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VIDEO/ILLUSTRATED ARTICLE

Totally intracorporeal robotic ileal ureter replacement: focus on surgical technique and outcomes

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ABSTRACT

BACKGROUND: The aim of the present study was to describe our totally intracorporeal robotic ileal ureter replacement technique, reporting perioperative and mid-term results and compare it with previous similar experiences, specifically focusing on technical considerations.

METHODS: Three patients were submitted to robotic ileal ureter substitution for long ureteral defects in our institution during 2019. The procedures were carried out fully intracorporeally. Two patients received a complete replacement of the urinary tract using an ileal segment, while in one patient the lower ureteral stump was maintained, and an ileal-ureter anastomosis was performed distally. Patients' baseline characteristics, as well as perioperative and mid-term results were collected. A detailed description of the technique is reported and compared with prior similar experiences.

RESULTS: Median operative time was 270 (range 240-300) min. No Clavien-Dindo complication >2 was collected. All patients experienced a fast return to oral intake and canalization. Antegrade pyelography, performed a 1-month follow-up, revealed full passage of the medium contrast in those patients submitted to complete ileal ureter replacement while, in the third one, stenosis at the level of ileal-ureter anastomoses was found.

CONCLUSIONS: Robotic ileal ureter replacement can be performed completely intracorporeal with optimal results and limited complication rate, in selected cases. According to our considerations, specific surgical steps are needed to reduce the risks related to this procedure, including avoiding partial ileal substitution.

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KEY WORDS: Surgical procedures, operative; Ureter; Ileum; Reconstructive surgical procedures; Robotic surgical procedures.

Ureteral injuries can occur after endoscopic procedures,[1, 2] radiation therapy and pelvic surgery[3] or can be secondary to retroperitoneal fibrosis or malignant disease.[4, 5] Moreover, unexpected events, such as ureteral avulsion, may even occur as a complication and need prompt treatment.[1] The surgical management can considerably differ depending on the localization (upper, middle or lower ureter) and the length of the ureteral defect. Under this light, an ileal ureter is a suitable option for the treatment of long segment ureteral disease. The first procedure of ileal ureter can be ascribed to Shoemaker in 1907. Although it became more popular thanks to Goodwin only fifty years later,[6] it remained limited to expert surgeons and open approach despite the ongoing improvements of surgical knowledge. In the last decades, minimally invasive surgery, and in particular robotic surgery, has expanded worldwide simplifying many advanced procedures.[7] However, data on robotic-assisted urinary reconstruction using ileal ureter are poor and mainly limited to case reports. The aim of present study was to report our completely intracorporeal robotic ileal ureter technique, performed in three consecutive patients and compare it with the prior experiences available in the literature, specifically focusing on the surgical steps and technical considerations.

Materials and methods

Patients' details

During 2019 three consecutive patients underwent completely intracorporeal robotic ileal ureter, at our Institution. Patient 1 (40-year-old male) presented with a diagnosis of retroperitoneal fibrosis, submitted to an unspecified retroperitoneal open surgery performed abroad in 2017. Soon thereafter, due to the worsening of clinical condition, bilateral indwelling nephrostomies and a ureteral stent on the left side were placed. On the right side, instead, the "plaque-like" fibrous tissue prevented from possible ureteral stenting (Figure 1A). A robot-assisted bilateral ureterolysis was tried in 2018 at our institution but, intraoperatively, the right-sided ureter was not found.

In its place, an extensively adherent fibrotic gangue was seen, avoiding any possible isolation.

Patient 2 (21-year-old male) was sent from a district hospital due to a left ureteral avulsion that occurred during ureteroscopy for a ureteral stone. After nephrostomy placing, a subsequent antegrade pyelography showed full stricture at the ureteropelvic junction level (Figure 1B), with complete interruption of the ureteral continuity. Retrograde stenting was tried confirming the entire involvement of the ureter.

Patient 3 (53-year-old male) had a prior history of stone disease treated endoscopically and concurrent left ureteropelvic junction obstruction (UPJO). As such, he underwent two left robotic pyeloplasties, in January and May 2019, with unsatisfactory results due to the presence of a 7 cm proximal iatrogenic ureteral stricture, starting from ureteropelvic junction level, and concurrent severe hydronephrosis, requiring left nephrostomy placement (Figure 1C).

