CURRENT OPINION

Evolution of robotic-assisted kidney transplant: successes and barriers to overcome

Ashley N. Matthew[a], *Lance J. Hampton*[a],
Riccardo Autorino[a], *and Chandra S. Bhati*[b]

Purpose of review
The aim of this study was to provide an updated review of robotic-assisted kidney transplant (RAKT) with an emphasis on advantages over the open kidney transplant (OKT), utility in special populations and resources available to overcome the learning curve of robotic surgery.

Recent findings
The majority of the reported studies showed that RAKT and OKT have similar functional outcomes including similar ischemia times and time to postoperative normalization of creatinine. However, RAKT results in fewer wound complications, decreased estimated blood loss and pain. Given these benefits, RAKT is a promising approach for obese patient across BMI subtypes and several studies showed decreased wound complications in this population compared with the open approach. Moreover, new 3D-print techniques are promising resources for robotic simulation, which may decrease the learning curve of robotic surgery.

Summary
Overall, RAKT is a feasible approach especially in obese patients. However, more data with long-term follow-up are needed to fully elucidate the advantages over OKT before universal implementation of this approach is possible.

Keywords
3D-printing, obesity, robotic-assisted kidney transplant, robotics, training

INTRODUCTION

According to the most recent US Renal Data System annual report, the prevalence of end-stage renal disease (ESRD) has continued to rise by 20 000 cases per year [1]. ESRD is often treated with renal replacement in the form of peritoneal dialysis or haemodialysis. Renal transplantation is a gold standard treatment option for patients with ESRD and offers significant advantages in terms of life expectancy and quality of life. Since the first successful living donor transplant which was performed between 23-year-old identical twins in 1954 by Doctor Joseph E. Murray, the classic open kidney transplant (OKT) is a well established approach that consists of anastomosis of the graft vessels to the recipient's iliac vessels [2,3]. For about 50 years, very little advancements were made in surgical techniques of kidney transplantation, while the immunosuppression field has made multiple revolutionary discoveries, which has led to excellent transplant outcomes. However, with the invention of advance minimal invasive surgery (MIS) techniques, there has been a growing interest from the transplant community to adopt these techniques for successful kidney transplantation for improved patient benefit with excellent outcomes. Transplantation of an organ is time-sensitive surgery and requires performing anastomosis within an acceptable time. Technically, laparoscopic suturing is considered difficult and requires significant laparoscopic expertise. Use of the da Vinci system allows for better 3D visualization of the surgical field, which is beneficial when performing technically challenging vascular anastomoses. The advantages of robotic MIS procedures have been demonstrated in multiple publications and they include both technical and outcome advantages [4,5]. In addition, there is decreased estimated blood loss (EBL, improved dexterity, elimination of tremor, as well more degrees of freedom

---

[a]Department of Urology and [b]Department of Transplant Surgery, Virginia Commonwealth University, Richmond, Virginia, USA

Lance J. Hampton, MD, Division of Urology, Department of Surgery, VCU Health, PO Box 980118, Richmond, VA, 23298-0118, USA.
Tel: +1 804 828 5320; fax: +1 804 828 2307. E-mail: Lance.Hampton@vcuhealth.org

Curr Opin Urol 2021, 31:29–36
DOI:10.1097/MOU.0000000000000834

KEY POINTS

- RAKT is a feasible approach with similar outcomes compared with OKT including postoperative normalization of kidney function.
- RAKT may serve as an avenue for kidney transplantation in obese patient, as this approach results in fewer wound complications compared with OKT.
- Universal implantation of RAKT is limited by need for extensive expertise in robotics, but new 3D-print techniques are promising resources for robotic simulation, which may decrease the learning curve of this approach.

when operating, which allows the surgeon to have better control of their ability to manipulate their instruments.

