Robotic Ureteral Reimplantation

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Introduction and Objectives

This chapter focuses on the management of distal ureteral obstruction and/or distal ureteral malignancy managed by ureteral reimplantation. Open reconstructive surgery of the lower ureteric segment in adults requires large incisions, to allow for wide exposure and complex reconstruction. This is especially true for pre-operated and or pre-irradiated patients in whom adhesions are a major obstacle. It has been suggested and reported that suturing and tissue handling in the limited space of the pelvis can be more easily performed with the robot compared to conventional laparoscopy. Nevertheless, published experience on minimally invasive techniques in this challenging field still remains limited [1–4].

Minimally invasive da Vinci robot-assisted procedures allow precise identification of proper tissue planes and thereby avoidance of unnecessary tissue damage [1–4]. All these allow a consistent and easier application of the gold standards of open surgery in the deep small pelvis. We feel the steps presented here are the most important steps of robot-assisted distal ureteral reconstruction (RAURI) using the

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da Vinci robot. The results of our RAURI series were presented recently in one of the largest European single-institution series on robot-assisted reconstructive surgery (RARS) of the lower ureteric segments (LUS) [4]. This chapter is based on our own previous publications [5] and videos [6] and hitherto unpublished new data, all focusing on the operative technique of RAURI.

Materials and Methods

We briefly describe the patient characteristics and perioperative data, the incidence of 90-day postoperative complications, and the results of follow-up examinations. We then present in detail the operative technique used. Each procedure was recorded and could be analyzed for the purpose of this article. All data were collected retrospectively using the patients' records and standardized questionnaires sent to the patients and their referring urologists. The follow-up examinations were done at the discretion of the referring urologists. Descriptive statistics comprise median and range for continuous variables and frequencies and percentages for categorical variables.

Preoperative Diagnostic Workup

There are no defined algorithms for preoperative diagnostic workup in the case of distal ureteral obstruction. Most patients are symptomatic, or the dilated ureter is detected as an incidental finding of abdominal sonography, a CT scan, or MRI of the abdomen. A malignant tumor as the cause of a ureteric obstruction should always be considered and ruled out. Cystoscopy should follow, and in the case of a suspected vesical or extravesical malignancy, biopsies should be taken. Bullous edema of the bladder mucosa from the ipsilateral side strongly suggests an extravesical tumor. The next steps are retrograde pyelography and, if indicated, ureterorenoscopy and targeted biopsies (Figs. 15.1 and 15.2). During these procedures, we fill the bladder with a diluted, slightly warmed x-ray dye to measure the bladder capacity and its cranial extension and so estimate if the psoas hitch procedure alone or in combination with a Boari flap will be necessary. If malignancy is disclosed and reasonable ipsilateral function can be expected, the diseased ureter should be excised and reimplant considered if negative margincs and no proximal tumor is confirmed.

Results

Between October 2009 and December 2016, ureteric resection and reimplantation of the distal part of the ureter were performed in 38 patients. Resection of the distal ureter was necessary due to urothelial carcinoma in nine patients, ureteric stricture secondary to advanced prostate cancer seen in two patients, ureteric stricture caused by an inflammatory conglomerate tumor of the adnexa in one patient, ureteric

Fig. 15.1 Retrograde pyelography in a patient with the iatrogenic right-side distal ureter

stricture of unknown cause in three patients, inflammation in one patient, ureteric stricture due to a B-cell lymphoma in one patient, and iatrogenic ureteric stricture following gynecologic or urologic surgery in eight patients.

