation

Complications were classified using the Clavien–Dindo system, and they occurred across all reconstruction types (Figures 2–15, Tables 3–17). Early complications were most frequently related to transfusion requirements and anastomotic leaks, whereas late complications were predominantly electrolyte disturbances and gastrointestinal events.

Reoperation was required in a subset of patients and was most associated with major late complications necessitating secondary intervention, including anas-

Table 4. *Minor and major complications vs repair type*

Repair	Minor complications	Major complications	Total
Montie	78	38	116
Ureteral substitution	56	40	96
Appendix	47	41	88
Fallopian Tube	18	18	36
Total	199	137	336

Table 5. *Expected minor and major complications vs repair type*

Repair	Expected minor complications	Expected major complications	Expected total
Montie	68.70238095	47.29761905	116
Ureteral substitution	56.85714286	39.14285714	96
Appendix	52.11904762	35.88095238	88
Fallopian tube	21.32142857	14.67857143	36
Total	199	137	336

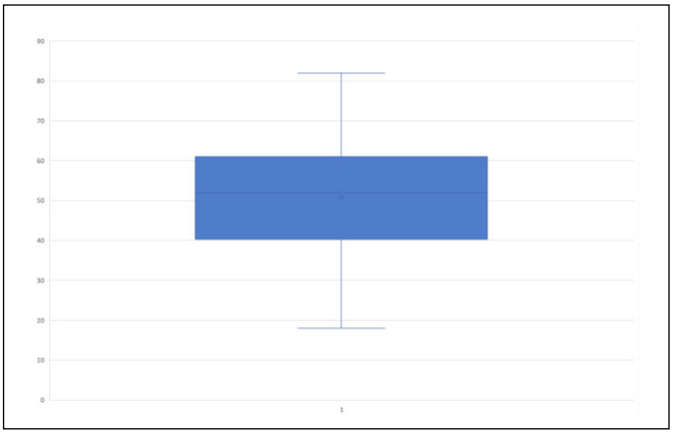

Figure 2. *Age ranges.*

Table 6. *The χ^2 test with p-value comparing observed vs expected minor and major complications with repair type*

Repair	Minor complications	Major complications	Expected minor complications	Expected major complications	p-value
Montie	78	38	77.67857143	38.32142857	0.42812734
Ureteral Substitution	60	36	64.28571429	31.71428571	
Appendix	59	29	58.92857143	29.07142857	
Fallopian tube	28	8	24.10714286	11.89285714	
Grand total	225	111	225	111	

Table 7. *Complications for repair type*

Repair	Sum of minor early complications	Sum of minor late complications	Sum of major early complications	Sum of major late complications
Montie	29	49	29	9
Ureteral substitution	26	34	22	14
Appendix	28	31	16	13
Fallopian tube	14	14	4	4
Grand total	97	128	71	40

tomotic stricture, abscess formation, or persistent obstruction. Rates of reoperation did not differ significantly among reconstruction techniques (χ^2, $p > 0.05$), suggesting comparable durability across approaches when applied to appropriately selected patients.

A modified composite durability outcome was assessed to better reflect clinically meaningful surgical success. This composite outcome was defined as freedom from reoperation, absence of chronic postoperative ureteral stenting, and available documentation of radiographic or functional patency at the most recent follow-up. Using this definition, most patients across all reconstruction techniques achieved the composite outcome. No statistically significant differences were observed between repair types with respect to this composite durability measure ($p > 0.05$).

Electrolyte disturbances

Electrolyte disturbances occurred in 12% of patients (n = 20) and represented the most frequent late complication (Table 15). These events were most commonly observed in the Yang–Monti (n = 7) and appendiceal interposition (n = 8) groups. A statistically significant association was identified between reconstruction type and electrolyte imbalance (χ^2, $p = 0.048$).

Infection and other late complications

Postoperative infections occurred in 11% of patients and included superficial wound infections, deep surgical site infections, fungal and *Candida* infections,

