Single Port Robotic Extra-peritoneal Dual Kidney Transplantation: Initial Preclinical Experience and Description of the Technique

Mohamed Eltemamy, Juan Garisto, Eric Miller, Alvin Wee, and Jihad Kaouk

OBJECTIVE To describe the surgical technique for single-port robotic extraperitoneal dual kidney transplantation (DKT) using the SP surgical system (Intuitive Surgical, Sunnyvale, CA, USA) in a preclinical model.

METHODS In 1 male cadaver, the SP Surgical System was used to perform an extraperitoneal DKT. Kidney grafts were obtained from the local organ procurement organization, after being declined by all transplant centers. Kidneys were benched and wrapped in cold sponges. A periumbilical midline incision was performed. A kidney-shaped balloon was inserted through the incision to create the extraperitoneal space. SP robot was docked followed by dissection of iliac vessels bilaterally. The robot was undocked and the first graft was inserted through the wound retractor. The robot was re-docked and the renal vein anastomosis to external iliac vein was performed followed by renal artery anastomosis to external iliac artery using 5-0 monofilament sutures. Ureteroneocystostomy was performed using the Lich-Gregoir technique over a trasplant stent. Same steps were replicated for the left kidney transplant. Once procedures were done, kidneys were then harvested with the iliac vessels to examine the quality of the anastomosis.

RESULTS The surgical procedure was completed successfully without the need of additional port or conversion to standard approach. Total bench kidney time was 30 minutes with overall transplantation time of 130 and 115 minutes of the right and left kidney, respectively.

CONCLUSION We demonstrated the feasibility of single-port extraperitoneal DKT using the novel SP robotic platform. Limitations include the preclinical model. Further assessment is necessary in a truly clinical setting. UROLOGY 134: 232−236, 2019.

Despite ongoing changes to the kidney allocation system, the annual increase in waiting times for recipients of deceased donor kidney allografts exceeds the current rate of donor pool expansion.[1] Concomittantly, there has been a steady increase in the proportion of available expanded criteria donor kidneys, which has led to an unfortunate rise in poorer quality marginal organs being discarded prior to successful allocation and transplantation.[3] The high demand for transplantable kidneys, in the setting of an ever shrinking supply, has naturally given rise to an increase in kidney transplant waiting times and thus exposes more patients to dialysis-related morbidity and mortality.[2] This increase in recipient waiting times deserves immediate attention, and innovative strategies are needed more than ever to address this growing concern. Such a strategy, known as dual kidney transplantation (DKT), entails transplantation of bilateral marginal kidneys into a single accepting recipient. This approach allows for utilization of suboptimal grafts—that would otherwise be discarded if offered to 2 separate recipients—by increasing the total number of functional nephrons.[4,5] Unfortunately, open DKT has failed to gain popularity largely because it is a complex surgical technique with an increased rate of notable complications. Despite the use of varying surgical approaches, including bilateral Gibson incisions, midline incisions, and extended Gibson incisions, DKT continues to exist as a technique rarely used by kidney transplant centers in the United States.[6-8] Robotic kidney transplantation has emerged as a novel and minimally invasive approach for kidney transplantation. Both robotically assisted laparoscopic single and DKTs have been reported using robotic assistance via a transperitoneal approach. When using the multiport robot, an additional incision is necessary to introduce the kidney in preparation for intracorporeal vascular and ureteral anastomoses. Initial work from groups in Chicago,[9] Europe,[10] and Detroit[11] have helped standardize an algorithmic approach using purely robotic

From the Glickman Urological and Kidney Institute, Cleveland Clinic, Cleveland, OH

Address correspondence to: Jihad Kaouk, M.D., Glickman Urology and Kidney Institute, Cleveland Clinic, 9500 Euclid Ave, Q-10, Cleveland, OH 44195. E-mail: kaoukj@ccf.org

