

Robotic ileal ureter replacement versus kidney autotransplantation for long ureteral strictures

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ABSTRACT

Objective: To compare functional and surgical outcomes of robot-assisted ileal ureter replacement (RAIUR) versus robot-assisted kidney autotransplantation (RAKAT).

Patients and Methods: This was a retrospective analysis of patients who underwent RAIUR or RAKAT for long ureteral strictures at eight European tertiary centers (2017–2024). Primary endpoints were maintenance of estimated glomerular filtration rate (eGFR) and postoperative complications within 30 days from surgery, described using the Clavien-Dindo classification (CDC). Secondary outcomes included infections, need for lifelong drainage, stricture persistence, and reintervention for the stricture during follow-up.

Results: A total of 15 and 39 patients underwent RAIUR and RAKAT, respectively. RAIUR patients were older (61 vs 45 years, $p=0.03$), with more comorbidities (Charlson Comorbidity Index ≥ 3 : 67% vs 28%, $p=0.03$) and lower baseline eGFR (60 vs 87 ml/min/1.73m², $p=0.007$). Median stricture length was 9.6 for RAIUR vs 7 cm for RAKAT. RAIUR had shorter surgical time (290 vs 355 min, $p=0.008$), whereas RAKAT had shorter hospitalization (5 vs 8 days, $p=0.001$). Overall complications were higher after RAIUR (73% vs 31%, $p=0.01$), but CDC ≥ 3 complications were similar (13% vs 10%). During follow-up, both groups showed slightly improved renal function, low infection rates (13% for RAIUR vs 10% for RAKAT), low stricture persistence (13% for RAIUR vs 7.7% for RAKAT), and minimal need for drainage or reintervention. The main limitation is the modest sample size.

Conclusion: In the first comparative analysis of RAIUR and RAKAT, we provide evidence that both techniques provide similar improvements in renal function and similar rates of postoperative high-grade complications. Both approaches represent definitive solutions for ureteral strictures in most patients. The choice of the technique should be based on patients' factors, patients' expectations and surgeon's experience.

Introduction

Among the definitive treatment of long and complex ureteral strictures, ileal ureter replacement and kidney autotransplantation are two of the most commonly offered alternatives.[1] Each reconstruction technique presents unique postoperative complications, including vascular, intestinal, and anastomotic issues such as stenosis or leakage.[2] The selection of the appropriate reconstruction modality is influenced by several factors, including laterality and location of the ureteral stricture, patient's overall health and comorbid conditions, and surgeon's expertise and preferences.[2]

In recent years, advancements in robotic surgery have enabled the application of these reconstruction techniques using robotic platforms.[3–7] For long ureteral strictures, preliminary works on robot-assisted ileal ureter replacement (RAIUR) and robot-assisted kidney autotransplantation (RAKAT) have demonstrated the safety and feasibility of robot-assisted procedures for ureteral reconstruction.[3, 5] However, a comprehensive comparative analysis of these surgical modalities is not described in the literature.

Given the importance of accurately reporting benefits and risks of these surgical options, the primary objective of this study was to conduct a comparative analysis of RAIUR and RAKAT for long ureteral strictures, focusing on intra- and postoperative complication rates, and long-term functional and surgical outcomes.

Patients and Methods

Study population

This is a retrospective analysis of a multicentre cohort of patients undergoing RAIUR or RAKAT between June 2017 and September 2024 at 8 European referral centers. One surgeon per center experienced in robotic surgery and (in the case of RAKAT) renal

transplantation performed the surgical procedures. Ethics requirements were met at all study centers, with most sites having a waiver of informed consent. No age limits were applied. All surgical procedures have been performed with the da Vinci® Surgical System (Intuitive Surgical, Sunnyvale, CA), either Si, X, Xi or single-port (SP) models.