RARS of the LUS comprised 26 cases of anti-refluxive ureteric reimplantation and psoas hitch technique with ($n = 13$) or without ($n = 13$) Boari flap. Furthermore, six cases of extravesical anti-refluxive ureteric reimplantation, two cases of intravesical anti-refluxive ($n = 1$) or refluxive ($n = 1$) ureteric reimplantation, three cases of ureteric stricture resection and end-to-end anastomosis, and one case of ureterolysis with omentum wrap were necessary due to benign conditions. In all cases, we aimed to reduce traumatic handling of the ureter by using a vessel loop and the fourth robotic arm for traction (Fig. 15.3). In those cases where a urothelial carcinoma of the LUS was the underlying pathological condition, an ipsilateral pelvic lymphadenectomy was always performed. Furthermore, in order to avoid tumor cell spillage, the affected segment was isolated, clipped proximally and distally with Hem-o-Lok® clips and transected proximally (Fig. 15.4). Then, the bladder was filled with distilled water, a bladder cuff was resected along with the distal ureter, and directly thereafter, the specimen was collected in a retrieval bag. When ureteric reimplantation was done with a psoas hitch technique (+/− Boari flap), the ureteral neo hiatus (entry point of the ureter into the bladder wall) and the direction of the submucosal tunnel were built in line with the anatomic course of the ureter to avoid angulation of the ureter in different filling states of the bladder (Fig. 15.5). Such a

Fig. 15.2 Retrograde pyelography in a patient with left distal ureteric tumor

tunnel of adequate caliber should also allow uncomplicated ureteral catheterization or ureterorenoscopy (Fig. 15.6). End-to-end anastomosis of the distal ureter should certainly not be regarded as routine. However, in the cases presented here, it was considered because of a well-preserved blood supply of the generously spatulated ureteral ends and the possibility of an absolutely tension-free anastomosis between them. To prevent any kind of tension postoperatively, the surrounding scar tissue was partially left in situ and used as an anchor point in one case. Extravesical anti-refluxive ureteric reimplantation was necessary due to benign intramural strictures following urological surgery ($n = 3$) and persistent vesicoureteral reflux after endoscopic injection therapy ($n = 1$). Intravesical ureteric reimplantation was performed in one case following resection of an upper kidney pole megaureter and ureterocele and in another case following inadvertent bilateral ureteral transection of upper-pole ectopic ureters inserting into the prostatic urethra in a patient undergoing radical prostatectomy.