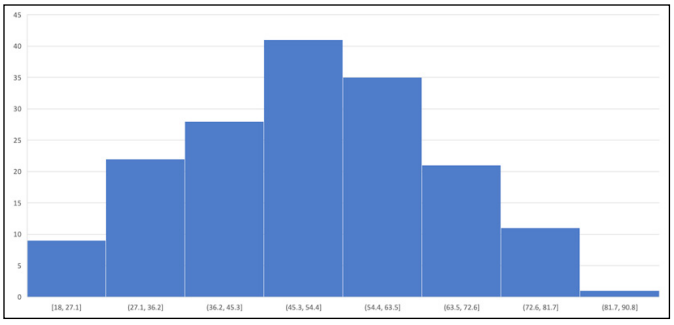

Figure 3. *Distribution of ages.*

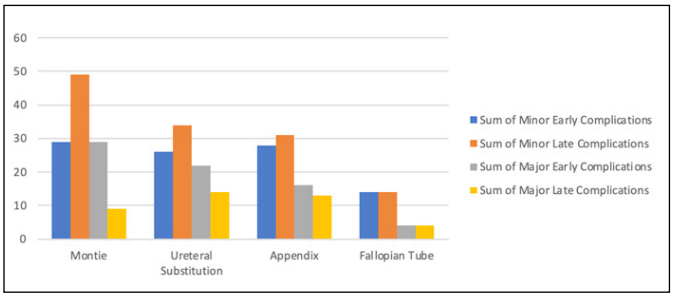

Figure 4. *Complications for repair type.*

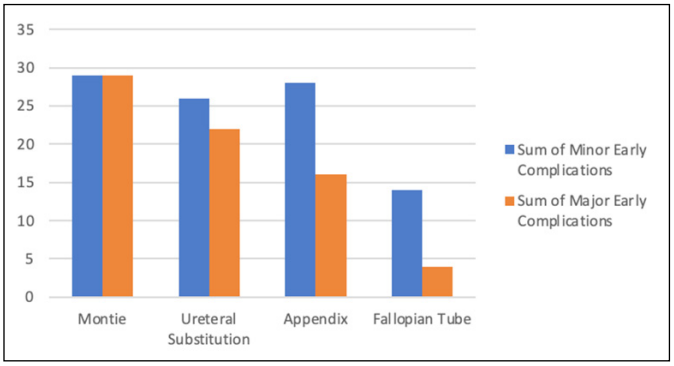

Figure 5. *Early complications based on repair type.*

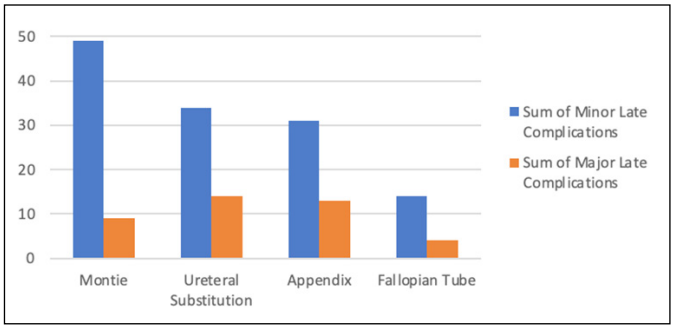

Figure 6. *Late complications based on repair type.*

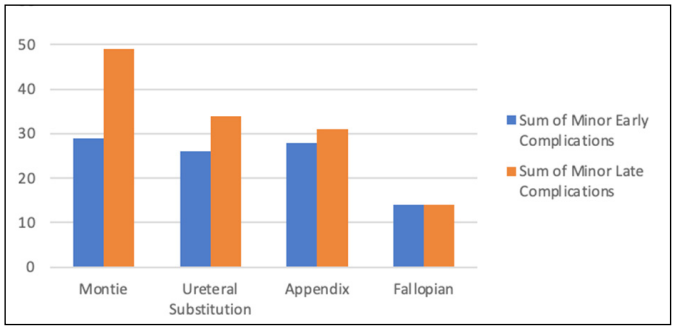

Figure 7. *Minor complications based on repair type.*

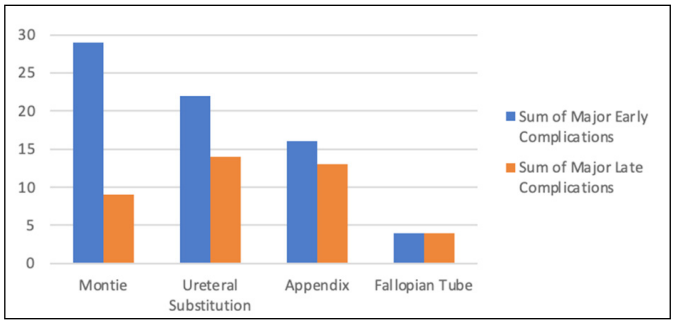

Figure 8. *Major complications based on repair type.*

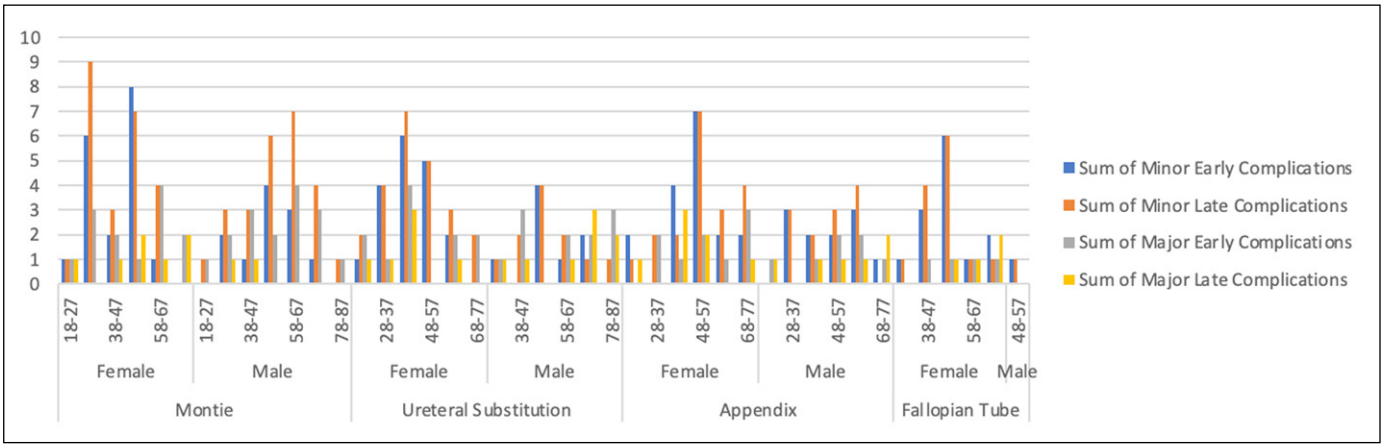

