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Technique Description and Outcomes of Robotic Transvaginal-Assisted Living Donor Kidney Transplantation

Mireia Musquera Felip Tarek Ajami Fardoun Lluis Peri Cusi
Antonio Alcaraz Asensio

Urology Department, Hospital Clinic of Barcelona, Barcelona, Spain

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Kidney transplantation · Minimally invasive surgery · Robotic surgery · Natural orifice transluminal endoscopic surgery

Abstract
Objective: The aim of the study was to describe the surgical technique of totally robotic kidney transplantation with transvaginal insertion and to assess its safety and feasibility. ***Methods:*** It is a prospective analysis of the first 5 cases of robotic kidney transplantation with transvaginal insertion. Robotic-assisted kidney transplantation was performed after transvaginal insertion of a living donor kidney graft. Donor's and recipient's characteristics, intraoperative variables, postoperative complications, and surgical outcomes were assessed. ***Results:*** The median operative time was 220 min. Mean rewarming ischemia time of 53 min, with immediate diuresis. No intraoperative complications were observed. Mean hospitalization period was 9 days, with mean Cr of 1.5 mg/dL at discharge. ***Conclusions:*** Robotic kidney transplantation with transvaginal insertion is feasible and safe. A greater number of procedures are required to confirm the results of this new technique.

Introduction

Surgery has evolved over the years to minimally invasive techniques in order to improve postoperative results and reduce morbidity [1]. Laparoscopy has been adopted by all specialties and for many surgical procedures worldwide. It is well known that kidney transplantation is the treatment of choice for patients with ESRD (end-stage renal disease), for its better survival and quality of life in comparison with dialysis [2], but the surgery itself has not changed very much over the years.

Few surgical groups have developed animal models for laparoscopic kidney transplantation to develop a suitable model for humans to minimize the surgical impact on these patients [3–5]. Laparoscopic kidney transplantation in humans has been performed, but it was not generalized because of its high technical difficulty. We can find experiences in a few laparoscopic autotransplant series [6]. In 2010, the first laparoscopic kidney transplant was published [7].

The introduction of robotics, specifically the da Vinci Surgical System (DVSS), offers many potential advantages compared with laparoscopy, allowing precise dissection and vessel sutures. Currently, many centers around

karger@karger.com
www.karger.com/uin

Tarek Ajami Fardoun
Urology Department, Hospital Clinic of Barcelona
Villaroel 170
ES–08036 Barcelona (Spain)
tajami10@gmail.com

the world are performing robotic-assisted kidney transplantation (RAKT) with promising results [8].

We must highlight that the vagina has been shown to be a viable route for organ removal, with excellent cosmetic and functional results [9, 10]; consequently, this route can be considered as a viable insertion route for intracorporeal kidney transplantation. In this article, we present our experience with RAKT with vaginal insertion.

Patients and Methods

Patients

We present the first 5 cases of RAKT with vaginal insertion. The first case was a 34-year-old male donating to his ABO-incompatible (ABOi) wife, a 36-year-old female with ESRD due to polycystic disease. She had previously received her first cadaveric kidney transplant in 1999 on the right side, and was in a pre-dialysis phase due to chronic graft dysfunction at the time of the second transplantation.

The second case was a 72-year-old male donating to his ABOi daughter. The recipient was a 47-year-old female with obesity (BMI: 34) and ESRD on hemodialysis for 12 months. The third case was a 54-year-old female donating her left kidney to her sister, a 51-year-old female with IgA nephropathy, in a preemptive situation.

The fourth patient was a 50-year-old female with ESRD of unknown cause. The donor was her sister, a 57-year-old female, for whom a transvaginal extraction of the left kidney was performed.

The fifth patient was a 30-year-old female with nephronophthisis. She had a previous transplant in her right iliac fossa. The donor in this case was her 73-year-old grandmother. In all cases, the left kidney was selected for donor nephrectomy.

Patient Selection

All recipients were selected for vaginal kidney insertion previous to the surgery. Vaginal digital exploration was performed to confirm sufficient elasticity and width for kidney introduction. Patients with any grade of cystocoele or urinary incontinence were excluded. CT angiography scan was used to assess aortoiliac vessels and to discard any pelvic abnormality like uterus varicosities, to avoid any problem with vaginal approach.

Surgical Technique

Following intubation, the recipient is placed in a decubitus position with low lithotomy position to permit vaginal access. The vagina is prepped with povidone. During anesthetic induction, the recipient receives an antibiotic prophylaxis with gentamycin and cephalosporin.