Demographic data included the following: age, sex, body mass index (BMI), the American society of Anesthesiologists (ASA) score, Charlson Comorbidity Index (CCI), smoking status, history of abdominal surgery, preoperative estimated glomerular filtration rate (eGFR); presence of a single kidney, side of the ureteral stricture, presence of multiple renal vessels, location and etiology of the stricture, stricture length, previous attempts to repair the stricture, and preoperative kidney drainage. Intraoperative data included the following: type of robotic platform and approach used, surgical time (from surgical incision to wound closure), estimated blood loss (EBL), and intraoperative placement of a renal drainage (double-J stent or percutaneous nephrostomy). Postoperative data included the following: length of hospital stay (LOS), time to stent removal and eGFR at 30 days postoperatively. Postoperative complications were classified according to the Clavien-Dindo Classification (CDC) and intended as any complication taking place within 90 days from the day of surgery. Data reported during follow-up comprise the development of any urinary tract infection (UTI), the lifelong need of renal drainage, the presence of a persisting stricture and the need of any reintervention.

Eligibility criteria

The main inclusion criterion for this study was the presence of a ureteral stricture not amenable for primary ureteroureterostomy, Boari flap or psoas hitch reconstruction, and ureteral reimplantation, thus requiring either RAIUR or RAKAT. Calcification of the iliac

118 arteries was a contraindication to RAKAT. RAIUR was contraindicated in cases of
119 inflammatory bowel disease.

120 *RAIUR*

121 After colon mobilization, the transection of the stenotic ureter is performed with the
122 patient in the lateral decubitus or in the supine position, depending on the cranial extent
123 of the ureteral stricture. Then, the isolation of an isoperistaltic ileal segment in anti-
124 refluxing fashion is performed with intestinal stapler, of a length adequate to the length of
125 the defect; this is anastomosed end-to-end to the proximal ureter or the renal pelvis and
126 distally to the urinary bladder. The margins of the stricture are delineated by applying
127 indocyanine green dye or optically assessing the vascularization at the proximal end of
128 the stricture, based on the surgeon's preference. In case of bilateral complex stenosis,
129 both ureters are reimplanted into a common ileal segment. The ureterovesical
130 anastomosis is performed with an extravesical direct reimplantation in all cases. Stenting
131 with a double-J catheter, placement of a nephrostomy tube and of an intraabdominal drain
132 is performed at discretion of the surgeon and depending on the clinical indication.

133 Follow-up consists in regular doppler-ultrasounds in the postoperative phase and after
134 removal of the double-J stent, together with regular checks of the renal function.

135 *RAKAT*

136 Patient and trocar positioning as well as surgical procedure have been previously
137 described into details by Decaesteker et al.[8] Briefly, RAKAT develops into three main
138 phases: nephrectomy, bench surgery, and transplantation. The nephrectomy phase is
139 performed with the patient in lateral decubitus; the renal vessels are transected as long

as possible, while the ureter is resected cranially to the proximal end of the stricture. In cases that require special reconstructions or additional care, such as in kidneys with multiple vessels or in the presence of kidney stones, a GelPOINT (Applied Medical Resources Corp, Rancho Santa Margarita, CA, USA) is placed to facilitate the extraction of the kidney for the extracorporeal phase (bench surgery). The transplantation phase follows the same principles of the Vattikuti-Medanta technique.[9–12] The ureterovesical anastomosis was performed with the Lich-Gregoir technique in all cases. Stenting with a double-J catheter was performed in all cases. The choice to leave an intraabdominal drain was taken on a case-by-case basis.

Follow-up consisted in regular doppler-ultrasounds in the postoperative phase and after removal of the double-J stent, together with regular checks of the renal function.

Renal scintigraphy

MAG-3 (Mercaptoacetyltriglycine) renal scintigraphy was typically deemed unnecessary preoperatively in cases of evident obstruction necessitating the placement of a JJ stent or nephrostomy tube to stabilize the eGFR, given that the utility of MAG-3 renal scintigraphy in the presence of stents is limited. Postoperatively, the absence of hydronephrosis on ultrasound or CT-scan obviated the need for MAG-3 renal scintigraphy to assess obstruction, particularly when eGFR had stabilized or improved. In instances of persistent hydronephrosis, MAG-3 renal scintigraphy remained a valuable diagnostic tool to distinguish between residual dilation and actual obstruction. In selected cases, this differentiation was pursued.

Preoperatively and postoperatively, DMSA (Dimercaptosuccinic acid) renal scintigraphy were generally utilized to evaluate potential changes in renal parenchyma attributable to ischemia or the compromise of small arterial branches following transplantation.