In 2001, Hoznek *et al.* was the first group to demonstrate the utility of a robotic system in the facilitation of a kidney transplant. This was a hybrid use of technology wherein a console surgeon performed the vascular dissection and anastomosis via the da Vinci robotic system and the bedside surgeon performed the ureteric anastomosis [6▪▪]. From 2001 to 2009, very little progress was made in the advancement of the robotic-assisted kidney transplants (RAKT) field. The first hand-assisted RAKT was published by Giulianotti *et al.* in a morbidly obese patient [7]. Since these sentinel cases, there have been multiple publications in the form of case series demonstrating the utility of the RAKT technique especially in unique populations of patients [8▪▪,9–11].

Herein, this review, various techniques of RAKT and outcomes differences in the OKT vs. RAKT approach will be reviewed. In addition, this review will highlight special populations to consider the RAKT approach as well as the barriers that exist for universal implementation of the RAKT technique.

ROBOTIC-ASSISTED KIDNEY TRANSPLANTATION

Various RAKT techniques have been described in literatures. Table 1 summarizes various techniques of robotic transplantation currently used by different groups across the world [7,12–14]. Giulianotti *et al.* performed this technique in obese patients by placing the patient in a left lateral decubitus position and docking the robot on the patient's right side since at that time only the Si platform was available. The camera port was placed in the left lower quadrant slightly left of the midline. In addition, the graft was placed transperitoneally via a paraumbilical vertical incision [7]. Boggi *et al.* performed the transplantation in a similar manner in nonobese patients but the patient was in Transdelenburg at 15°, and a suprapubic horizontal incision for graft placement

Table 1. Robotic-assisted kidney transplant techniques

	Study			
Variables	**Guillinotti *et al.* [5]**	**Boggi *et al.* [24]**	**Tsai *et al.* [25]**	**Menon *et al.* [23]**
Patient Position	Left lateral decubitus	left lateral decubitus, 15° transdelenburg	15° to the left for right transplant	Supine lithotomy, steep transdelenburg
Robot docking position	Right side of patient	Right side of patient	From patient back	Between patient's legs
Incision	Paraumblical	Suprapubic horizonal	Iliac foss	Paraumblical
Hand assist device	Present	Present	Present	Present
Placement of camera port	Left lower quadrant slightly left of midline	Left of midline below umblicus	At the umblicus	Through gel port at paraumblical incision
Graft placement	Transperitoneal	Intially transperitoneal, shifted to extraperitoneal for final position	Retroperitoneal	Intially transperitoneal, shifted to extraperitoneal for final position
Patient characteristics	Obese	Nonobese	Non obese	Nonobese
Regional hypothermia	No	No	No	Approximately 300 ml of ice slush
Ureteric reimplantation	Redocking of robot	Open surgery	Open surgery	No-redocking of robot needed
Postoperative creatinine Clearance RAKT vs. OKT	Initial slow clearance, normalized at 3 months	Not reported	Not reported	Similar clearance with experienced surgeon from day one. Slow clearance in less experienced surgeon