Submitted: September 6, 2019, accepted (with revisions): September 6, 2019

 https://doi.org/10.1016/j.urology.2019.09.007
0090-4295

transperitoneal kidney transplantation. Potential benefits of robotically assisted kidney transplantation include faster recovery, decreased surgical site infections, fewer incisional hernias, shorter length of stay, and an earlier return to normal activities of daily living. Additionally, robotically assisted transplantation is thought to allow for enhanced access to vascular structures, improved visualization, and better ergonomics when transplanting obese patients, a population of patients who are otherwise less likely to receive an allograft due to complications related to open surgery in obese recipients.[12-15] Critics of the robotically assisted approach argue that the incision required to introduce the renal allograft is of similar size when compared to the standard open surgical incision, of which makes the robotic approach less appealing. Furthermore, with the addition of up to 5 laparoscopic trocar sites, the vast majority of transplant centers have failed to support and then adopt a robotically assisted approach.

The single port (SP) robot is a newly designed robotic platform that allows for introduction of a camera scope and 3 robotic arms through a single incision, which can be as short as 2.7 cm. If used in the setting of a kidney transplantation,[16,17] the same incision can be utilized to introduce the kidney for intracorporeal transplantation, thus reducing the overall number of incisions required in multiport robotic surgery. In this feasibility study, we investigated the potential use of the SP robot in performing an extraperitoneal intracorporeal DKT through a single incision in a human cadaver.

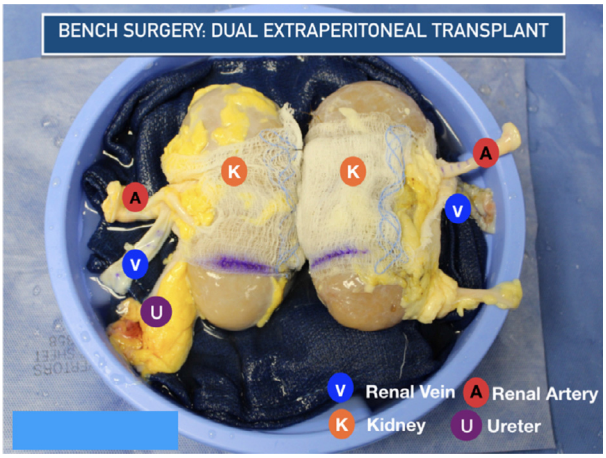

Figure 1. Kidney benching. Both kidneys were wrapped in ice cold Ray-Tec sponges prior to intra-corporeal placement. (Color version available online.)

METHODS

The da Vinci SP (Intituitve Surgical, Sunnyvale, CA) Robotic platform is a novel purpose-built robot designed to operate through a single incision. A new 25-mm port with multiple channels has been designed to allow for passage of an articulating camera and 3 additional articulating robotic arms. The design allows for a versatile multi-quadrant approach.

Kidney Benching

Through our local organ procurement organization, 2 cadaveric kidneys were obtained after being declined by all participating transplant centers in the United States. Both kidneys were benched in a usual fashion. A Carrel aortic patch was fashioned around the right and left renal arteries. The left renal vein was thoroughly dissected up to the renal sinus being careful to ligate all identifiable venous tributaries. In the right kidney, the inferior and superior border of the inferior vena cava were trimmed and sewn with nonabsorbable monofilament vascular suture in running fashion, with the intention of using the left renal vein ostia for the end to side venous anastomosis. Both kidneys were wrapped in ice cold Ray-Tec (Johnson & Johnson) sponges prior to intracorporeal placement (Fig. 1).