Outcomes

The primary outcome of this study was the rate of intraoperative and postoperative complications experienced in patients receiving RAIUR or RAKAT. Secondary outcomes consisted in surgical time, EBL, requirement to place a stent intraoperatively, LOS, change in eGFR over time, and development of any urinary infection or stricture during follow-up.

Statistical considerations

Descriptive statistics for categorical variables were presented as frequencies and proportions. Continuous variables were described using either means and standard deviation (SD) or medians and interquartile ranges (IQR). Postoperative complications were described as the proportion of patients experiencing a complication, considering the highest grade per patient, and reported separately segregated into early and late complications. Comparison between RAIUR and RAKAT were performed using the t-student test, Kruskal-Wallis test, chi-squared test and the Wilcoxon signed rank test as appropriate. A two-sided p-value <0.05 was used to determine statistical significance. Statistical analyses were performed using R (R project, Vienna, Austria).

Results

Patients baseline characteristics

Patients baseline characteristics are described in **Table 1**. Median age at surgery was 61 years (IQR: 58-63) for RAIUR and 45 (IQR: 30-59) for RAKAT ($p=0.03$). Patients undergoing RAIUR had more comorbidities than those undergoing RAKAT (unadjusted CCI 0-2 53.3% vs 84.6%, respectively, $p=0.01$) and had a lower preoperative eGFR (60 vs 87 ml/min/1.73m², respectively, $p=0.007$). There was no difference between the RAIUR and the RAKAT groups in terms of smoking habits, BMI, previous abdominal surgery, and single kidney. Multiple renal vessels were present in 15 (38%) patients undergoing RAKAT.

Patients undergoing RAIUR had mostly left-sided ureteral strictures ($n=9$, 60%), while 3 (20%) were bilateral. No patient had a bilateral stricture in patients undergoing RAKAT, while the majority had left-sided ureteral strictures ($n=25$, 64%). The etiology of the stricture was iatrogenic in most cases (60% vs 85% in the RAIUR and RAKAT groups, respectively, $p=0.3$). The median length of the stricture was 9.6cm vs 7 cm in RAIUR vs RAKAT patients ($p=0.1$), respectively, and previous attempts to repair the stricture were done in 40% vs 56% of the cases ($p=0.4$). Urinary drainage was present in 93% vs 79% of patients undergoing RAIUR and RAKAT ($p=0.03$), respectively.

A preoperative renogram was performed in 5 (33%) patients undergoing RAIUR and in 33 (84%) patients undergoing RAKAT. Split renal function for the affected kidney was 29 (IQR 28-46) and 46 (IQR 40-49) in RAIUR and RAKAT patients, respectively.

Intraoperative data

Intraoperative data are reported in **table 2**. Surgery was performed mostly with the Da Vinci multiport Xi (47% vs 51% in RAIUR vs RAKAT, respectively). Median surgical time was shorter for RAIUR (290 vs 355 minutes, $p=0.008$), while estimated blood loss was

similar between the two groups (75ml vs 175ml, $p=0.07$). A urinary stent was placed in 47% of patients receiving RAIUR versus all patients receiving RAKAT ($p<0.001$).

Postoperative data

Postoperative data are reported in **table 3**. Median LOS was shorter for patients undergoing RAKAT (72% vs 28%, $p<0.001$), while median time to urinary stent removal was shorter in patients undergoing RAIUR (12 vs 27 days, $p=0.03$).

Overall, more complications were recorded in patients undergoing RAIUR (73% vs 31%, $p=0.01$). However, the rate of grade CDC ≥ 3 complications was similar between RAIUR and RAKAT (13% vs 10%, $p=0.1$). Most common complications were urinary tract infections in both groups, with 9 (60%) registered in the RAIUR group and 5 (13%) in the RAKAT group. Of note, one ileal perforation was registered in the RAIUR group, while two cases of anastomotic leak (one of which requiring surgical intervention) were reported in the RAKAT group. One case of leg compartment syndrome and one case of renal thrombosis were reported in the RAKAT group.