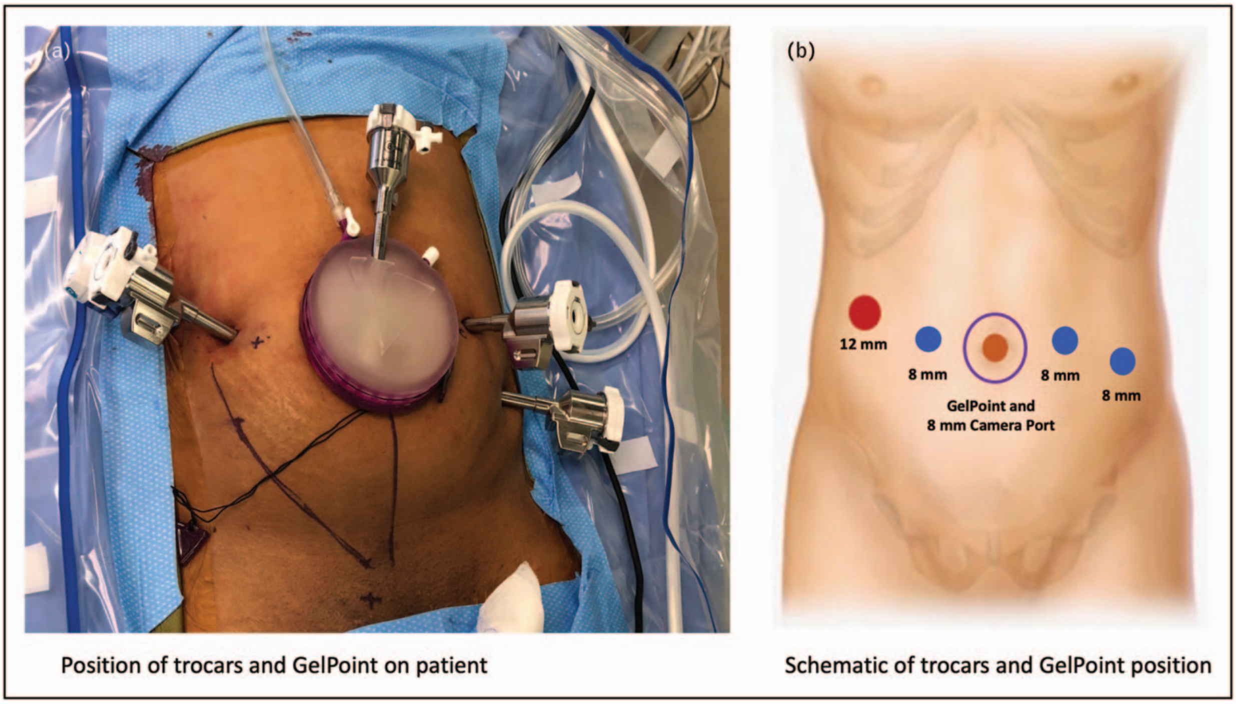
was initially transperitoneal that was shifted to extraperitoneal for finally positioning of the graft [12]. Menon *et al.* used a similar incision and graft placement as Boggi *et al.* [12]. However, their patients were placed in the supine position in steep Transdelenburg with the robot docked between the patient's legs and regional hypothermia was used to limit rewarming during transplantation [14]. Tsai *et al.* used robotic-assisted retroperitoneal approach wherein retroperitoneal space was created by making an incision in iliac fossa. Two additional robotic ports were placed and the vascular anastomosis was done using a robotic approach while the ureteric anastomosis was done using an open approach [13]. All of these techniques were performed with the use of a gel port. Menon *et al.* did not utilize hand assistance during vascular anastomosis [14]. Interestingly, indocyanine green (ICG) has been used to confirm the vascular patency during RAKT [15].

VIRGINIA COMMONWEALTH UNIVERSITY ROBOTIC-ASSISTED KIDNEY TRANSPLANT TECHNIQUE

At VCU, we use a modified technique from Menon *et al.* (Table 1). The patient is placed in Transdelenburg ('head-down') position (15°–20°) to facilitate better intraoperative exposure. Four robotic ports and one 12 mm assistant port is used. A GelPoint (Applied Medical Inc., Rancho Santa Margarita, California, USA), is placed by creating 7–9 cm large midline incision involving the umbilicus. An 8 mm robotic trocar is placed through the GelPoint. Then, a 30° robotic endoscope is inserted through this port, while two 8-mm robotic trocars are inserted on both sides of the GelPoint in the mid-axillary line. One additional 8 mm port is placed close to left anterior superior iliac spine. (Fig. 1). A 12-mm assistant port is placed in the right hypochondric region. A large peritoneal flap is created for retroperitonization of the kidney after reperfusion. The external iliac artery and vein are prepared for vascular anastomosis by dividing lymphatic tissue. The kidney is then placed inside the abdominal cavity using an ice jacket via GelPoint (Fig. 2). Bulldog clamps are used to control the vessels. Polytetrafluoroethylene (PTFE) is the commonly used suture material for arterial and venous anastomosis because it displays minimal suture memory (Fig. 2). The ureteric anastomosis is generally created over a ureteric stent inserted into the ureter/bladder without redocking. Previously fashioned peritoneal flaps are used to reposition the graft in the extraperitoneal plane. Figure 3 is showing immediate and 6 weeks postoperative incisions, respectively.