Surgical Technique

Port Placement and Docking. A male cadaver was placed and prepped in standard low lithotomy position. A single 4.5-cm periumbilical incision was made and deepened through the subcutaneous tissue and abdominal fascia. The extraperitoneal space was developed bilaterally through gentle blunt dissection to peel the peritoneum from the posterior surface of the anterior abdominal wall. This space was developed as widely as possible in the direction of the right and left iliac fossa. An oval Spacemaker Dissection Balloon (Covidien) was then placed in a vector towards the right anterior superior iliac spine and inflated with 40 pumps to further develop the extraperitoneal space (Fig. 2). The left extraperitoneal space was developed in similar fashion. A GelPOINT Advanced Access Platform (Applied Medical, Rancho Santa Margarita, CA, USA) was applied in combination with the Alexis O Wound Retractor (Applied Medical, Rancho Santa Margarita, CA, USA) at the previously made 4.5-cm midline incision site. The newly designed multi-channel SP cannula and a Surgiquest AirSeal (ConMed) port were placed through the GelPOINT cap. Following successful insufflation of the extraperitoneal space, the SP Robotic platform was then docked (Fig. 3).

Dissection of Iliac Vessels and Kidneys Placement. The extraperitoneal space was further developed between the posterior peritoneum and the psoas muscles. The right and left lateral umbilical ligaments were identified and the space of Retzius was developed to expose the dome of the urinary bladder. Beginning at the bifurcation of the common iliac vessels and moving in the caudad direction, the surrounding connective tissues and regional lymphatics were carefully divided. The external iliac vessels were isolated, exposed, and cleared in preparation for vascular anastomoses. The robot was undocked and the GelPOINT cap was removed. The left kidney was introduced into the intracorporeal space through the Alexis O Wound Retractor and placed in the vicinity of the right iliac fossa. Insufflation was reinitiated and the robot was re-docked.

Vascular Anastomosis. Two laparoscopic bull dogs (Scanlan International, St. Paul, MN) were advanced through the assistant port, placed through the gel cap, and the external iliac vein (EIV) was clamped in the proximal and then distal position. A venotomy was created using the robotic scissors. The donor renal vein anastomosis was completed in end to side fashion to the EIV using expanded polytetrafluoroethylene CV5 sutures (W.L Gore Gore & Associated Inc, Flagstaff, AZ) sutures sewn in running fashion (Supplementary Fig. 1). More specifically, with the kidney in the more medial position, we started the anastomosis

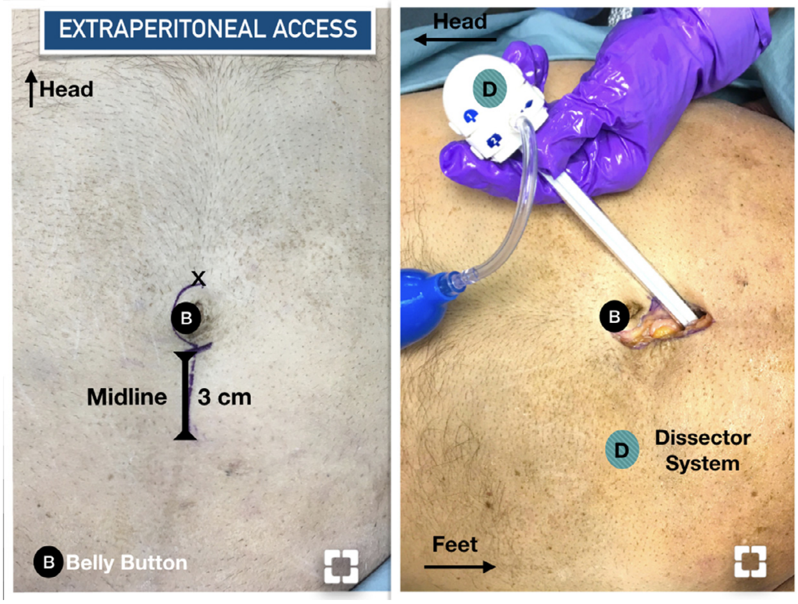

Figure 2. Port placement and development of extraperitoneal space. (**A**) A single 4.5 cm periumbilical incision was made and deepened through the subcutaneous tissue and abdominal fascia; (**B**) Extraperitoneal space was developed bilaterally using a Spacemaker Dissection Ballon (Covidien). (Color version available online.)

with the medial wall and then completed by closing the lateral portion of donor vein and EIV. A third bulldog was applied to the donor renal vein and both EIV bull-dogs were removed. The donor renal artery was sewn in similar fashion. The kidney was then rotated laterally to lie on the psoas muscle.