Follow-up data

Follow-up data are reported in **supplementary table 1**. Over a median follow-up of 16 months for RAIUR and 35 months for RAKAT, there was no differences in terms of incidence of urinary tract infections, lifelong need of renal drainage, rate of persisting strictures, and need for reintervention for a stricture between RAIUR and RAKAT (respectively: 13% vs 10%, 0 vs 2.6%, 13% vs 5.1%, 0 vs 5.1%; all $p>0.05$). The four patients with a persisting stricture were diagnosed with CT-urography; two of these (both in the RAIUR group) refused surgical reoperation. Of note, one patient receiving RAKAT

required a transplantectomy because of thrombus of the renal artery. At last follow-up, no difference in overall survival was detected.

Even though median postoperative eGFR was superior in patients receiving RAKAT (90 vs 68 ml/min/1.73m², p=0.004), these patients had a better preoperative renal function, and the change in eGFR before and after surgical intervention was similar between the groups. The eGFR trends in **figure 1** communicate the maintenance of stable eGFR values between the preoperative and the postoperative settings for both RAIUR and RAKAT.

Discussion

Surgical options for long or complex ureteral stenosis are limited, mainly represented by ileal ureteral replacement and kidney autotransplantation[13, 14]. Robot-assisted surgery has emerged as an attractive alternative to open surgery given its known advantages permitted by the minimally invasive approach. Recently, limited experiences on RAIUR and RAKAT have been proposed by a few international groups, demonstrating their feasibility and safety.[3, 5, 6, 8] Yet, there is no comparative analysis on these two techniques, which would be important for both patients' counselling and clinical decision making in case of complex ureteral strictures. With our study, we compared the outcomes of 15 patients undergoing RAIUR with 39 patients undergoing RAKAT. We reported that despite the rate of total postoperative complications is higher for RAIUR, that of high-grade complications is similar in both types of surgery. Additionally, the outcomes of surgery in terms of maintenance of renal function, need for reintervention during follow-up, and need for keeping the ureteral stent were similar in both groups.

Our study is important for several reasons. First and foremost, both techniques lead to similar results in terms of functional outcomes. The renal function maintains stable over time, probably because the preoperative renal function collected in our database referred to the last eGFR measured before surgical repair, when a renal drainage was already in place. The literature is not univocal on this point, with some studies suggesting improvement and others stability of renal function.[3, 15, 16]

Second, most patients do not require reinterventions during follow-up or the placement of urinary tract drainage because of relapses of stenotic processes. Previous investigations have already demonstrated that kidney transplantation leads to acceptable surgical outcomes for robot-assisted kidney transplantation and showed that complications are mainly related to the beginning of the learning curve, stressing the need of appropriate training to approach this surgery.[17–20]. Similarly, small series on RAIUR showed that surgical outcomes are acceptable if the surgery is performed by experienced hands and the approach is standardized.[5, 6] In this sense, it is of outmost importance to provide adequate training to surgeons, in a standardized and reproducible manner, ideally adopting tested and validated metrics.[21–23]

Third, our study is the first to compare RAIUR and RAKAT, and it communicates that both approaches lead to similar rates of high-grade complications. Patients undergoing RAIUR are more burdened by infectious complications than patients undergoing RAKAT, while patients undergoing RAKAT might expect more vascular complications. These aspects are intrinsically related to the type of surgical reconstruction and should be adequately reported and explained during patients' interview. In our view, it is unlikely that the higher incidence of infectious complications in the RAIUR group should be related

to the reduced ability to wash the bowel segment, as randomized trials have shown no difference in infectious complications between open and robot-assisted radical cystectomy.[24] Instead, it could be hypothesized that the observed differences in infectious complications between RAIUR and RAKAT may be attributed to factors not routinely collected, such as the duration of preoperative renal drainage and the type and duration of perioperative antibiotic prophylaxis. Future studies should consider these aspects to provide a more comprehensive understanding. To be noted, RAIUR is the only technique that allows to face the challenging scenario of bilateral ureteral strictures.

Third, all procedures have been performed with different models of the da Vinci® Surgical System (Intuitive Surgical, Sunnyvale, CA). This means, on one side, that different surgical platforms could be used for RAIUR and RAKAT; on the other side, our study does not permit to extend the information regarding feasibility and safety on other surgical platforms. In this regard, we recommend to adopt the ideal framework to access new platforms in these types of surgery (<https://www.ideal-collaboration.net/>) and especially for RAKAT, given that it requires a long ischemia time for the kidney.