A robotic port is placed under vision in the mid line, 2 cm above the umbilicus, to archive the pneumoperitoneum. A 35° angle of Trendelenburg is performed, and the other three 8-mm ports are placed (2 in the left flank and the other to the right). A 12-mm port is placed on the right fossa and a 5-mm port cranial and between the camera and the first robotic trocar for assistance. In the first and fifth cases, the trocars were placed in a mirror position because it was performed on the left site (Fig. 1). The Da Vinci Robot Xi is then centrally docked.

The left external iliac vessels in the first and fifth cases, and the right external iliac vessels in the rest of the cases, are identified and carefully dissected. A peritoneal flap is opened to create a space to place the grafted kidney in an extraperitoneal position at the end of the surgery. The bladder then is detached from the abdominal wall and distended with saline solution to permit the correct performance of the muscular tunnel, for posterior ureteral implantation.

The uterus is pulled to assess the posterior "cul de sac." Bowel adhesions were liberated in the first case, and under direct vision, a 12-mm obesity trocar was introduced into the posterior fornix. The vagina is then incised combining electrocautery through the abdominal side and digital disruption from outside. An Alexis retractor is placed through the vagina to assist during the kidney insertion and to maintain pneumoperitoneum (Fig. 2).

At the same time, in a door-to-door operating room, a laparoscopic living donor nephrectomy is performed. Immediately after kidney removal, the graft is perfused with Celsior solution. Bench surgery is carried out to prepare the kidney for transplantation; small vessels were tied to prevent any posterior bleeding. The kidney is wrapped in gauze on ice, with a small window for vascular pedicle exposure, also keeping the ureter outside. After that, the kidney is introduced into a 15-mm endobag. Jelly solution was used to help kidney insertion through the vagina, combining a gentle push from the outside and a pull from the inside.

The bag is opened and the graft is exposed and placed medially for vascular sutures, removing the bag through the vagina. The vaginal opening is closed temporally with the help of the Alexis retractor to preserve pneumoperitoneum.

The assistant introduces the bulldogs through the 12-mm port. The iliac vein is clamped, and a venotomy is performed using robotic Potts scissors. The vein is then flushed with heparinized saline solution through a ureteral stent. A continuous end-to-side anastomosis is carried out using 6/0 Gore-Tex suture. Before completing the suture, the vein is flushed again with heparinized saline solution. A bulldog is placed on the renal vein for anastomosis testing. The iliac artery is then clamped using the same bulldogs. The arteriotomy is performed using the Potts scissors and then flushed with heparinized saline solution. We usually resect a small arterial wall to obtain a correct orifice. The renal artery is anastomosed in an end-to-side continuous fashion using the same 6/0 Gore-Tex suture. A bulldog clamp is placed on the artery to check for bleeding. After clamp removal, in all 5 cases, the kidney achieved correct reperfusion. The gauze is removed to expose the kidney permitting inspection for any possible bleeding. Laparoscopic ultrasound is introduced to confirm the correct perfusion of the graft. At this point, the kidney is placed laterally in the definitive position, under the peritoneum flap.

As for the ureterovesical anastomosis, a modified extravesical Lich-Gregoire technique is performed. The ureter is passed through the previously performed tunnel, the bladder mucosa is reached via a single cystotomy, and the distal ureter is sutured to the bladder mucosa using 2 running 5/0 monocryl sutures with the previous insertion of a double J stent.

The vagina is closed using the robotic trans-abdominal approach using a continuous barbed suture (3/0 V-lock). Vaginal packing using a gauze is carried out and is usually removed 24 h later.

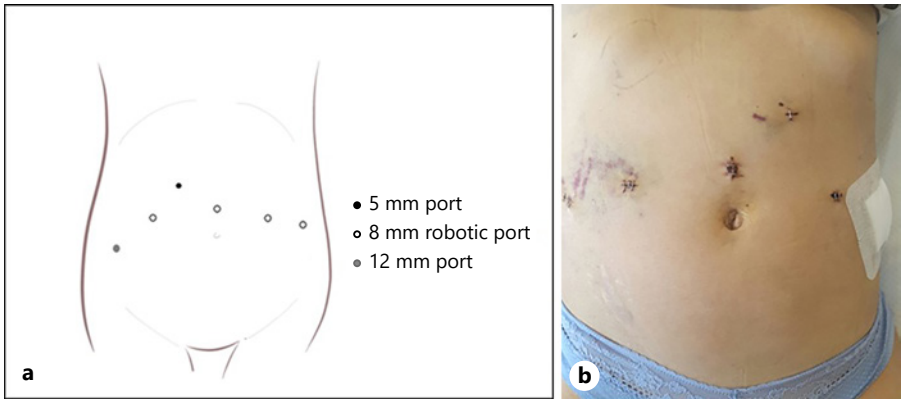

Fig. 1. a Trocar placement in case of right-sided RAKT. **b** Abdomen of 1 of the recipients showing trocar incision scars 1 week after surgery (left-sided RAKT). RAKT, robotic-assisted kidney transplantation.