Figure 9. *Complications of repair type based on age and gender.*

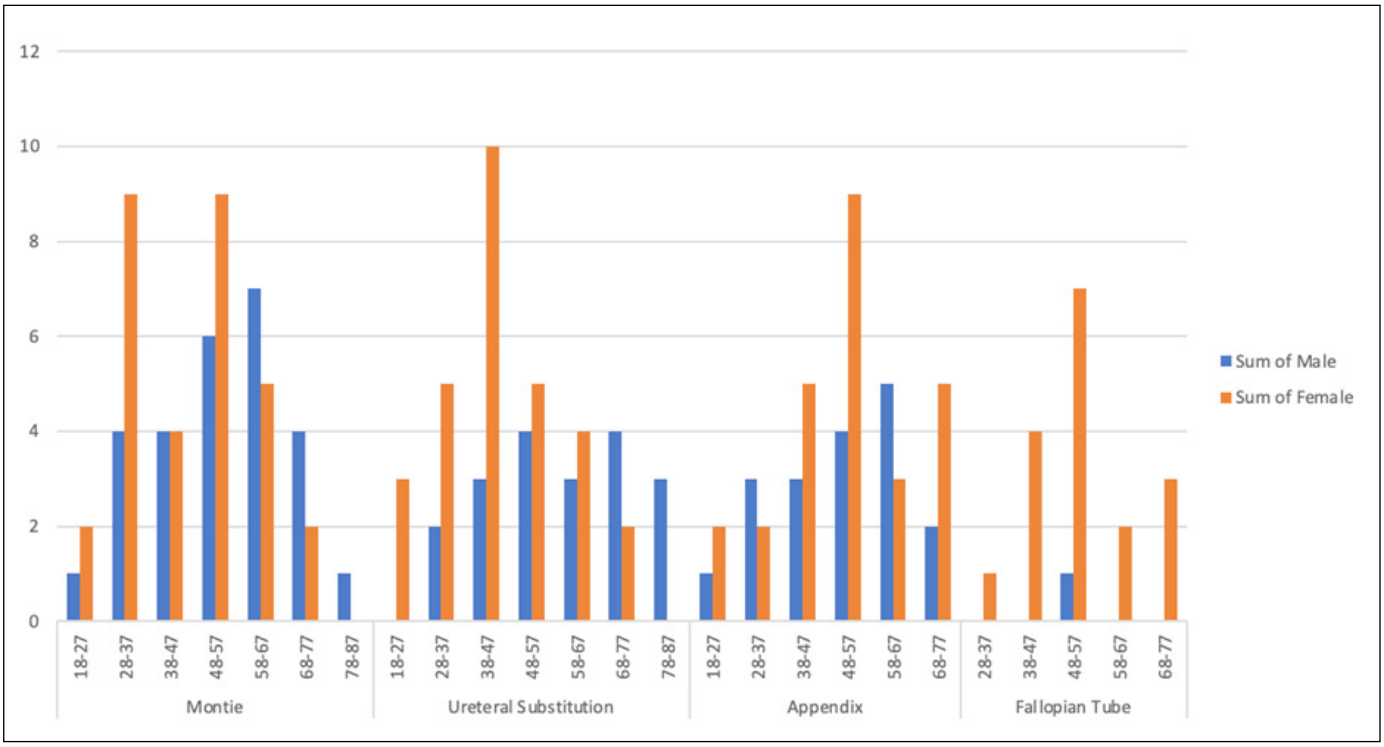

Figure 10. *Age and gender based on repair type.*

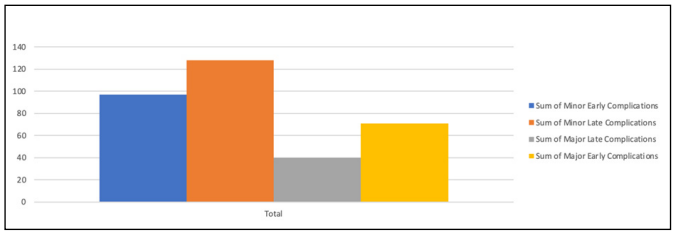

Figure 11. *Complications.*

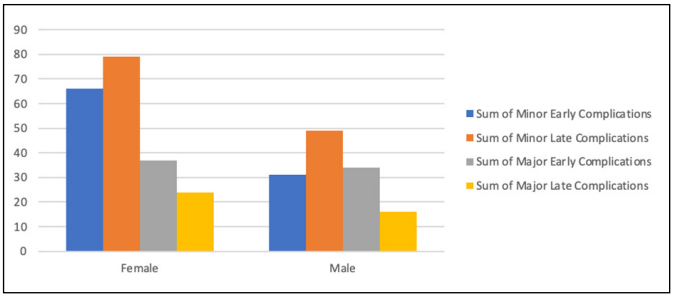

Figure 12. *Gender vs major and minor complications.*

and one case of endomyocardial infection. Abscess formation was documented in 14 patients, including one case complicated by sepsis. No cases of mucus-related obstruction were observed. Postoperative urinary tract infections occurred in approximately 6% of patients across all reconstruction types.