While this study did not directly compare robot-assisted with open procedures, it is important to stress a few important details. Through this study we cannot infer any conclusion whether functional or surgical differences exist between the open and the robotic approaches for the management of complex ureteral strictures. While some studies have shown similar length of hospital stay and similar stricture-free rates,[25, 26] evidence from well-conducted comparative studies is lacking and needed to guide decision making in this setting.

There are a few limitations that need to be highlighted. First and foremost, the limited sample size and the absence of randomization impede any generalizations. The second limitation is the retrospective design with its inherent biases, which however is counterbalanced by the presence of complete data from the whole cohort, and the fact that chart review of limited data permitted to retrieve all the information required for the study. As a matter of fact, given the complexity of these surgeries, patients are followed up in the same clinic that performed the surgery, thus allowing to detect complications at follow-up. Third, RAIUR and RAKAT surgeries are performed by expert surgeons, thus outcomes might not be comparable with surgeons who are in their learning curve. Fourth, slight modifications in RAIUR and RAKAT might be present from center to center, which our collective database did not collect. Fifth, our investigation did not focus on differences between extracorporeal and intracorporeal RAKAT; however, previous studies have shown that these techniques lead to similar surgical and functional results.[3] Sixth, patients' groups differed in terms of age, Charlson comorbidity score, preoperative eGFR, and follow-up time. These factors might have influenced our results, considering that older and frailer patients might be more prone to complications related to surgery.[27] Moreover, despite most strictures or reoperations took place in the first few months after the intervention, different follow-up lengths might have influenced the detection of postoperative complications.

Quality of life in patients receiving RAIUR and RAKAT has not been evaluated yet, but it might be important information that could help patients and providers to decide which treatment option would be most suitable. Moreover, an analysis of long-term functional outcomes and complications is needed for further assessment of the relative benefit of

318 these procedures. Lastly, considering the complexity of these surgeries, centralization of
319 these patients to centers with experience with such cases is strongly recommended.

320 **Conclusions**

321 This study presents the first comparative analysis of RAIUR and RAKAT,
322 demonstrating that both techniques achieve comparable improvements in renal function
323 and similar rates of high-grade postoperative complications. Specifically, a predominancy
324 of infective complications should be expected in patients undergoing RAIUR, and of
325 vascular ones in patients undergoing RAKAT. Our findings suggest that both approaches
326 serve as effective and definitive treatments for complex ureteral strictures in most
327 patients. The decision between these techniques should be guided by patient-specific
328 factors, individual expectations, and the expertise of the surgeon.

References

- [1] Serafetinidis E, Campos-Juanatey F, Hallscheidt P, et al. Summary Paper of the Updated 2023 European Association of Urology Guidelines on Urological Trauma. *Eur Urol Focus* 2023; S2405-4569(23)00196–7.
- [2] Engel O, Rink M, Fisch M. Management of iatrogenic ureteral injury and techniques for ureteral reconstruction. *Curr Opin Urol* 2015; 25: 331–335.
- [3] Breda A, Diana P, Territo A, et al. Intracorporeal Versus Extracorporeal Robot-assisted Kidney Autotransplantation: Experience of the ERUS RAKT Working Group. *Eur Urol* 2022; 81: 168–175.
- [4] Zhao LC, Weinberg AC, Lee Z, et al. Robotic Ureteral Reconstruction Using Buccal Mucosa Grafts: A Multi-institutional Experience. *Eur Urol* 2018; 73: 419–426.
- [5] Yang K, Wang X, Xu C, et al. Totally Intracorporeal Robot-assisted Unilateral or Bilateral Ileal Ureter Replacement for the Treatment of Ureteral Strictures: Technique and Outcomes from a Single Center. *Eur Urol* 2023; 84: 561–570.
- [6] Grosso AA, DI Maida F, Mari A, et al. Totally intracorporeal robotic ileal ureter replacement: focus on surgical technique and outcomes. *Minerva Urol Nephrol* 2021; 73: 532–539.
- [7] Schiavina R, Zaramella S, Chessa F, et al. Laparoscopic and robotic ureteral stenosis repair: a multi-institutional experience with a long-term follow-up. *J Robotic Surg* 2016; 10: 323–330.
- [8] Decaestecker K, Van Parys B, Van Besien J, et al. Robot-assisted Kidney Autotransplantation: A Minimally Invasive Way to Salvage Kidneys. *Eur Urol Focus* 2018; 4: 198–205.
- [9] Boggi U, Vistoli F, Signori S, et al. Robotic renal transplantation: first European case. *Transpl Int* 2011; 24: 213–218.
- [10] Menon M, Abaza R, Sood A, et al. Robotic kidney transplantation with regional hypothermia: evolution of a novel procedure utilizing the IDEAL guidelines (IDEAL phase 0 and 1). *Eur Urol* 2014; 65: 1001–1009.
- [11] Musquera M, Peri L, Ajami T, et al. Robot-assisted kidney transplantation: update from the European Robotic Urology Section (ERUS) series. *BJU Int* 2021; 127: 222–228.
- [12] Breda A, Territo A, Gausa L, et al. Robotic kidney transplantation: one year after the beginning. *World J Urol* 2017; 35: 1507–1515.