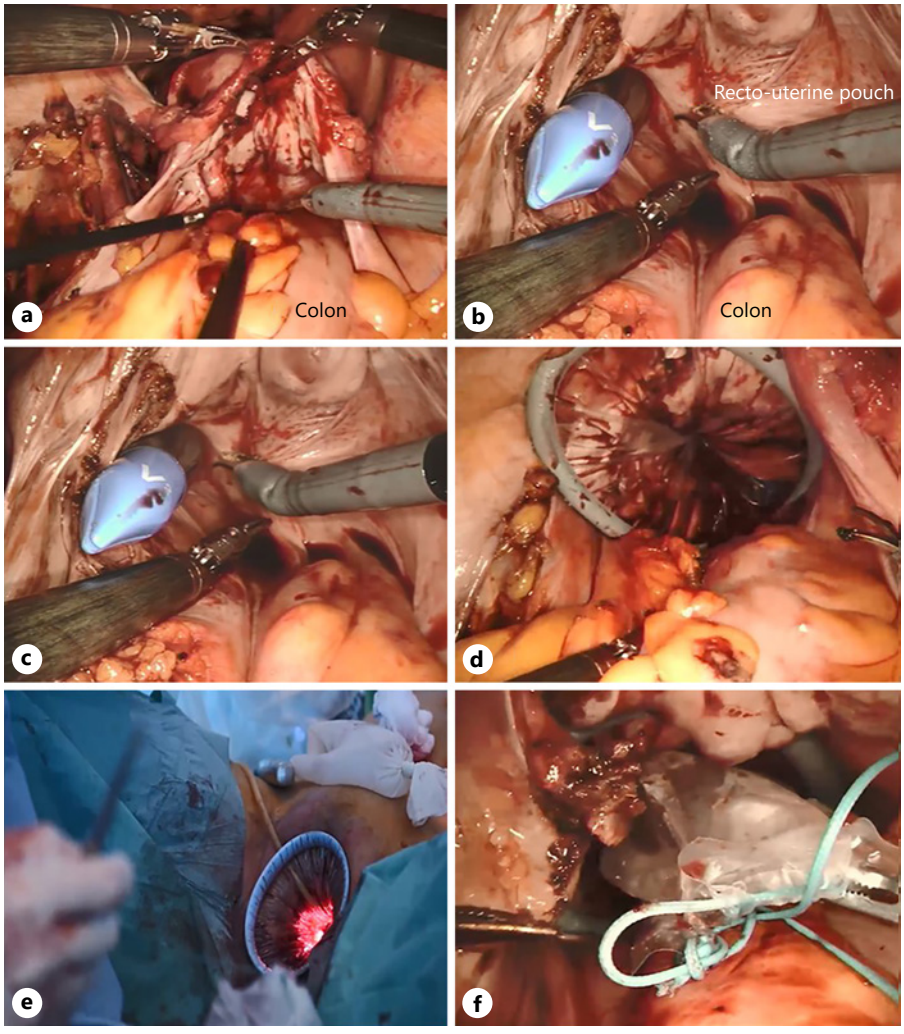

Fig. 2. a Retraction to access the recto-uterine pouch. **b** Placement of 15-mm obesity trocar through the posterior vaginal fornix. **c** Further incision of the posterior vaginal wall. **d** Placement of Alexis retractor. **e** External view of vaginal insertion of the graft. **f** Internal view of the graft insertion inside a bag.

Results

The median operative time was 220 min. Mean rewarming ischemia time was 53 min, with immediate diuresis. No intraoperative complications were observed. Mean hospitalization period was 9 days, with mean Cr of 1.5 mg/dL at discharge.