Table 8. *Early complications based on repair type*

Repair	Sum of minor early complications	Sum of major early complications
Montie	29	29
Ureteral substitution	26	22
Appendix	28	16
Fallopian tube	14	4
Grand total	97	71

Radiation status and complication risk

Radiation exposure was not significantly associated with early, late, or overall complication rates when stratified by reconstruction technique (χ^2, $p > 0.05$). Further stratified analyses demonstrated no meaningful differences in renal outcomes when comparing irradiated and non-irradiated patients within each reconstruction group.

Follow-up considerations

Due to the retrospective and multicenter nature of the study, follow-up duration was heterogeneous. Renal function outcomes, complication events, and need for secondary intervention were analyzed based

Table 9. *Late complications based on repair type*

Repair	Sum of minor late complications	Sum of major late complications
Montie	49	9
Ureteral substitution	34	14
Appendix	31	13
Fallopian tube	14	4
Total	128	40

Table 10. *Minor complications based on repair type*

Repair type	Sum of minor early complications	Sum of minor late complications
Montie	29	49
Ureteral substitution	26	34
Appendix	28	31
Fallopian tube	14	14
Total	97	128

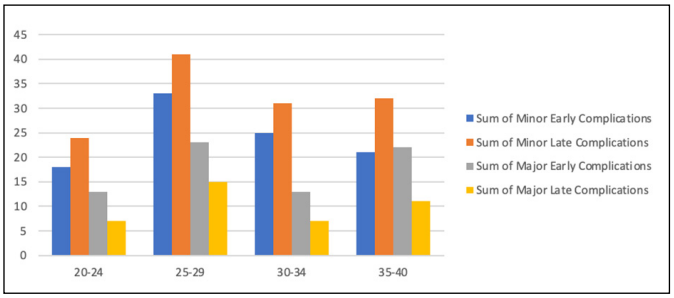

Figure 13. *BMI and complications.*

Table 11. *Major complications based on repair type*

Repair	Sum of major early complications	Sum of major late complications
Montie	29	9
Ureteral substitution	22	14
Appendix	16	13
Fallopian tube	4	4
Total	71	40