Ureteral Implantation. The urinary bladder was filled with normal saline to help identify the bladder and the optimal position for ureteroneocystotomy. When the anastomotic position was chosen, the donor ureter was spatulated and a cystotomy was created in the urinary bladder with the robotic scissors. The ureter was then sewn in continuous direct onlay fashion to the urinary bladder with concurrent placement of a 4.6 French by 14 centimeter Double-J ureteral stent (Supplementary Fig. 2). Our choice of suture for the ureteral anastomosis included 4-0 Vicryl.

Contralateral Donor Kidney Transplantation. We then focused our attention of the left iliac fossa and the identical steps were performed to prepare the left iliac fossa. The robot was undocked to introduce the previously prepared right kidney in the left iliac

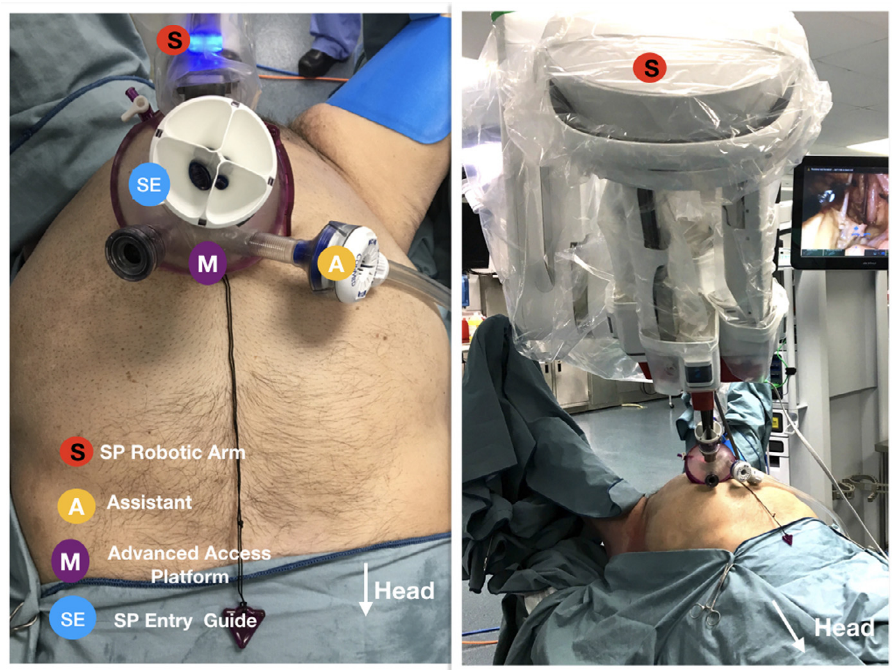

Figure 3. Docking of SP robotic system using the designed multi-channel SP cannula and a 12-mm port. (Color version available online.)

fossa. The vascular and ureteric anastomoses were performed in an identical fashion. Once we finished the contralateral kidney transplantation, both kidneys were explanted to examine patency of vascular anastomosis (Supplementary Fig. 3).

RESULTS

Using the da Vinci SP Robotic Platform, we successfully designed and then performed a bilateral extraperitoneal DKT in a fresh human cadaver. A single 4.5 cm incision was used to introduce the robotic arms as well as both donor renal allografts. There was no need for conversion to the standard multiport technique or placement of additional assistant ports. No accidental intraoperative punctures or obvious organ damage was identified during the procedure. Total operative time was 270 minutes. Vascular and ureteric anastomosis times are reported in Supplementary Table 1.