The second recipient, an ABO-i kidney transplant, had a humoral rejection treated with blood apheresis. No late complications were described in the other recipients. No

Table 1. Recipients' baseline characteristics, surgical data, and outcomes

	Recipient 1	Recipient 2	Recipient 3	Recipient 4	Recipient 5
Age, years	36	47	51	50	30
BMI, kg/m^2	23	34	20	26	20
CKD cause	Polycystic disease	Unknown	IgA nephropathy	Unknown	Nephronopthisis
ABO compatibility	No	No	Yes	Yes	Yes
Relationship with the recipient	Couple	Parent	Sibling	Sibling	Grandmother
Type of extraction	LESS	Conventional laparoscopic		Transvaginal extraction	Conventional laparoscopic
Preemptive	No	No	Yes	Yes	No
Side of transplant	Left	Right	Right	Right	Left
Time of surgery, min	300	240	200	180	200
Rewarming time, min	65	60	38	50	53
Vein anastomosis time, min	28	26	16	25	25
Artery anastomosis time, min	18	21	14	15	16
Immediate diuresis	Yes	Yes	Yes	Yes	Yes
Renal scintigraphy (tracer uptake)	749	555	1,367	917	1,758
Postoperative complication	No	Acute rejection	No	1 unit blood transfusion	No
Hospitalization days	9	14	8	7	7
Follow-up time, months	34	3	12	9	4

LESS, laparoendoscopic single site surgery.

other complications derived from the access route were detected.

Recipient's characteristics, surgical timing, and results are shown in Table 1. Figure 3 represents the Cr curve in the 5 recipients.

Discussion

Surgery has evolved toward minimally invasive techniques over the last 20 years, from open to laparoscopic and more minimally invasive techniques such as NOTES (natural orifice translumminal endoscopic surgery) or LESS (laparoendoscopic single site surgery), but in the kidney transplant setting, this evolution has been thwarted by the difficulty of the surgery itself because of the instrumentation and vision available on laparoscopy. The introduction of robotic surgery has enabled surgeons to perform more complex cases, even kidney transplantation.

Laparoscopic transplantation has been developed by many groups in animal models; our group has been involved in laparoscopic kidney transplant in a pig model, where we confirmed in our hands the difficulty and limitations of the technique. We could finish 8 out of 10 procedures; we observed a technical improvement over time [3]. In another recent article, an orthotopic laparoscopic kidney animal model was developed by Han et al. [5], confirming the feasibility of the technique. When we translate all this knowledge to the human setting, we find that there is little experience. In 2004, Bluebond-Langer et al. [6] reported their bad experience with laparoscopic-assisted renal autotransplantation. They tried to perform 2 laparoscopic autotransplantations, and they could not finish the procedures. In 2010, the first laparoscopic living donor kidney transplantation was reported [7]. In 2013, the largest series on laparoscopic kidney transplantation arrived. The authors presented the results of 72 laparoscopic living donor kidney transplants compared with 217 open ones. The operative time and rewarming ischemia time were longer in the laparoscopic group. They lost 2 grafts because of pedicle torsion, warning of the importance of graft fixation with peritoneal fold [11].

With the introduction of the DVSS, all laparoscopic limitations are improved; the magnification, the 3D vision, and the articulated instruments permit a wide range of movements allowing for accurate and delicate vascular anastomosis. In 2002, Hoznek el al. [12] used the DVSS to perform a kidney transplant; at that time, they performed the robotic-assisted surgery using an open approach, to control vascular dissection and vascular anas-

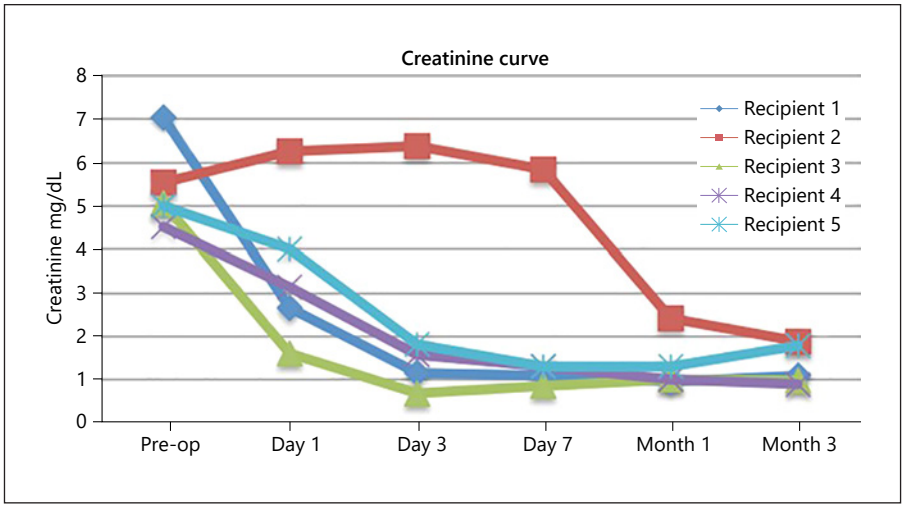

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Fig. 3. Cr evolution curve of the 5 RAKT cases till third month. RAKT, robotic-assisted kidney transplantation.

tomosis directly. Seven years later, Giulianotti et al. [13] published the first pure robotic kidney transplantation in a morbidly obese patient. The surgery took 223 min with a 50-min rewarming ischemia time, with immediate kidney function. The patient was discharged on postoperative day 5 [13].