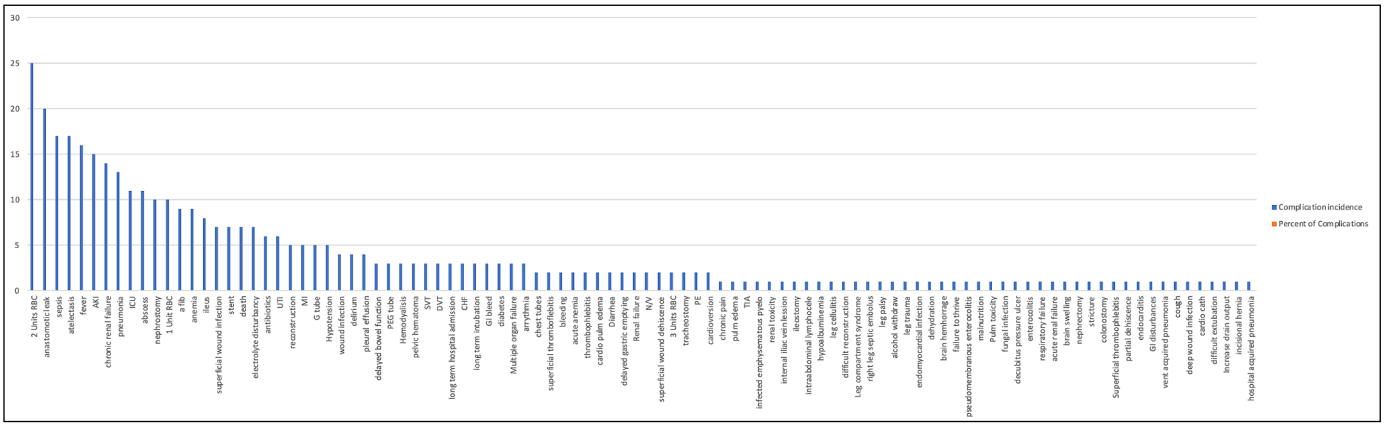

Figure 14. *Incidences of early complications.*

Table 12. *Complications of repair type based on age and gender*

Repair type based on gender and age range	Sum of minor early complications	Sum of minor late complications	Sum of major early complications	Sum of major late complications
Montie	29	49	29	9
Female	18	24	13	7
18–27	1	1	1	1
28–37	6	9	3	0
38–47	2	3	2	1
48–57	8	7	1	2
58–67	1	4	4	1
68–77	0	0	2	2
Male	11	25	16	2
18–27	0	1	1	0
28–37	2	3	2	1
38–47	1	3	3	1
48–57	4	6	2	0
58–67	3	7	4	0
68–77	1	4	3	0
78–87	0	1	1	0
Ureteral substitution	26	34	22	14
Female	18	23	11	6
18–27	1	2	2	1
28–37	4	4	1	1
38–47	6	7	4	3
48–57	5	5	0	0
58–67	2	3	2	1
68–77	0	2	2	0
Male	8	11	11	8
28–37	1	1	1	1
38–47	0	2	3	1
48–57	4	4	0	0
58–67	1	2	2	1
68–77	2	1	2	3
78–87	0	1	3	2
Appendix	28	31	16	13
Female	17	19	9	7
18–27	2	1	0	1
28–37	0	2	2	0
38–47	4	2	1	3
48–57	7	7	2	2
58–67	2	3	1	0
68–77	2	4	3	1
Male	11	12	7	6
18–27	0	0	1	1
28–37	3	3	0	0
38–47	2	2	1	1
48–57	2	3	2	1
58–67	3	4	2	1
68–77	1	0	1	2
Fallopian tube	14	14	4	4
Female	13	13	4	4
28–37	1	1	0	0
38–47	3	4	1	0
48–57	6	6	1	1
58–67	1	1	1	1
68–77	2	1	1	2
Male	1	1	0	0
48–57	1	1	0	0
Total	97	128	71	40

Table 13. *Age and gender based on repair type*

Repair type and age range	Sum of male	Sum of female
Montie	27	31
18–27	1	2
28–37	4	9
38–47	4	4
48–57	6	9
58–67	7	5
68–77	4	2
78–87	1	0
Ureteral substitution	19	29
18–27	0	3
28–37	2	5
38–47	3	10
48–57	4	5
58–67	3	4
68–77	4	2
78–87	3	0
Appendix	18	26
18–27	1	2
28–37	3	2
38–47	3	5
48–57	4	9
58–67	5	3
68–77	2	5
Fallopian tube	1	17
28–37	0	1
38–47	0	4
48–57	1	7
58–67	0	2
68–77	0	3
Grand total	65	103

Table 14. *Complications*

Sum of minor early complications	Sum of minor late complications	Sum of major late complications	Sum of major early complications
97	128	40	71

Table 15. *Electrolyte imbalances*

Repair type	Electrolyte imbalance	
	No	Yes
Yang–Monti	51	7
Ileal	47	1
Appendix	36	8
Fallopian tube	14	4
Total	148	20

Table 16. *Gender vs major and minor complications*

Gender	Sum of minor early complications	Sum of minor late complications	Sum of major early complications	Sum of major late complications
Female	66	79	37	24
Male	31	49	34	16
Total	97	128	71	40

Table 17. *BMI and complications*

BMI ranges	Sum of minor early complications	Sum of minor late complications	Sum of major early complications	Sum of major late complications
20–24	18	24	13	7
25–29	33	41	23	15
30–34	25	31	13	7
35–40	21	32	22	11
Total	97	128	71	40

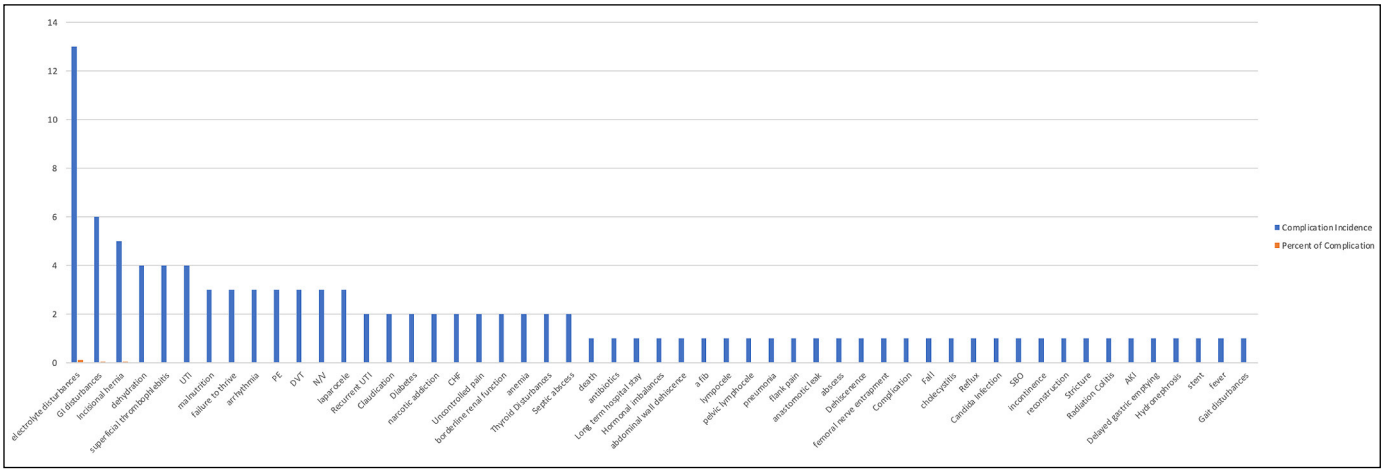

Figure 15. *Incidences of late complications.*

on the most recent postoperative evaluation available for each patient.