DISCUSSION

In the preclinical and laboratory setting, we have demonstrated the feasibility of a SP robotic extraperitoneal kidney transplantation using the novel SP Robotic platform. While multiple port robotically assisted transperitoneal kidney transplantation has been established as a safe alternative to the current gold standard open extraperitoneal kidney transplantation, our newly established technique allows for a truly minimally invasive approach to robotic kidney transplantation.[22,23] By utilizing the SP incision site, our protocol avoids multiple trocar incision sites and is accomplished through a small midline 4.5 cm incision. Furthermore, through the versatility of the SP robot, we designed a protocol that allows for efficient and effective bilateral iliac fossa DKT.

Due to its safety and comparable long-term outcomes, the total number of dual kidney transplants performed each year is on the rise.[5,18] Evaluation of available data has revealed that when compared to single kidney transplantation (SKT), deceased donors for DKTs are significantly older, have higher rates of comorbid conditions (ie, hypertension and diabetes), significantly lower admission creatinine clearance, and lower urine outputs.[19] These data may deter many transplant surgeons from accepting dual kidneys for transplantation, but centers explain the disparities between DKT and SKT donors by the fact that recipients who are selected to receive a DKT have higher rates of age-related muscle mass reduction and lower metabolic demands, therefore the possible rates of suboptimal renal function following DKT is potentially more tolerable in well matched recipients. Furthermore, under the current allocation system, younger recipients are favored to undergo SKT sooner, thus DKT provides a safe and viable option for older patients who would otherwise remain on the wait list for extended periods of time.[20,21]

When considering our surgical approach, the primary advantage of an extraperitoneal approach for DKT includes the ability to avoid steep Trendelenburg position, a position that is typically required to maintain the bowels outside the pelvis during transperitoneal pelvic surgery. Furthermore, by remaining in the extraperitoneal space we provide a route of entry that avoids pneumoperitoneum, which enhances respiratory mechanics, reduces negative effects on venous return and cardiac output, avoids lower limb ischemia, and optimizes cerebral and ocular pressures.[24-26] Our approach is theoretically more suitable for an older patient population, who bear increased comorbid conditions and who also constitute a larger proportion of patients receiving DKT.

Additional benefits credited to the extraperitoneal approach include elimination of the need for retroperitoneal fixation via nephropexy. This maneuver is otherwise required in transperitoneal robotic surgery as it is thought to reduce the odds of donor vessel kinking and potential graft thrombosis.[11] Finally, by eliminating the need for intraperitoneal bowel mobilization, the risk of bowel injuries is greatly minimized and by avoiding direct placement of allograft ice slush in contact with the bowel, some reports suggest that postoperative ileus can be reduced.[27]

Our technique was designed and tested in the preclinical setting using a fresh cadaver, therefore only the procedural aspects have been established. While our approach was successful from a technical standpoint, our study is limited by the very important functional assessment of the transplanted allograft. Clinical trials in well-chosen recipients who consent to proceed are the obvious next step and will be forthcoming.

To our knowledge, this is the first preclinical report using the novel SP Robotic platform in retroperitoneal DKT. As outlined above, our approach bears the benefits of a minimally invasive extraperitoneal approach and therefore is potentially suitable for a cohort of recipients, with more comorbid conditions, who are more likely to receive DKT. Our investigation outlines improvements that may increase the acceptance and utilization of robotic surgery, especially with regards to DKT.[28,29]

CONCLUSION

Herein, we describe a novel technique for robotically assisted extraperitoneal DKT. This technique builds on the fundamentals of the gold standard open extraperitoneal approach, but with the added benefits of minimally invasive surgery. Most importantly, the avoidance of steep Tredelenburg patient positioning and lack of pneumoperitonemum allows for an approach that is suitable for patients with more severe comorbid conditions and who are more likely to undergo DKT. Further functional and post-transplant assessments are necessary before determining the safety and feasibility of this approach in the truly clinical setting.