After a careful internal case discussion, a urinary reconstruction using an ileal interposition was decided in all three cases. All cases were performed using robotic assistance by three highly trained robotic surgeons.

Patients were fully informed of the risks and benefits of the procedure and agreed with the intervention. Preoperative and postoperative features were recorded. Complications were divided into "early" and "late" since they occurred before or after the 30th postoperative day and graded according to the modified Clavien-Dindo classification system.[8]

Enhanced Recovery After Surgery (ERAS) protocol

In our institution, the ERAS protocol was introduced in 2018 and was applied to those surgical procedures involving the bowel (neoblad-

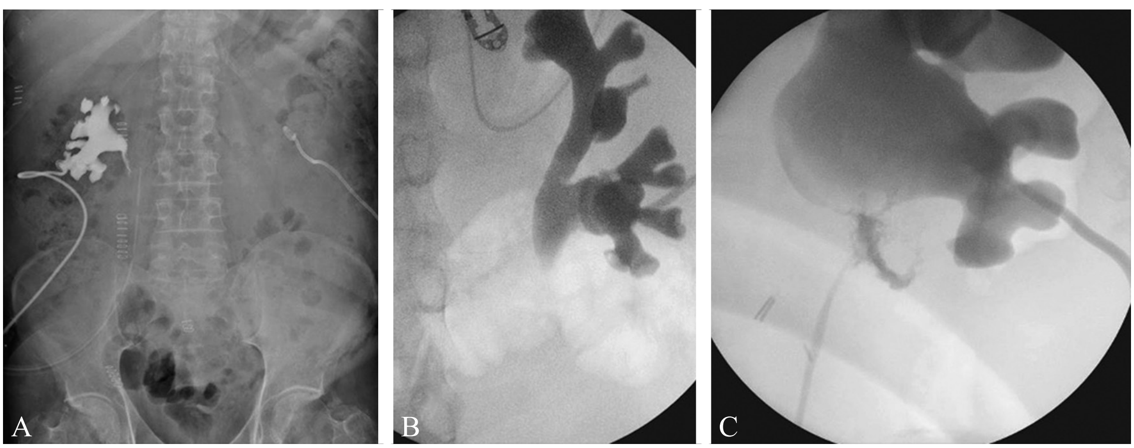

Figure 1.—Preoperative antegrade pyelography.

der, bricker diversion, ileal ureter, augmentation cystoplasty)[9] ERAS protocol aims to improve surgical outcomes, shorten hospital stay, fasting patient's recovery by standardizing perioperative care.[10] Suitable patients are submitted to a pre-operative nutritional assessment and instructed to follow a specific immune-nutrition, beginning 7 days before the hospitalization date. All three patients were treated following the key features of the protocol, including: 1) perioperative diet management; 2) advanced anesthesiologic technique; 3) specific antalgic postoperative care (based on non-opioid drugs); and 4) early oral diet intake and mobilization.

Surgical technique

A detailed description of the surgical steps is available in the Supplementary Digital Material 1 (Supplementary Video 1, 2 minutes, 5 seconds, 8.56 mb).

Patients were placed in a flank position elevated at approximately 70°. Si and Xi da Vinci surgical system (Intuitive Surgical, Sunnyvale, CA, USA) were used in one and two cases, respectively, always in a four-arm configuration. Pneumoperitoneum was induced by standard mini-open access and a 12-mm or 8-mm camera port was placed 2 cm above the level of the umbilicus, depending on the different robotic platforms used.

Then, three 8-mm robotic ports were inserted. One in mid-clavicular line, 3 cm below the costal margin, one caudally, along the same line, to obtain an optimal triangulation. According to the complexity of the procedure, a third 8-mm port was placed on the same line of the camera port, 5 cm caudally (Figure 2).