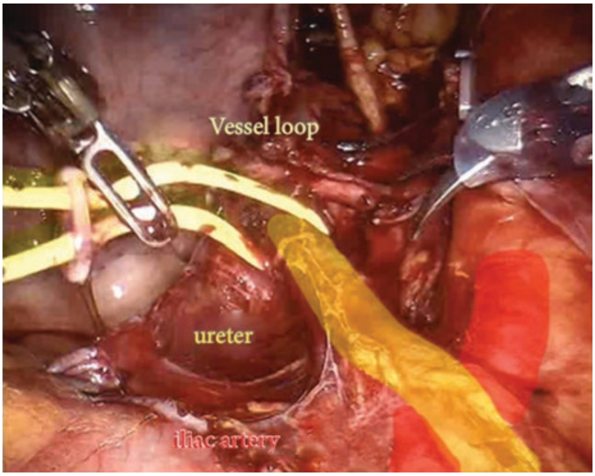

Fig. 15.3 Vessel loop to put the ureter in position

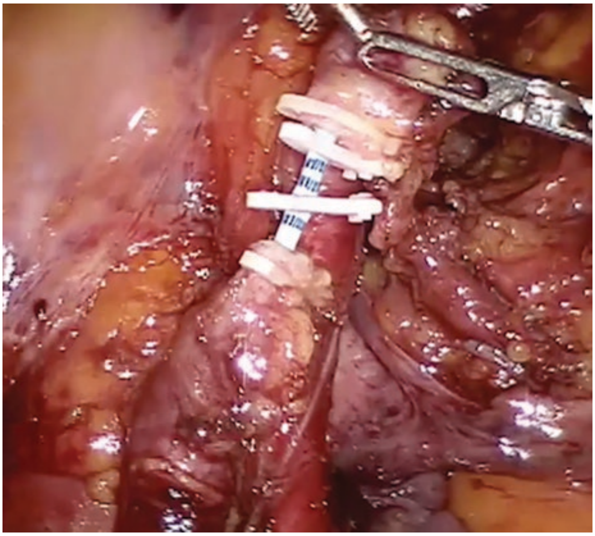

Fig. 15.4 Use of Hem-o-Lok clips to prevent tumor cell spillage

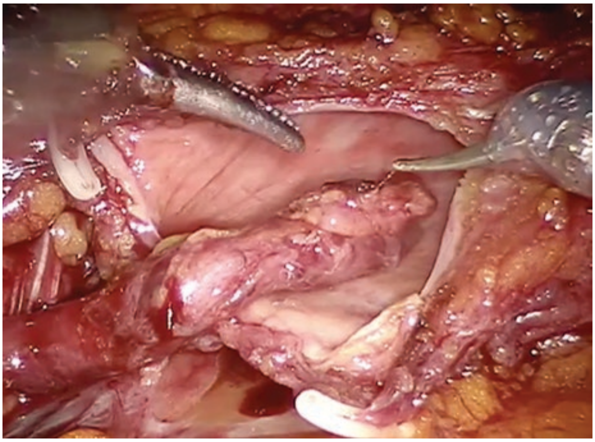

Fig. 15.5 Positioning of the ureter to preserve the natural course

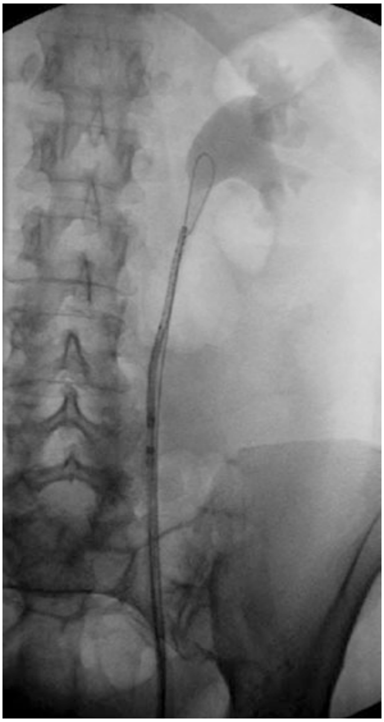

Fig. 15.6 Follow-up ureterorenoscopy in patients who underwent distal ureteric resection because of ureteric carcinoma

Robot Used

A standard four-arm da Vinci® surgical system (Intuitive Surgical Inc., Mountain View, CA, USA) was used at the beginning of the study, replaced from January 2011 with a da Vinci Si HD surgical system and an Xi HD surgical system in 2015.

RAURI

The principles of ureteric reconstruction and reimplantation that were applied here with robot assistance are generally accepted as the gold standard in open surgery and described in detail in Campbell-Walsh Urology in the chapter "Management of Upper Urinary Tract Obstruction" by Nakada and Hsu [7].

RAURI can be divided into the following important steps:

Positioning of the Patient on the Operating Table and Trocar Placement

After placing the patient in a steep Trendelenburg position, an 18-F Foley urethral catheter was inserted. Trocar positioning was as follows: a 12-mm robotic camera

Fig. 15.7 Trendelenburg and trocar placement

port 5 cm above the umbilicus in the median line, two 8-mm robotic ports bilaterally along the midclavicular line at the level of the umbilicus, a fourth 8-mm robotic port on the contralateral side of the diseased ureter 10 cm lateral to the other ipsilateral 8-mm robotic port, and a 5-mm assistant port between the camera port and the 8-mm port.

The patients operated on with a standard, Si HD, or Xi robot were always put in a steep Trendelenburg position with the legs spread and slightly flexed at the knee (Fig. 15.7). In the patients operated on with a Xi robot, we routinely use side docking without flexing of the legs. In all three types of a robot, we used an abdominal pressure of 12 mmHg. All operations were performed using a four-arm robotic setting, with the fourth arm placed either on the left side of the patient or contralaterally to the operating field when possible. Careful padding of all conceivable pressure points was performed. In the case of severe arteriosclerosis, a pulse oximeter was placed on the toes of both legs and oxygen saturation measured continuously. Preoperative identification of high-pressure glaucoma is essential. The steep Trendelenburg position should be checked before starting the operation to make sure that the patient has not changed his position. This sounds banal, but a high number of patients can have positioning-related pain after steep Trendelenburg position, and some remain prescriptive and are partially disastrous [8] (Table 15.1).