- 362 [13] Krocak T, Reynolds LF, Ordon M. Robotic Autotransplantation and Management
363 of Post-transplant Anastomotic Strictures: the Future Is Here. *Curr Urol Rep* 2018;
364 19: 31.
- 365 [14] Asghar AM, Lee Z, Lee RA, et al. Robotic Ureteral Reconstruction in Patients with
366 Radiation-Induced Ureteral Strictures: Experience from the Collaborative of
367 Reconstructive Robotic Ureteral Surgery. *J Endourol* 2021; 35: 144–150.
- 368 [15] Singh J, Wang L, Smith TG, et al. Ileal Interposition for Ureteral Reconstruction
369 Following Treatment for Abdominopelvic Malignancy: Complications and Outcomes
370 From a Comprehensive Cancer Center. *Urology* 2024; 183: 215–220.
- 371 [16] Gwon JG, Kim YH, Han DJ. Real Renal Function After Renal Autotransplantation
372 Through the Analysis of Solitary Kidney Autotransplantation Cases. *Transplant*
373 *Proc* 2017; 49: 2055–2059.
- 374 [17] Gallioli A, Territo A, Boissier R, et al. Learning Curve in Robot-assisted Kidney
375 Transplantation: Results from the European Robotic Urological Society Working
376 Group. *Eur Urol* 2020; 78: 239–247.
- 377 [18] Campi R, Pecoraro A, Vignolini G, et al. The First Entirely 3D-Printed Training
378 Model for Robot-assisted Kidney Transplantation: The RAKT Box. *European*
379 *Urology Open Science* 2023; 53: 98–105.
- 380 [19] Breda A, Territo A, Gausa L, et al. Robot-assisted Kidney Transplantation: The
381 European Experience. *Eur Urol* 2018; 73: 273–281.
- 382 [20] Territo A, Afferi L, Musquera M, et al. Robot-assisted Kidney Transplantation: The
383 8-year European Experience. *Eur Urol* 2025; S0302-2838(24)02758–1.
- 384 [21] Basile G, Pecoraro A, Gallioli A, et al. Robotic kidney transplantation. *Nat Rev Urol.*
385 Epub ahead of print 13 March 2024. DOI: 10.1038/s41585-024-00865-z.
- 386 [22] Pecoraro A, Territo A, Boissier R, et al. Proposal of a standardized training
387 curriculum for open and robot-assisted kidney transplantation. *Minerva Urol*
388 *Nephrol* 2024; 76: 110–115.
- 389 [23] Campi R, Pecoraro A, Piramide F, et al. The ERUS course on robot-assisted kidney
390 transplantation. *World J Urol* 2024; 42: 205.
- 391 [24] Catto JWF, Khetrapal P, Ricciardi F, et al. Effect of Robot-Assisted Radical
392 Cystectomy With Intracorporeal Urinary Diversion vs Open Radical Cystectomy on
393 90-Day Morbidity and Mortality Among Patients With Bladder Cancer: A
394 Randomized Clinical Trial. *JAMA* 2022; 327: 2092–2103.
- 395 [25] Rossanese M, Giannarini G, Scalia R, et al. Outcomes and treatment failure after
396 open or robotic ureteral reconstruction for iatrogenic injuries. *BJUI Compass* 2023;
397 4: 673–679.