Two additional ports were positioned for the bed-side assistant, one 5-mm and one 12-mm for the Air Seal®. Finally, only for the right-sided kidney, a supplementary 5-mm port was placed below the costal margin for liver retraction. The following are the main features related to the procedure:

The colon is medialized and, once the Gerota's fascia is incised, all anatomical landmarks are identified. Soon thereafter, after careful lysis of connective tissue, the renal pelvis is exposed, and the upper ureteral stump is transected and

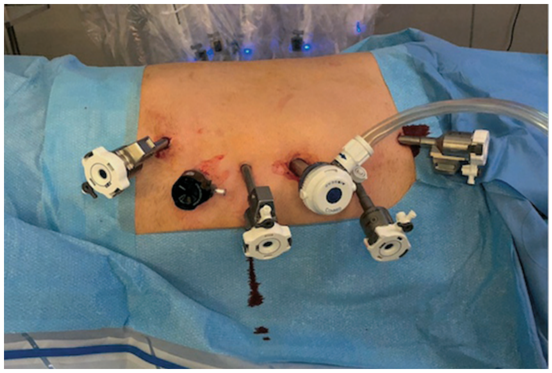

Figure 2.—Robot docking and ports' placement.

excised. In patient 3, the lower ends of the stricture were cut, leaving the final portion of the ureter in site.

A 20-cm ileal segment is then measured by double fenestrated grasper and isolated approximately 20 cm proximal to the ileocecal valve. A 4-0 Monosyn stay suture is placed to mark the point and the ileum is then sectioned using Endo-GIA 60 mm Echelon Powered Endopath® Stapler (Ethicon Inc., Cincinnati, OH, USA) (Figure 3A). The device is inserted by placing a supplementary 12-mm port in either right or left iliac fossa. Continuity of the bowel is re-established with an intracorporeal side-to-side anastomosis using an Endo-GIA stapler with one longitudinal fire (Figure 3B). The two transversal holes are then closed by a double layer 3-0 Stratafix

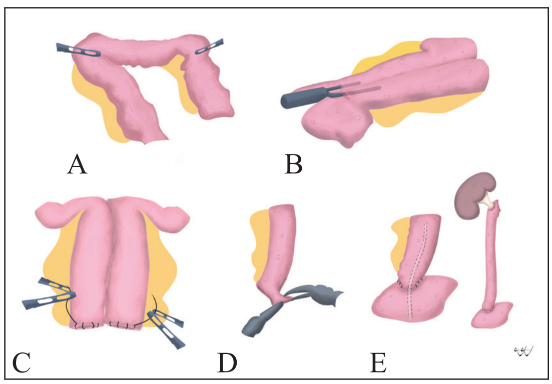

Figure 3.—Intraoperative surgical steps: A) isolation of 20-cm ileal segment; B) re-establishment of the bowel continuity by one Endo-GIA stapler longitudinal fire; C) closing the two transversal holes with 3-0 Stratafix running suture; D) isoperistaltic configuration of the bowel segment; and E) completion of the ileal interposition by pyelo-ileal and ileo-vesical anastomoses.

running suture (Figure 3C). In cases of Xi platform, indocyanine green dye (Firefly®) is used to assess the perfusion at the level of the intestinal anastomosis.

The proximal end of the isolated ileum is therefore anastomosed directly with the renal pelvis using two 4-0 Monosyn semi-continuous (B-Braun, Milan, Italy). Great attention is taken to ensure that the orientation of the bowel segment is in an isoperistaltic configuration (Figure 3D). In case of left-sided ileal ureter, the creation of a window in the sigmoid colon mesentery is necessary to restore the proper setting of the urinary tract in the retroperitoneum. The isolated ileum segment is passed through this window allowing the ileal ureter to be below the sigmoid and descending colon to lower the risk of kinking. In the right-sided case, the same principle is guaranteed by lifting the previously mobilized cecum anteriorly and medially.

Undocking and re-docking the robot is now necessary for subsequent ileo-vesical anastomosis. The Xi platform allows maintaining the patient in the flank position, while the supine position is adopted in case of Si console. Afterward, in patient 1 and 2, the bladder is mobilized, and a direct ileo-vesical anastomosis is performed at the level of bladder dome, using two 4-0 Monosyn running sutures (Figure 3E). A waterproof test is therefore performed by filling the bladder with 100 mL saline solution through the catheter. In case of Xi surgical platform, indocyanine green dye is used to confirm that pyelo-ileal and ileo-vesical anastomoses are properly perfused at the end of the procedure.