Operative Procedure

The Steps of the Operation in a Case Where a Part of the Ureter Had to Be Resected

The principles and steps of the operation are shown in Table 15.2.

After resection of the diseased distal ureter, the bladder was mobilized as far as possible. Care was taken not to harm the bilateral vascular pedicles of the bladder, which is distinctly easier to do robotically than during an open procedure. Then, the bladder was filled with physiological saline until maximal capacity was reached. In the case of urothelial carcinoma of the ureter, the bladder is filled with air to avoid

Table 15.1 Patient characteristics

Procedure	Distal ureter resection and/or reconstruction
Patient no.	38
Localization (uni−/bilateral)	35/3
Gender (♀/♂)	19/19
Age (years) (median (range))	60 (25–86)
BMI (kg/m^2) (median (range))	26 (17.6–36.2)
Surgical time (min) (median (range))	225 (105–380)
Hospital stay (day) (median (range))	8 (5–35)
Postoperative complications	
Clavien grade IIIa-b	3
Clavien grade IVa-b	1
Clavien grade V	0
Follow-up (month)	17.3 (1.1–81.8)
(median (range))	Follow-up of 27 patients
No obstruction	26
	Follow-up of 27 patients
Asymptomatic	27
	Follow-up of 27 patients

Table 15.2 Principles of distal ureteric reconstruction and reimplantation used in the present series

1	Adequate mobilization of the distal ureter without traumatic tissue manipulation to preserve its blood supply
2	Gentle handling of the bladder to reduce postoperative hematuria and bladder spasms
3	Generous mobilization of the bladder with the preservation of its blood supply (dissection of the contralateral bladder pedicle only if necessary)
4	Fixation of the bladder on the psoas muscle carefully avoiding injuries to the genitofemoral or femoral nerves (Fig. 15.5)
5	Choosing the position of the neo-hiatus (entry point of the ureter into the bladder) and the direction of the submucosal tunnel to correspond well with the anatomical course of the ureter (Figs. 15.6 and 15.10)
6	Creation of a submucosal tunnel of adequate width and length and with sufficient muscular backing
7	Spatulation of the ureter
8	Anchoring sutures of the ureter
9	Meticulous suturing when creating the neo-orifice
10	Complete covering of the ureter with bladder mucosa to avoid fibrosis (Fig. 15.7)
11	Tension-free vesico-ureteric anastomosis
12	Meticulous watertight closure of the bladder
13	Adequate postoperative drainage is obligatory
14	Omentum majus wrap, if impaired blood supply is suspected

spillage of potentially contaminated urine. Thereafter, as said before, the decision should be made as to whether the anti-refluxive psoas hitch procedure will be enough to achieve a tension-free anastomosis between the bladder and the ureter or a

Boari-flap should be additionally used. In our opinion, an anti-reflux reimplantation should be done whenever possible because it is technically easier to perform, imitates the natural course of the ureter, and prevents an anastomotic stenosis (Fig. 15.8).