DISCUSSION

While different ureteral substitution techniques are traditionally associated with distinct indications and anatomical advantages, our findings suggest that when patients are appropriately selected, these techniques yield comparable functional and complication outcomes. This does not imply equivalence between procedures but rather highlights the importance of individualized surgical planning based on stricture characteristics, prior treatments, and patient comorbidities.

Our analysis consisted of 168 patients with a mean age of 50.9 years (range: 18–82). Out of all the cases, 51.2% underwent radiation exposure which did not show any statistical change in renal function when stratified by repair type and complication presence. Preoperative variables such as BMI, creatinine, and GFR did not affect the length of the procedure or estimated blood loss across all repair types. Among the analyzed cohort, postoperative renal function improved significantly. However, ANOVA showed no significant differences in renal improvement across repair types ($p = 0.87$ for creatinine, $p = 0.16$ for GFR). Serum creatinine represents a global marker of renal function and may be influenced by contralateral renal units. Although more granular measures such as split renal function and standardized imaging would provide greater specificity, these data were not uniformly available across institutions. This represents an inherent limitation of retrospective multicenter analyses

Monti and appendix cohorts had the highest instances of electrolyte disturbances, with a total of 20 cases across all repair types. A slight significant association was found between electrolyte disturbance events and repair type ($p = 0.048$) with electrolyte disturbances and GI disturbances as the most frequent late complications (respectively, $n = 13$, $n = 6$). The observed association between electrolyte disturbances and repair type, particularly in Yang–Monti and appendiceal reconstructions, warrants consideration during preoperative counseling. Although the absolute incidence was low, this finding underscores the importance of metabolic monitoring, especially in patients with marginal baseline renal function.

Our study identified 11% of infections across all repair types with 7 superficial wounds, 4 wound site infections, an endomyocardial infection, fungal infection, candida infection, and 1 deep wound infection. Across all repair types, 14 patients developed abscesses with one sepsis in nature. No patients reported mucosal obstruction-related complications, and 6% ($n = 168$) of all cases, regardless of repair type, reported at least one occurrence of postoperative UTI.

To better capture clinically meaningful durability beyond isolated endpoints, we incorporated a modified composite ("trifecta") outcome. This was defined as freedom from reoperation, absence of chronic postoperative ureteral stenting, and available documentation of functional or radiographic patency at the most recent follow-up. Using this pragmatic composite measure, no reconstruction technique demonstrated superiority, supporting the concept that durable success is primarily driven by appropriate patient selection and technique indication rather than inherent procedural advantage.

Surgical approach techniques

Surgical ureteral substitution techniques are formidable solutions to various complex ureteral pathologies, such as ureteral strictures, yet are not void of general surgical risk. Techniques involving autological grafting use tissues from the ileum, fallopian tube, and appendix to create tabularized segments for ureteral reconstruction and interposition. Determining tissue structure substitution and surgical technique relies on the anatomical advantages while limiting the postoperative complications, stricture recurrence, and renal function deterioration. The relatively small number of fallopian tube substitutions limits statistical power for subgroup comparisons, and the absence of significant differences should therefore not be interpreted as definitive equivalence. Despite surgical indications and outcomes for each method in the study, the lack of statistical significance between techniques provides physicians clinical discretion while simultaneously ensuring high-quality care.

Ileal ureter interposition: a durable but complex reconstruction

Ileal ureter interposition entered the surgical domain in 1906 via Shoemaker, and Goodwin et al, in the late 1950s popularized the reconstructive procedure [1, 2, 7–13]. Ileal segment substitution is particularly beneficial for patients with radiation-induced strictures, extensive ureteral damage, or prior failed reconstructive attempts [14–16].

Regardless of the advantages, ileal ureter replacement remains subject to traditional surgical risk resulting in notable complications. Originally

the absorptive properties of the ileum suggested a hyperchloremic metabolic acidosis, but another study confounded the theory, alternatively suggesting that the increased chloride absorption did not contribute as much as the potassium absorption to create an overriding hyperkalemia metabolic acidosis when renal function is concomitantly impaired [7, 17]. Kaufman et al. [8] described a study with 64 patients under 89 years old with creatinine less than 2.0 mg% and reported an 87.5% successful outcome rate compared to 11 patients with a 45% successful outcome who had more than 2.0 mg% creatinine levels preoperatively, concluding that non-azotemic patients did not show significant electrolyte imbalances. Our study showed that 12% of total cases (n = 168) exhibited electrolyte imbalances across all repair types, with ileal transposition accounting for 35% of those affected. Recent studies indicate postoperative development of metabolic acidosis risk ranges (2.9–12%) with long-term follow-up studies postulating that the creation of metabolic derangement contributes to an increased mortality rate [9, 14].