In patient 3 the distal portion of the ureter was spatulated and then an end-to-end anastomosis with the ileum was completed using two 5-0 Monosyn semi-continuous sutures. Suture started from the corner of the spatulated ureter and, once the posterior plate had been completed, a double J stent was placed through cystoscopy. Finally, the anterior part of the anastomosis was completed.

Results

Overall operative time (OT) was 300 min, 240 min and 270 min, respectively. No surgical or anesthesiologic intraoperative complications occurred. However, in patient 2, lateral ileo-ileal anastomosis was performed twice, after indocyanine green dye revealed poor perfusion at the level of the first anastomosis. Solid oral intake was restored at 2nd POD, according to ERAS protocol. All patients removed the drainage at 3rd POD and had full canalization at 5th, 6th and 3rd POD, respectively.

During hospitalization, patient 1 and 2 experienced fever on the first POD and broad-spectrum oral antibiotics were successfully administered with immediate return on normal temperature.

Vesical catheter was removed at the 4th POD while the nephrostomy tube was closed the day before the discharge. Length of hospital stay was 7, 8 and 6 days, respectively, and all patients were discharged with nephrostomy maintained closed, after abdominal ultrasonography had excluded signs of hydronephrosis (Table I). Patient 3 had the double J stent removed in the 21st POD. Four weeks after surgery an antegrade pyelography through the nephrostomy tube was performed. In patient 1 and 2 it revealed full passage of the contrast medium from the pelvis to the bladder without signs of obstruction, while in patient 3 a stricture at the level of the ileo-ureter anastomosis was reported. In particular, this patient did not experience fever and only reported mild flank pain (visual analog pain scale (VAS) was 3). No late postoperative complication or readmission was reported.

At a median follow-up of 8 months (range 4-8), creatinine serum level was 1.18, 0.68 and 1.23 mg/dL, respectively.

Discussion

To date, several options for the reconstruction of long ureteral defects have been proposed, including transureteroureterostomy, renal autotransplantation, combined Boari flap and psoas hitch and, last but not least, ureteral substitution.[11] The ideal substitute should have intrinsic characteristics intimately resembling a native ureter: Adequate peristalsis and blood supply, optimization of the electrolyte balance, avoiding urine reflux as well as stones or stenosis.[12] To this regard, ileal ureter is utilized as the last

TABLE I.—*Preoperative and postoperative patients' features.*

	Patient 1	Patient 2	Patient 3
Sex	Male	Male	Male
Age (years)	49	21	57
Side	Right	Left	Left
Indication for surgery	Retroperitoneal fibrosis	Ureteral avulsion	Long iatrogenic ureteral stricture
Robotic platform	Si	Xi	Xi
Preoperative creatinine serum level (mg/gL)	1.5	0.98	1.57
Preoperative hemoglobin blood level (g/dL)	11.5	13.9	11.9
Operative time (min)	300	240	270
Estimated blood loss (mL)	100	70	150
Intraoperative complication	0	0	0
POD 1 creatinine serum level (mg/gL)	1.7	0.82	1.27
POD 1 hemoglobin blood level (g/dL)	10.7	12.3	10.9
Time to solid oral feeding (days)	2	2	2
Time to full canalization (days)	4	4	3
Catheterization time (days)	4	4	4
Time to nephrostomy removal (days)	21	21	21
Length of hospital stay (days)	7	8	6
Creatinine serum level at discharge (mg/gL)	1.3	0.67	1.11
Hemoglobin blood level at discharge (g/dL)	11	12.7	11.7
Early Postoperative complication	Fever on 1 POD treated with antibiotics (Clavien II)	Fever on 1 POD treated with antibiotics (Clavien II)	None
Late postoperative complication	None	None	None
Creatinine serum level at last follw-up (mg/dL)	1.18	0.68	1.23
Follow-up (months)	8	8	4

POD: postoperative day.