In cases where a psoas hitch procedure was judged sufficient for a tension-free anti-refluxive anastomosis, the bladder was dorsally detached from the overlying peritoneum in a meticulous fashion. If this was done properly, in our experience, it was not necessary in a single case to transect the ipsilateral or even the contralateral pedicle. The author of this text would prefer to use a Boari flap rather than transect the pedicles to mobilize the bladder. We feel that such a decision is most probably the result of the robot-assisted procedure which allows such precise preparation of functional tissue such as vessels and nerves that the pedicle resection is rendered obsolete. Then, two 2-0 polyglactin sutures with UR-5 needles were used to fix the spread posterior bladder wall to the psoas muscle on the side of the affected ureter (Fig. 15.9), carefully avoiding the genitofemoral and the femoral nerves. The

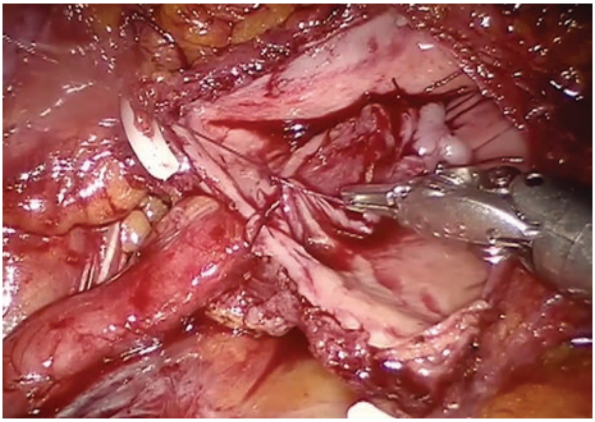

Fig. 15.8 Anti-reflux ureteric reimplantation of the left ureter

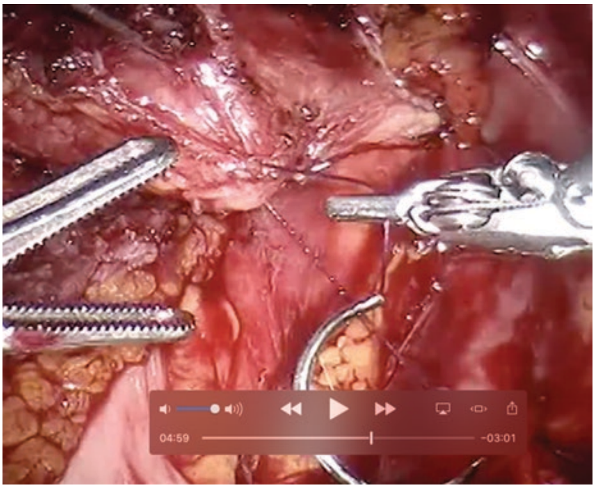

Fig. 15.9 Fixation of the bladder on the psoas muscle

bladder was filled again with physiological saline, and a longitudinal incision was made at the anterior bladder wall in the direction between the two fixing sutures to ensure an appropriate anatomic course of the ureter (Fig. 15.10). The sides of the incised bladder were then fixed to the surrounding tissue with Weck clips to facilitate further procedure (Fig. 15.5). Then, the ureter was spatulated, brought through a 3–4 cm-long submucosal tunnel into the bladder, and anchored in the detrusor with three 3-0 polyglactin sutures (Fig. 15.11). Using interrupted 5-0 polyglactin sutures, the reconstruction of the neo-orifice was completed (Fig. 15.12). Then, a 6-F JJ stent was passed into the reimplanted ureter via a guidewire through one of the assistance ports. If the creation of a Boari flap was necessary, it was fashioned