- 398 [26] Launer BM, Redger KD, Koslov DS, et al. Long-term Follow Up of Ileal Ureteral
399 Replacement for Complex Ureteral Strictures: Single Institution Study. *Urology*
400 2021; 157: 257–262.
- 401 [27] Ornaghi PI, Afferi L, Antonelli A, et al. Frailty impact on postoperative complications
402 and early mortality rates in patients undergoing radical cystectomy for bladder
403 cancer: a systematic review. *Arab J Urol* 2020; 19: 9–23.
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Table 1. Baseline characteristics of patients with ureteral strictures undergoing robot-assisted ileal ureter replacement (RAIUR) or robot-assisted kidney autotransplantation (RAKAT).

	RAIUR (N=15, 28%)	RAKAT (N=39, 72%)	P-value
Age [years], median (IQR)	61 (58-63)	45 (30-59)	0.03
Male sex, n (%)	8 (53%)	18 (46%)	0.8
ASA score, n (%)			
1-2	12 (80%)	35 (90%)	0.6
3-4	3 (20%)	4 (10%)	
Charlson comorbidity index			
0-2	5 (33%)	28 (72%)	0.003
3-5	3 (20%)	8 (20.5%)	
6-10	7 (47%)	3 (8%)	
BMI [kg/m²], median (IQR)	24 (23-26)	24 (21-28)	0.6
Smoking status, n (%)			
Active smoker	8 (53.3%)	30 (76.9%)	0.2
Past smoker	3 (20%)	3 (7.7%)	
Never smoker	4 (26.7%)	6 (15.4%)	
Preoperative eGFR [ml/min/1.73m²], median (IQR)	60 (50-85)	87 (78-103)	0.007
Previous abdominal surgery, n (%)	14 (93%)	31 (79%)	0.4
Single kidney, n (%)	2 (13%)	3 (8%)	0.9
Side of the ureteral stricture, n (%)			
Left	9 (60%)	25 (64%)	0.01
Right	3 (20%)	14 (36%)	
Bilateral	3 (20%)	0	
Multiple renal vessels, n (%)	1 (6.7%)	15 (38%)	0.05
Location of the stricture, n (%)			
Proximal ureter	1 (6.7%)	16 (41%)	0.1
Middle ureter	2 (13.3%)	2 (5.1%)	
Distal ureter	0	2 (5.1%)	
Proximal-middle ureter	3 (20%)	6 (15.4%)	
Middle-distal ureter	7 (46.7%)	10 (25.6%)	
Pan-ureteral	2 (13.3%)	3 (7.7%)	
Etiology of the stricture, n (%)			
Iatrogenic	9 (60%)	33 (85%)	0.3

	RAIUR (N=15, 28%)	RAKAT (N=39, 72%)	P-value
Retroperitoneal fibrosis	1 (7%)	0	
Urological malignancy	2 (13%)	2 (5%)	
Radiation therapy	3 (20%)	4 (10%)	
Stricture length [cm], median (IQR)	9.6 (6-12)	7 (4-11)	0.1
Previous attempts to repair the stricture, n (%)	6 (40%)	22 (56%)	0.4
Preoperative kidney drainage, n (%)			
No	1 (6.7%)	8 (20.5%)	0.03
Double-J	5 (33.3%)	13 (33.3%)	
Nephrostomy	5 (33.3%)	17 (43.6%)	
Double-J and nephrostomy	4 (26.7%)	1 (2.6%)	
Preoperative renogram, n (%)	5 (33.3%)	33 (84.6%)	<0.001
Type of preoperative renogram, n (%)			
DMSA	2 (13.3%)	9 (23.1%)	0.1
MAG-3	3 (20%)	24 (61.5%)	
Not performed	10 (66.7%)	6 (15.4%)	
Split renal function (affected side, %), median (IQR)	39 (28-46)	46 (40-49)	0.2

Abbreviations: IQR = interquartile range; ASA = American Society of Anesthesiologists; BMI = Body Mass Index; eGFR = estimated glomerular filtration rate; DMSA = Dimercaptosuccinic acid; MAG-3 = Mercaptoacetyl triglycine

Table 2. Intraoperative characteristics and surgical outcomes of patients with ureteral strictures undergoing robot-assisted ileal ureter replacement (RAIUR) or robot-assisted kidney autotransplantation (RAKAT).