SUPPLEMENTARY MATERIALS

Supplementary material associated with this article can be found in the online version at https://doi.org/10.1016/j.urology.2019.09.007.

References

1. Hart A, Smith JM, Skeans MA, et al. OPTN/SRTR 2016 annual data report: kidney. *Am J Transplant*. 2018;18:18–113. https://doi.org/10.1111/ajt.14557.
2. Wolfe RA, Ashby VB, Milford EL, et al. Comparison of mortality in all patients on dialysis, patients on dialysis awaiting transplantation, and recipients of a first cadaveric transplant. *N Engl J Med*. 1999;341:1725–1730. https://doi.org/10.1056/NEJM199912023412303.
3. Tanriover B, Mohan S, Cohen DJ, et al. Kidneys at higher risk of discard: expanding the role of dual kidney transplantation. *Am J Transplant*. 2014;14:404–415. https://doi.org/10.1111/ajt.12553.
4. Salifu MO, Norin AJ, O'Mahony C, et al. Long-term outcomes of dual kidney transplantation-a single center experience. *Clin Transplant*. 2009;23:400–406. https://doi.org/10.1111/j.1399-0012.2009.00956.x.
5. Remuzzi G, Cravedi P, Perna A, et al. Long-term outcome of renal transplantation from older donors. *N Engl J Med*. 2006;354:343–352. https://doi.org/10.1056/NEJMoa052891.
6. Salehipour M, Bahador A, Nikeghbalian S, et al. En-bloc transplantation: an eligible technique for unilateral dual kidney transplantation. *Int J Organ Transplant Med*. 2012;3:111–114. http://www.ncbi.nlm.nih.gov/pubmed/25013633. Accessed January 20, 2019.
7. Ekser B, Baldan N, Margani G, et al. Monolateral placement of both kidneys in dual kidney transplantation: low surgical complication rate and short operating time. *Transpl Int*. 2006;19:485–491. https://doi.org/10.1111/j.1432-2277.2006.00309.x.
8. Masson D, Hefty T. A technique for the transplantation of 2 adult cadaver kidney grafts into 1 recipient. *J Urol*. 1998;160:1779–1780.. http://www.ncbi.nlm.nih.gov/pubmed/9783951. Accessed January 20, 2019.
9. Giulianotti P, Gorodner V, Sbrana F, et al. Robotic transabdominal kidney transplantation in a morbidly obese patient. *Am J Transplant*. 2010;10(6):1478–1482. https://doi.org/10.1111/j.1600-6143.2010.03116.x.
10. Boggi U, Vistoli F, Signori S, et al. Robotic renal transplantation: first European case. *Transpl Int*. 2011;24(2):213–218. https://doi.org/10.1111/j.1432-2277.2010.01191.x.
11. Menon M, Sood A, Bhandari M, et al. Robotic kidney transplantation with regional hypothermia: a step-by-step description of the Vattikuti Urology Institute−Medanta Technique (IDEAL Phase 2a). *Eur Urol*. 2014;65:991–1000. https://doi.org/10.1016/j.eururo.2013.12.006.
12. Lassalle M, Fezeu LK, Couchoud C, Hannedouche T, Massy ZA, Czernichow S. Obesity and access to kidney transplantation in patients starting dialysis: a prospective cohort study. Aguilera AI. *PLoS One*. 2017;12: e0176616. https://doi.org/10.1371/journal.pone.0176616.
13. Segev DL, Simpkins CE, Thompson RE, Locke JE, Warren DS, Montgomery RA. Obesity impacts access to kidney transplantation. *J Am Soc Nephrol*. 2008;19:349–355. https://doi.org/10.1681/ASN.2007050610.