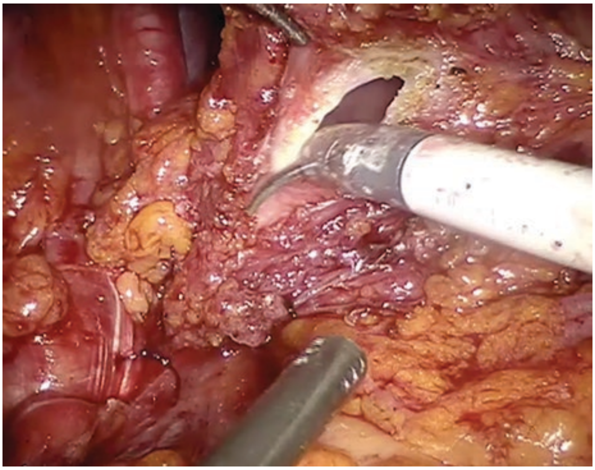

Fig. 15.10 Bladder opening

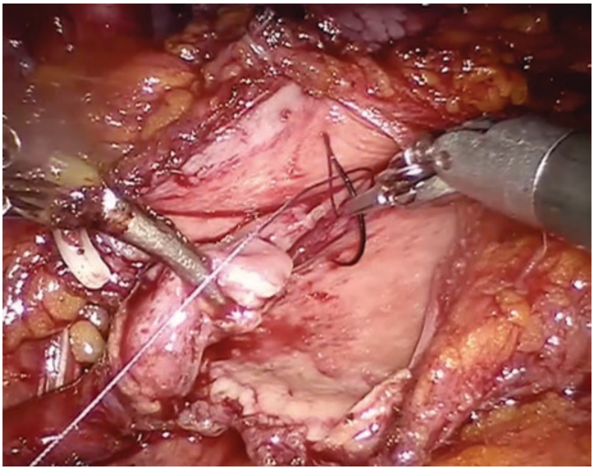

Fig. 15.11 Anchoring of the ureter

from the anterior wall of the bladder with a length-width ratio of 2:1 (e.g., 8 cm in length and 4 cm in width). The technique for anti-refluxive implantation of the ureter when a Boari flap is used is the same as described previously for the psoas hitch procedure. Implantation of the ureter in the flap was performed with the same technique as described previously for the psoas hitch procedure. Thereafter, the Boari flap was tubularized with 4-0 poliglecaprone sutures in two layers. If anti-refluxive reimplantation was not possible, a wide oval anastomosis between a spatulated ureter and Boari flap was performed with 5-0 and 4-0 polyglactin sutures in two layers (Fig. 15.13).

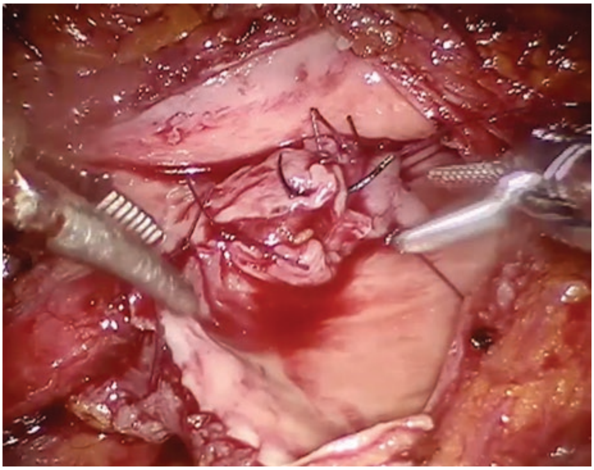

Fig. 15.12 Reconstruction of neo orifice

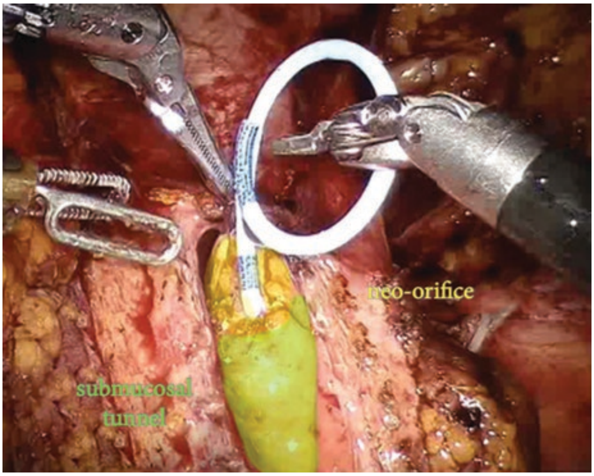

Fig. 15.13 DJ placement

Extravesical Anti-Refluxive Ureteric Reimplantation

In some cases with short ureteral stenosis or symptomatic vesicorenal reflux where a psoas hitch was not necessary, there is an indication for a ureteric reimplantation on the anterolateral bladder wall [9].