The first European case was published in 2011, by Boggi et al. [14], from Italy; they performed a living donor pure robotic kidney transplantation. In that specific case, the kidney insertion was through a Pfannenstiel incision, using a hand-access device. The total operative time was 153 min with 51 min of rewarming ischemia time, with immediate graft function [14].

After this small initial experience, RAKT has been popularized over the last 2 years by Dr. M. Menon and Dr. R. Alahawat. In 2014, multiple publications from this group appear. Concretely, in their IDEAL phases 0 and 1, they developed a novel surgical technique to perform robotic kidney transplantation with hypothermia. In this first article, they present the results of the first 7 patients, with a mean operative time of 229 and 51 min of rewarming time [15]. In the IDEAL phase 2 study, they reported the results of 50 patients with optimal kidney function results and without intra- or postoperative complications [16].

During the same year, Tsai et al. [17] presented the initial experience on retroperitoneal RAKT. They performed 10 procedures with immediate graft function in 9 and delayed graft function in 1 due to prolonged warm ischemia time in the donor [17].

Nowadays, many groups have reported their own good experience with RAKT [18, 19] even in an autotransplantation setting [20, 21], and as an option in obese patients. Oberholzer et al. [22] compared 28 robotic versus 28 open approach kidney transplants, with similar results. The robotic approach causes an increase in rewarming time but this does not have any effect on graft function [23].

As we mentioned before, surgery is evolving to minimize incisions. In that way, the transvaginal approach should be considered for organ extraction as we have proved before for tumoral kidney and for living donor nephrectomy [9, 10] and why not for kidney insertion?

Recently, Doumerc et al. [24] published the first case of RAKT with vaginal insertion in an obese patient, with good results. After our outstanding experience in laparoscopic NOTES-assisted nephrectomies for tumor and in living donors, we realized that this entrance route for grafts would be of interest, avoiding abdominal incision in those patients that are at a higher risk of complications due to associated co-morbidity and with immunosuppressant treatment.

The main question that could be raised in the field of robotic kidney transplantation is the cost-benefit analysis. One of the principal drawbacks of robotic surgery is the huge cost. Although innovation toward minimally invasive surgery is an important advance, the medical benefit that could be obtained should be able to justify such investment for healthcare professionals instead of performing standard competing techniques. Oberholzer et al. [22] estimated an increment difference of USD 15,000 for performing RAKT, taking into account an equal length of stay (LOS) and number of readmissions. In our center, we performed a matched paired analysis of robotic versus open kidney transplant; the cost differ-

ence was approximately 3,000 EUR, taking into account similar LOS between both groups [25]. Long-term analysis should be performed to assess whether the elevated cost of robotic surgery could be mitigated by other clinical variables such as LOS and postoperative complications.

A limitation could be the risk of causing an intra-abdominal infection with the transvaginal insertion, which we feel is very low, and we prevent by correct vaginal prepping, antibiotics, and using barriers device such as Alexis retractor [26]. From the sexual point of view, we have seen that no impairments in sexual function are caused after using this route. We previously have presented our results of 100 women treated by the transvaginal approach specifically studying their sexual function; we did not find any difference in the FSFI (female sexual function index) score before and after surgery [27]. Correct preoperative gynecological exam and precise patient selection can avoid complications during vaginal insertion of the graft.

Conclusion

This is the first case series that describes transvaginal access for kidney insertion in robotic-assisted kidney transplant. Albeit the number of cases is small, the results seem satisfactory with no complications found due to this mode of access.

Supplementary Materials

A supplementary video is provided to explain the part of vaginal insertion of the graft (for all online suppl. material, see www.karger.com/doi/10.1159/000511756).

Statement of Ethics

All procedures performed in studies involving human participants were in accordance with the ethical standards of the Hospital Clinic of Barcelona Committee of Ethics and Research and with the 1964 Helsinki Declaration and its later amendments or comparable ethical standards. Informed consent was obtained from all individual participants included in the study.

Conflict of Interest Statement

The authors declare that they have no conflict of interest.

Author Contributions

M. Musuqera: protocol/project development and manuscript writing/editing. T. Ajami: data collection and management, data analysis, and manuscript writing/editing. L. Peri: protocol/project development and manuscript writing/editing. A. Alcaraz: protocol/project development and manuscript writing/editing.

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