	RAIUR (N=15, 28%)	RAKAT (N=39, 72%)	P-value
Robotic platform, n (%)			
Da Vinci multiport Si	4 (26.7%)	8 (20.5%)	0.8
Da Vinci multiport X	4 (26.7%)	10 (25.6%)	
Da Vinci multiport Xi	7 (46.7%)	20 (51.3%)	
Da Vinci single-port	0	1 (2.6%)	
Surgical time [min], median (IQR)	290 (246-358)	355 (305-418)	0.008
Estimated blood loss [ml], median (IQR)	75 (50-160)	175 (95-200)	0.07
Placement of a stent intraoperatively, n (%)	7 (47%)	39 (100%)	<0.001

Table 3. Postoperative functional and surgical data of patients with ureteral strictures undergoing robot-assisted ileal ureter replacement (RAIUR) or robot-assisted kidney autotransplantation (RAKAT).

	RAIUR (N=15, 28%)	RAKAT (N=39, 72%)	P-value
Length of hospital stay [days], median (IQR)	8 (6-8.5)	5 (4-7)	0.001
Time to stent removal [days], median (IQR)	12 (6-24)	27 (24-30)	0.03
eGFR at 30 days postoperative, median (IQR)	68 (52-88)	90 (76-106)	0.004
Positive change in eGFR, mean (SD)	7 (9.9)	8 (7.9)	0.9
Postoperative complications, n (%)	11 (73%)	12 (31%)	0.01
CDC ≥ 3 complications, n (%)	2 (13%)	4 (10%)	0.1
Grade 1, n (%)	1 (6.7%)	-	
Diarrhea	1 (100%)	-	
Grade 2, n (%)	8 (53.3%)	8 (20.5%)	
UTI	4 (50%)	1 (12.5%)	
Pyelonephritis	3 (37.5%)	4 (50%)	
Peritonitis	1 (12.5%)	-	
Anastomotic leak	-	1 (12.5%)	
Pulmonary embolism	-	1 (12.5%)	
Ileus	-	1 (12.5%)	
Grade 3, n (%)	1 (6.7%)	4 (10.3%)	
Ileal perforation	1 (100%)	-	
Anastomotic leak	-	1 (25%)	
Midline eventration	-	1 (25%)	
Leg compartment syndrome	-	1 (25%)	
Absence of renal vascularization	-	1 (25%)	
Grade 4, n (%)	1 (6.7%)	0	
Sepsis	1 (100%)	-	

Abbreviations: IQR = interquartile range; SD = Standard deviation; eGFR = estimated glomerular filtration rate; CDC = Clavien Dindo Classification; UTI = urinary tract infection

Supplementary table 1. Clinical data during follow-up.

	RAIUR (N=15, 28%)	RAKAT (N=39, 72%)	P-value
Duration of follow-up [months], median (IQR)	16 (8-24)	35 (11-63)	0.04
eGFR at last follow-up, median (IQR)	65 (51-75)	90 (75-103)	0.001
Urinary tract infections, n (%)	2 (13%)	4 (10%)	1
Lifelong need of renal drainage, n (%)	0	1 (2.6%)	1
Persisting stricture during follow-up, n (%)	2 (13%)	2 (5.1%)	0.6
Reintervention during follow-up, n (%)	0	2 (5.1%)	0.6
Alive at last follow-up, n (%)	15 (100%)	38 (97%)	1

Abbreviations: IQR = interquartile range; eGFR = estimated glomerular filtration rate

Figure 1. Changes in the median estimated glomerular filtration rate (eGFR) during follow-up of patients who underwent robot-assisted ileal ureter replacement (RAIUR) or robot-assisted kidney autotransplantation (RAKAT). Error bars refer to interquartile ranges. Median last follow-up was 16 months for RAIUR and 35 months for RAKAT.