The ureter is identified where it crosses the iliac vessels and followed caudally to its insertion into the bladder. Utmost care is necessary to avoid injury of the vesical nerve plexus and vascular pedicle, especially in cases with a bilateral stenosis or reflux. Based on the original position of ureteric insertion, the musculature of the bladder wall was incised on the anterolateral side of the filled bladder along a distance of 4–5 cm to avoid kinking of the ureter. The stenotic part was identified and resected. When the ureter was placed in proper position, its distal end was spatulated, and after finishing one half of the anastomosis, the JJ-stent was inserted over the guidewire and the neo-orifice reconstructed with 5 or 4.0 single Vicryl sutures. In the case of vesicorenal reflux, after creating a muscular incision leaving the intact, the detrusor is closed over the ureter taking care to avoid the creation of a too narrow tunnel (Fig. 15.14).

Ureteric End-to-End Anastomosis

There is no doubt that an end-to-end anastomosis of the ureter in the deep pelvis is very seldom indicated and should certainly not be propagated as routine procedure. But in a case presented here of a female patient with severe surrounding scarring, a wide tension-free anastomosis was judged to be possible. The left ureter was identified as it crossed the iliac vessels and followed caudally to its insertion into the bladder. In its distal course, the ureter was completely released from an encircling endometriosis focus. After ureteric stricture resection and before accomplishing an oval-shaped end-to-end anastomosis, the partially left surrounding scarred tissue

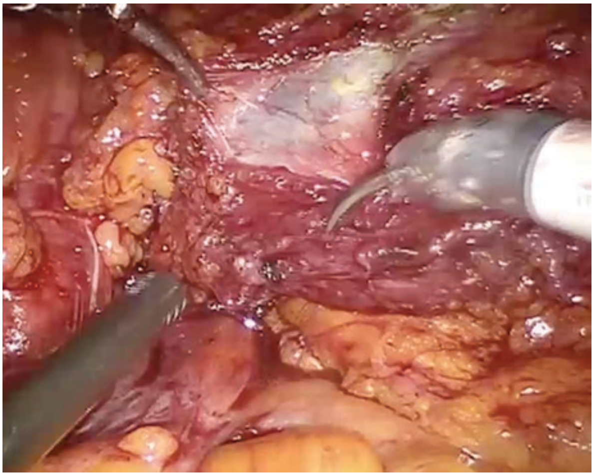

Fig. 15.14 Extravesical anti-refluxive ureteric reimplantation and creating a tunnel between bladder mucosa and bladder muscle

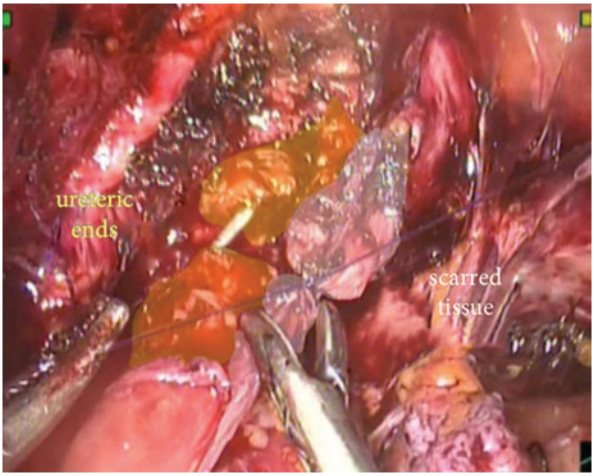

Fig. 15.15 Ureteric end-to-end anastomosis

was used as an anchor point for approximation sutures of the ureteric ends to remove tension and create a tension-free spatulated ureteric end-to-end anastomosis. The left ureter was covered with a mobilized omentum majus wrap. The preoperatively implanted 6-F JJ stent was left in place for 4 weeks. The long-term follow-up was uneventful (Fig. 15.15).