Postoperative ileal mucosal secretion can accumulate in the lumen, creating obstruction or introducing a conducive environment for infection. Some patients have been reported to undergo regular bladder irrigation to mitigate the risk [7, 17, 18]. In most studies reviewed, infections prevailed as the most common short-term complication, with urinary tract infections arising from natural flora introduced from surgical manipulation and successful treatment with antibiotics [13, 15, 17, 18]. The inherent peristaltic propulsion in the ileum promotes theories of intrinsic protection against postoperative reflux. Esmat et al. implemented an anti-reflux implantation of the ileal ureter to reduce the potential of reflux into the kidney, with the assumption that the technique contributed to the lack of recurrent urinary tract infections in their 3-year follow-up period, although the technique remains disputed [2, 18]. Excluding UTIs, the infections treated with antibiotics reported by Launer et al. include wound and surgical site infections, pneumonia, and *Clostridium difficile* infections. The study also reported an abscess needing incision and drainage, and multiple ileuses requiring total parenteral nutrition [14].

Long-term studies provide limited insight on the probability of secondary revisions for anastomotic strictures. A comparative series in which failure was defined as reoperation or formation of an anastomotic stricture reported a total of 21% of procedures as failures [14]. For indications where strictures require subsequent operation, salvaging restorative function remains satisfactory, but the severity of the stricture may necessitate an ultimate nephrectomy [14]. Despite these risks, a 32-year institutional study demonstrated that ileal ureter interposition remains an effective long-term solution with renal preservation [15]. Robotic techniques reduce the morbidity generally associated with traditional open surgical procedures [10]. Yang et al. [10] reported their study to have a 100% subjective success rate and 86.7% functional success rate for robotic unilateral and bilateral ileal reconstruction, respectively. The increasing success rates and low complication rates incentivize surgeons to opt for robotic cases; however, additional longitudinal studies are needed to quantify the outcomes of robotic procedures compared to open approaches.

Yang–Monti ileal ureter reconstruction: a viable alternative

The Yang–Monti technique was initially designed for catheterizable channels in urinary diversion, but was then adapted as a modification of standard ileal ureter interposition in ureteral reconstruction [18]. The Yang–Monti procedure creates an incision across the antimesenteric border, and then the segment is transversely tabularized [18–21]. The mesentery remains intact to maintain adequate blood supply and prevent ischemic complications [19–21]. In comparison with the traditional approach using a longer ileal segment, the Yang–Monti involves a shorter segment of ileum that is tabularized [18]. The shorter segment used in this technique provides less surface area for absorption of electrolytes and secretion of mucus. Subsequently, this decreases postoperative electrolyte imbalances or mucosal induced infection and obstruction [18]. Complications of the Yang–Monti technique coincide with traditional approaches in regard to the formation of anastomotic strictures and metabolic disturbances [13, 18].

Appendiceal interposition: a less common approach

In 1912, the appendix as a ureteral substitution was first utilized [22]. A modernized technique appeared in 1999 as a solution to a traumatic ureteropelvic disruption in a pediatric patient [23]. According to Cho et al. [24], the first robotic appendiceal substitution was in 2017, with an increasing number of reported cases being documented each year. Right-sided appendiceal substitutions provide anatomical benefit compared to left-sided defects, which require advanced technical skill [24].

Left-sided transpositions incorporate more of the mesentery for tensionless anastomosis and require ideal ileocecal angles [1]. Indications for appendix transposition are vast, with the majority of literature stating the most common as radiation induced strictures. However, scarring due to previous radiation resulted in lumen obliteration intraoperatively [3]. The defect length must measure around 5 cm, due to the finite size of the appendix, with a postmortem study in 1936 claiming a mean length of 8.21 cm [1, 25, 26]. However, segments with cecum involvement that include the Gerlach valve extend the functionality of the transplanted appendix with an anti-reflux mechanism. The mucosal lining resembles the ureter, resulting in less mucosal output compared to ileal interposition and fewer concerns for obstruction, and the lymphatic portions of the tissue assist in minimizing metabolic disruption [1, 26]. Preoperative inspection of the appendix evaluates for narrowing due to inflammation and scarring, which prevent its viability as a substitution [1]. Inherent complications of the appendix anatomy remain after the operation, requiring long-term assessment for signs of appendicitis [22]. Strictures can occur at the uretoappendicular junction site of anastomosis. One longitudinal study of 26 patients showed a 15.4% stricture formation after 3 months, necessitating a revision, whereas another study with 14 patients reported a 92.9% ureteral patency rate at a median follow-up of 14 months [24, 25]. The procedure, although less commonly utilized than other techniques, enable additional options to patients who lack the ability to transpose a segment of ileum.