resort for long ureteral injured segments replacement since a non-negligible postoperative complications rates have meaningfully limited its extended use. Concerns about this technique were primarily referred to significant technical difficulties, electrolytic impairment secondary to mucosal absorption[13] and absence of an antireflux mechanism.[14] However, more recent exploratory analyses have widely questioned the real impact of urinary reflux on renal function impairment, although biased by the limited sample size and the retrospective nature of the studies.[15, 16] On the other hand, relative contraindications were addressed to inflammatory bowel disease, radiation enteritis, neurogenic bladder, bladder outlet obstruction, and hepatic dysfunction.[17]

The current study explored the intraoperative feasibility, perioperative results and medium-term functional outcomes after totally intracorporeal robot-assisted ileal ureter replacement. The first case of minimally invasive ileal ureter replacement was performed laparoscopically in 2000[18] and clear benefits of conventional laparoscopy over open surgery in terms of early postoperative outcomes were further confirmed, afterward.[19] Ever since, the ongoing improvements of computer-enhanced technology have provided the necessary means for surgeons to assimilate minimally invasive surgical options in everyday surgical practice. In this light, the da Vinci platform is representative of how technology can support this regard, making possible to translate to robotic scenario even extensively complex reconstructive procedures, previously performed only by open approach.[20] Wagner *et al*. in 2008 described the first case of robot-assisted ureterectomy with ileal ureter replacement.[21] In this report, a transperitoneal, 4-arm robotic approach was used. Intracorporeal bowel isolation was performed using stapling devices. Overall operative time was nearly 9 hours with favorable perioperative outcomes. Since then, several other cases of ileal ureter replacement using laparoscopic, as well as a robotic approach, were described either with extracorporeal reconstructive phase[22] or performed fully intracorporeally,[23-29] showing progressively improving outcomes in term of safety and efficacy. However, data are mainly limited to single case reports (Supplementary Digital Material 2: Supplementary Table I).

After extensive experience in robotics, may be the robotic ileal ureter technique a valid option suitable for selected patients?

The present surgical technique has some peculiarities compared to previous reports. We did not combine the ileal ureter to bladder psoas Hitch, as showed by preceding authors,[23, 25-28] as we believe that an adequate length of ileal segment ensures a tension-free anastomosis. Furthermore, in patients submitted to complete ileal interposition, we avoided stent placement at the end of the procedure, without recording related postoperative complications.

The current paper reported an overall operative time significantly lower as compared to other contemporary experiences.[23, 26] Postoperatively, all patients experienced a fast recovery, with early mobilization and full canalization occurring in the 2nd and 4th POD, respectively. This may be also explained by ERAS protocol adoption.[30]

Regarding the success rate, we recorded optimal results in 2/3 patients, with favorable functional outcomes persisting also at a median follow-up of 8 months (Figure 4). In one patient a partial ileal interposition was conducted to preserve the distal native ureteral tract, however, we recorded the occurrence of stenosis at the level of the ileo-ureter anastomosis one month after surgery (Figure 4C). The ideas under maintaining a "ureteral plate" as an anchor for the on laid reconfigured intestine were preserving blood supply to the remaining ureter and decreasing the risk of metabolic impairment. However, in our opinion, this failure may be attributed to the different caliber of the two conducts (*i.e.,* the bowel and the distal ureter) which may have eventually led to increased pressure, possibly associated with a suboptimal vascularization of the ureteral stump.

Based on our experience, the following recommendation with respect of surgical technique can be provided: 1) we believe that using the fourth robotic arm might add clear advantages in this kind of surgery, especially during renal pelvis exposure and bowel mobilization; 2) Xi robotic platform may be even more performing as compared to Si, since allows maintaining the patient in the flank position also for ileo-vesical anastomosis, after robot redocking, and, thus, considerably reduces overall operative time. Moreover, the use of the indocyanine green dye (Firefly®; Firefly Medical, Inc., Fort Collins, CO, USA) provides meaningful assistance when ensuring the proper vascularization after ileo-ileal and ileo-vesical anastomosis, as showed in other surgical experience.[31] Notably, in patient 2, ileo-ileal anastomosis was performed twice, after indocyanine green dye revealed poor perfusion at the level of the first anastomosis; 3) placing the ileal segment in the retroperitoneal space is of pivotal importance to minimize the risk of kink-