In the case of a fresh accidental iatrogenic ureteric transection, we spatulate the ureter on both sides and put a stay suture on the cranial and distal parts of the spatulated ureter and run a 5.0 PDS suture in semicircular technique. The JJ stent is left for 4 weeks and the wound drained. In such a case, the use of indocyanine is probably very helpful to identify the viability of ureteral edges, but we have no personal experience of this to date.

Discussion

It has been reported that suturing and tissue handling in the limited space of the pelvis can be more easily performed with the robot compared with conventional laparoscopy [10]. Successful robot-assisted distal ureterectomy with psoas hitch and Boari flap reconstruction in patients with urothelial cancers has already been described [1, 11–14]. In this context, recently published studies suggest that a minimally invasive laparoscopic approach to upper tract urothelial carcinoma provides good oncological outcomes and does not result in a clinically significant increased risk of tumor spillage, provided that principles of oncological surgery are obeyed [15, 16].

As with urothelial carcinoma of the distal ureter, the use of robotics for surgery of benign distal ureteric defects or strictures is also still limited, probably due to the relative rarity of these conditions [1, 3, 13, 14, 17–19]. Furthermore, in almost all of these series, a refluxive ureteric reimplantation was performed. Only De Naeyer et al. [2] reported a robot-assisted anti-refluxive psoas hitch reimplantation in an early case report in 2007. In an evidence-based review, Tracey AT et al. analyzed 13 cases and showed the feasibility, safety, and success of robotic ureteral reconstruction in reconstruction of the ureter as well as the usefulness of fluorescence imaging and the use of buccal mucosa in ureteral reconstruction [20]. Our experience with robot-assisted treatment of ureteric injuries is limited but good, with successful outcomes in all patients thus treated.

Robot-assisted laparoscopic extravesical ureteral reimplantation is a minimally invasive alternative to open surgery in vesicorenal reflux or anomalies such as a ureterocele or megaureter in children and adults. In the meantime, this technique has been adopted by a substantial number of surgeons and has shown low complication rates and good results in long-term follow-up [21].

Prospective long-term analysis of nerve-sparing extravesical robotic-assisted laparoscopic ureteral reimplantation is needed.

We feel that an anti-refluxing reimplantation of the ureter regardless of whether performed extra- or intravesically, by open surgery or robot-assisted laparoscopy, has some advantages. If the position of the ureteric neo-hiatus (entry point of the ureter into the bladder wall) and the direction of the submucosal tunnel are in line with the anatomical course of the ureter, angulation of the ureter in different filling states of the bladder should be more easily avoided. Furthermore, such a tunnel of adequate caliber should also allow uncomplicated ureteric catheterization or ureterorenoscopy. In the context of ureteric reimplantation, it is also important to mention that we avoided long-term ureteric stenting before surgery whenever possible, in order to prevent alterations such as ureteric wall thickening complicating surgical reconstruction [22].

In patients with extrinsic endometriosis, ureterolysis alone may be sufficient to correct ureteric obstruction [23]. Following the surgical technique in retroperitoneal fibrosis, we additionally placed an omental wrap around the diseased ureter to prevent entrapment of the ureter in forming scars [24].

An incidentally encountered ectopic ureter in a man undergoing radical prostatectomy (RP) is a rare condition that has only been reported in a few case reports [25, 26]. To our knowledge, the present description of bilateral robot-assisted intravesical reimplantation of upper-pole ectopic ureters inserting into the prostatic urethra in a patient undergoing RP is the only case published to date.

Our experience with robotics in ureteric reconstruction for defects of the distal ureter is largely concordant with the still-limited worldwide experience. The present study has shown that robot-assisted reconstructive surgery of the distal ureter is feasible and can be performed without compromising the generally accepted principles of open surgical procedures. The functional outcome was good in short-term follow-up. The incidence of minor complications was high, but the number of severe complications was low, thus not discouraging. It is the personal opinion of the senior author that in the future, robotics will replace conventional laparoscopy in reconstructive surgery of the distal ureter and even come to challenge open surgery.

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