Minimally invasive surgical techniques

Advancements in ureteral reconstruction continue to shape the management of complex structures. Robotic-assisted techniques, in particular, are gaining popularity due to their potential to reduce morbidity with improvements in surgical precision. Accessibility to obscured strictures, or smaller strictures, requires the benefit of visual amplification from robotic procedures. Most reported cases for ureteral substitution robotic approaches are single-institutional studies with 15 patients or less [10]. Yang et al. [12] reported a 100% success rate, defined as Clavien scores less than 2, among 15 robotic-treated participants. Integration of robotic and laparoscopic techniques used concurrently led to a decrease in hospital stays, with all 3 of their patients having a 100% success rate. Merging minimally invasive techniques increased the maneuverability within the abdominal cavity, aiding in visualizing and mobilizing the stricture. Stein et al. described promising efficacy of robot assistance in buccal mucosal grafts and appendiceal interpositions, although another study published in 2024 presents possible limitations [9, 12]. Cho et al. [9] reported some of the challenges in obtaining adequate buccal mucosal graft extractions while the robot docked. Additionally, when attaching the buccal mucosa, a large portion of ureter is needed to successfully secure the graft. The initial stricture length must be short due to the increased surface area of ureter needed for the anastomosis [9]. Increasing participation in robotic studies would provide more solidified statistical validation in larger case series among multi-institutional applications.

Autotransplantation of kidney considerations

Kidney transplantation procedures require extensive operative experience to prevent complications, and autotransplantation specifically necessitates a specific niche within that subset. With proper training and experience, the outcomes are promising, although the lack of expert routine autotransplantation kidney surgeons to operate make this technique a challenging integration for this particular study when comparing ureteral substitution techniques for strictures. Despite lower complication rates, complications still arise, such as thrombosis, bleeding, renal infarction, graft failure, or stricture formation [27, 28]. Cowan et al. [27] described 54 kidney autotransplantations in a 27-year, two-institution study, which included 20.4% of procedures due to ureteral strictures. The study found that 14.8% of patients reported early high-grade complications, with 18.5% of patients having vascular events, although vascular complication subgroups were not stratified for ureteral stricture operative indications [27]. They noted that increased cold ischemia times correlated with increased vascular complications such as thrombosis, pseudoaneurysms, renal infarction, or hemorrhage, with two of the patients in the study resulting in graft failure [27]. In fact, Cowan's study concluded that all the complication rates were comparable to other major urological procedures, with cold ischemic times as the only correlation between postoperative complications [27]. A smaller study focusing on ureteral strictures as a transplantation indication stratified vascular complications, with approximately 6% of their cases resulting in intervention for pseudoaneurysm formation [28]. However, due to the limited number of pa-

tients in the study group, the results cannot be generalized [28]. Recent studies from the "Central European Journal of Urology" further support the expanding role of robotic techniques in complex ureteral reconstruction [29, 30]. Due to the complexity, complication risk, and expertise required to perform kidney autotransplantation for ureteral stricture management, the technique was not performed or included in the data analyzed for our study.

Limitations include the retrospective, multicenter design with heterogeneous follow-up, reliance on global renal function markers, and use of major late complications as surrogate measures of durability. The smaller subgroup sizes, particularly for fallopian tube substitution, limit its statistical power. These factors reflect real-world reconstructive practice and should be considered when interpreting comparative outcomes.

Summary

Most of the literature reviewed relied on ileal ureter interpositions compared to other techniques discussed in this article. Ileal transpositions are utilized to repair lengthy strictures with complications of metabolic disturbances, mucus obstruction, and recurrence of strictures at the anastomotic site. Literature previously supported the Yang–Monti technique and appendix substitution to decrease the probability of metabolic complications, but our study did not find statistical significance in electrolyte disturbances between repair types. No cases in our study reported mucus production; however, according to review, this may still occur. Evolutionary use of the fallopian tube may provide additional options to those who have undergone an appendectomy or do not want to use the ileum. Our literature review combined with our multicentered institutional data review demonstrates that the outcome of a ureteral substitution relies on selecting the most appropriate technique based on the characteristics of the stricture.

CONCLUSIONS

This comprehensive overview of all major ureteral substitution techniques demonstrates no significant differences in complication rates or postoperative renal function across the different approaches. Our study, which consisted of 18 fallopian tube cases, did not show any statistical significance in complication rates compared to any other anatomical substitution or approach technique. Minimally invasive procedures continue to prevail in the operating room, with robotic techniques having improved recovery rates and reduced complication severities according to the Clavien scale. Our study did not find any statistical significance in the repair approach between open, laparoscopic, or robotic techniques. Higher patient numbers in the literature among all discussed procedures would increase the statistical viability when comparing the complication risks for the various approaches. Long-term studies with retained follow-up remain a limiting factor in the already low number of reported cases for each of the procedures. Emerging techniques and anatomic structure utilization provide surgeons with options when evaluating the unique needs of a patient, without concern for increasing or altering the expected outcomes.

CONFLICTS OF INTEREST

The authors declare no conflict of interest.

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ETHICS APPROVAL STATEMENT

The study was approved by Institutional Review Boards Italy (Ospedale Cristo Re, Ospedale San Filippo Neri and Ospedale Sant'Eugenio Rome, Policlinico Campus Biomedico; No. approval: ITEUAI 233976655-21.1.2.3.4; date: 11.2.2025); Institutional Review Board Spain (Uros Associates, Clinica Sagrada Familia; No. approval: EUES 0288679_11, date: 10.12.2025); United States Institutional Review Board (Mount Sinai) of Icahn School of Medicine at Mount Sinai (No. approval: 8554223/22A date: 3.4.2025).

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