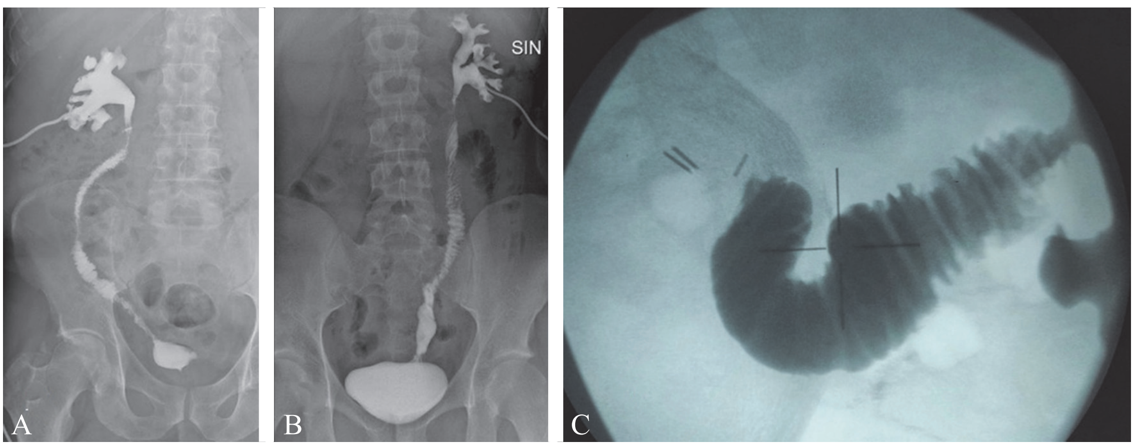

Figure 4.—One-month postoperative antegrade pyelography.

ing. When the defect relates to the left urinary tract, this is performed by passing the ileal ureter through a window created in the sigmoid colon mesentery. Conversely, in right-sided disease, the retroperitonealization is ensured by lifting the previously mobilized cecum anteriorly and medially; 4) despite some authors hypothesized a reduced risk of metabolic disorders when combined boari flap and/or psoas Hitch are performed,[27] we think that, through a careful choice of the length of the ileal segments, both tension-free anastomosis and metabolic homeostasis can confidently be reached; and 5) completely ileal replacement is desirable when performing urinary tract reconstruction. In fact, despite the theoretical advantages of maintaining a native ureteral segment, the ileo-ureteral anastomosis may elicit an increase in pressure, ultimately undermining the proper healing process, especially in patients being treated for recurrent ureteral strictures.

Limitations of the study

We acknowledge the following study's limitations. First, the small sample size related to a case series and the relatively short follow-up might have underrated possible late complications. Second, all cases were performed by highly trained surgeons with extensive experience in both open and robotic surgery. As such, our findings could not be applied to all surgeon- or center-related scenario. Acknowledged these limitations, we sincerely believe that this paper might add significant data towards a more extensive knowledge regarding totally intracorporeal robot-assisted ileal ureter replacement. As such, we hope our findings might pave the way to consider the robotic ileal ureter technique as a safe treatment option, keeping in mind that is of pivotal importance that surgical management is carried out by highly trained robotic surgeons in selected patients. Based on our experience, however, a completely ileal ureter interposition is to prefer rather than maintaining a native ureteral segment, due to an increased risk of developing stenosis at the level of the ileal-ureter anastomosis. Further studies with larger cohorts and longer follow-up would be needed to corroborate our preliminary results.

Conclusions

In conclusion, complex robotic reconstructive procedures are still considerably challenging. Nevertheless, robot-assisted ileal ureter can be performed with a completely intracorporeal technique with optimal results and a limited complication rate, in selected cases. Further evidence, including randomized controlled trials with an adequate number of patients, are necessary to compare safety and efficacy among different surgical approaches.

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Conflicts of interest.—The authors certify that there is no conflict of interest with any financial organization regarding the material discussed in the manuscript.

Authors' contributions.—Antonio A. Grosso and Fabrizio Di Maida have given substantial contributions to the material and data collection; Antonio A. Grosso, Fabrizio Di Maida and Andrea Mari contributed to the manuscript first draft; Andrea Minervini and Marco Carini contributed to the study and team supervision; all authors equally contributed to the study conception and design and to the manuscript draft comment. All authors read and approved the final version of the manuscript.

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