14. Garcia-Roca R, Garcia-Aroz S, Tzvetanov I, Jeon H, Oberholzer J, Benedetti E. Single center experience with robotic kidney transplantation for recipients with BMI of 40 kg/m^2 or greater. *Transplantation*. 2017;101:191–196. https://doi.org/10.1097/TP.0000000000001249.
15. Oberholzer J, Giulianotti P, Danielson KK, et al. Minimally invasive robotic kidney transplantation for obese patients previously denied access to transplantation. *Am J Transplant*. 2013;13:721–728. https://doi.org/10.1111/ajt.12078.
16. Raveendran V, Adiyat KT, Koduveli RM, John R. Robotic renal transplant recipient surgery with vaginally inserted allograft. *J Robot Surg*. 2017;11:473–477. https://doi.org/10.1007/s11701-017-0691-3.
17. Doumerc N, Roumiguié M, Rischmann P, Sallusto F. Totally robotic approach with transvaginal insertion for kidney transplantation. *Eur Urol*. 2015;68:1103–1104. https://doi.org/10.1016/j.eururo.2015.07.026.
18. Gill J, Cho YW, Danovitch GM, et al. Outcomes of dual adult kidney transplants in the united states: an analysis of the OPTN/UNOS database. *Transplantation*. 2008;85:62–68. https://doi.org/10.1097/01.tp.0000296855.44445.af.
19. Bunnapradist S, Albin Gritsch H, Peng A, Jordan SC, Cho YW. Dual kidneys from marginal adult donors as a source for cadaveric renal transplantation in the United States. 2003. doi:10.1097/01.ASN.0000054494.85680.1C.
20. Brenner BM, Cohen RA, Milford EL, Jordan SC, Cho YW. In renal transplantation, one size may not fit all. *J Am Soc Nephrol*. 1992;3:162–169. https://doi.org/10.1097/01.asn.0000054494.85680.1c.
21. Lee CM, Carter JT, Weinstein RJ, et al. Dual kidney transplantation: older donors for older recipients. *J Am Coll Surg*. 1999;189: 82–91; discussion 91-2. http://www.ncbi.nlm.nih.gov/pubmed/10401744. Accessed January 20, 2019.
22. Sood A, Ghosh P, Jeong W, et al. Minimally invasive kidney transplantation. *Transplantation*. 2015;99:316–323. https://doi.org/10.1097/TP.0000000000000590.
23. Territo A, Gausa L, Alcaraz A, et al. European experience of robot-assisted kidney transplantation: minimum of 1-year follow-up. *BJU Int*. 2018;122:255–262. https://doi.org/10.1111/bju.14247.
24. Sood A, Ghosh P, Jeong W, et al. Minimally invasive kidney transplantation. *Transplantation*. 2015;99:316–323. https://doi.org/10.1097/TP.0000000000000590.
25. Lee JR. Anesthetic considerations for robotic surgery. *Korean J Anesthesiol*. 2014;66:3–11. https://doi.org/10.4097/kjae.2014.66.1.3.
26. Awad H, Santilli S, Ohr M, et al. The effects of steep Trendelenburg positioning on intraocular pressure during robotic radical prostatectomy. *Anesth Analg*. 2009;109:473–478. https://doi.org/10.1213/ane.0b013e3181a9098f.
27. Tuğcu V, Şener NC, Şahin S, Yavuzsan AH, Akbay FG, Apaydın S. Robotic kidney transplantation: the Bakırköy experience. *Turkish J Urol*. 2016;42:295–298. https://doi.org/10.5152/tud.2016.12369.
28. Frongia M, Cadoni R, Solinas A. First robotic-assisted dual kidney transplant. *Transplant Direct*. 2015;1:e34. https://doi.org/10.1097/TXD.0000000000000547.
29. Himanshu S, Ramaprasad MK, Vishnu R, Kishore TA. Robotic-assisted dual kidney transplantation. *Urol Ann*. 2018;10:330–332. https://doi.org/10.4103/UA.UA_14_18.