ROBOTIC-ASSISTED KIDNEY TRANSPLANT VS. OPEN KIDNEY TRANSPLANT: COMPARATIVE OUTCOMES

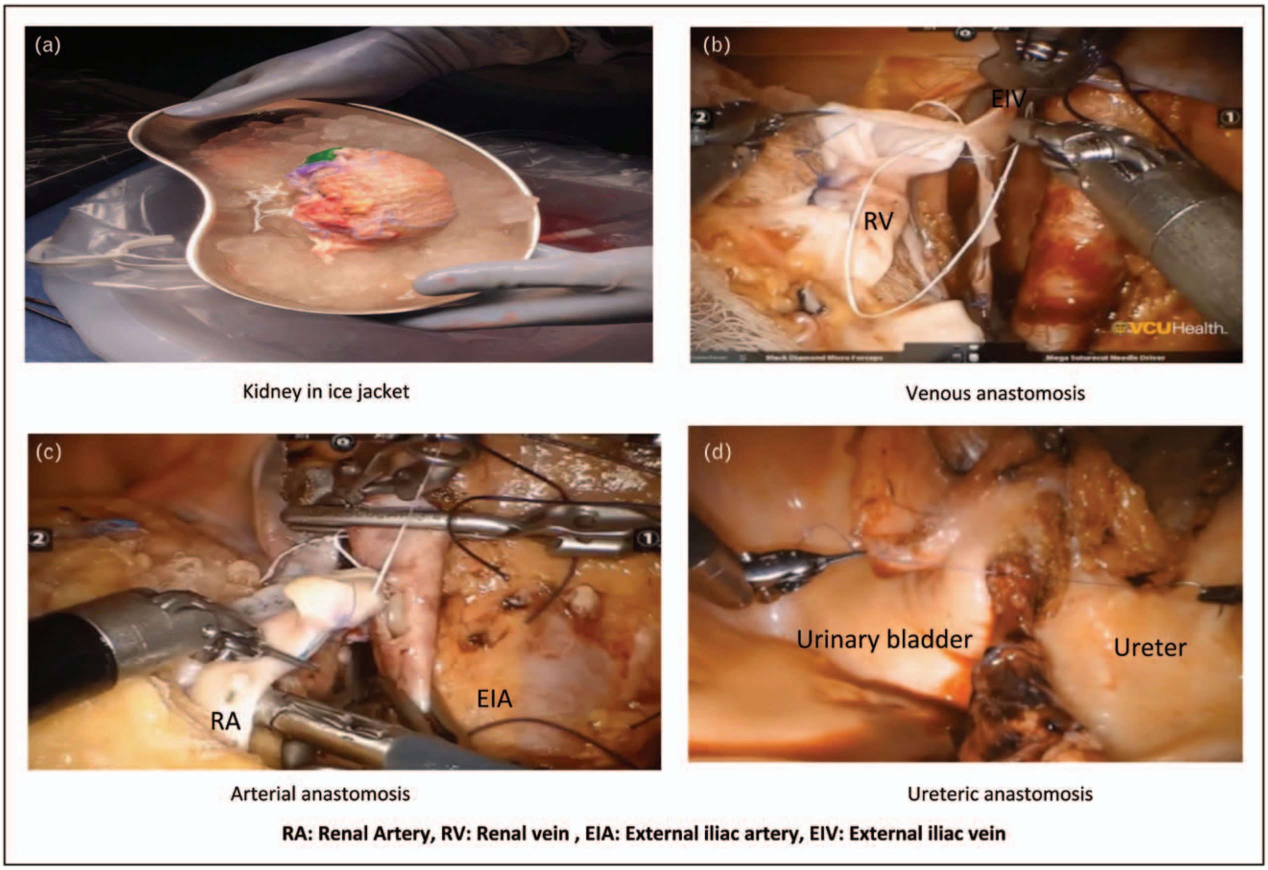
The evolution of RAKT is still in infancy and outcomes of OKT and RAKT approach have been



Position of trocars and GelPoint on patient

Schematic of trocars and GelPoint position

FIGURE 1. Port placement for robotic-assisted kidney transplant.



Kidney in ice jacket

Venous anastomosis

Arterial anastomosis

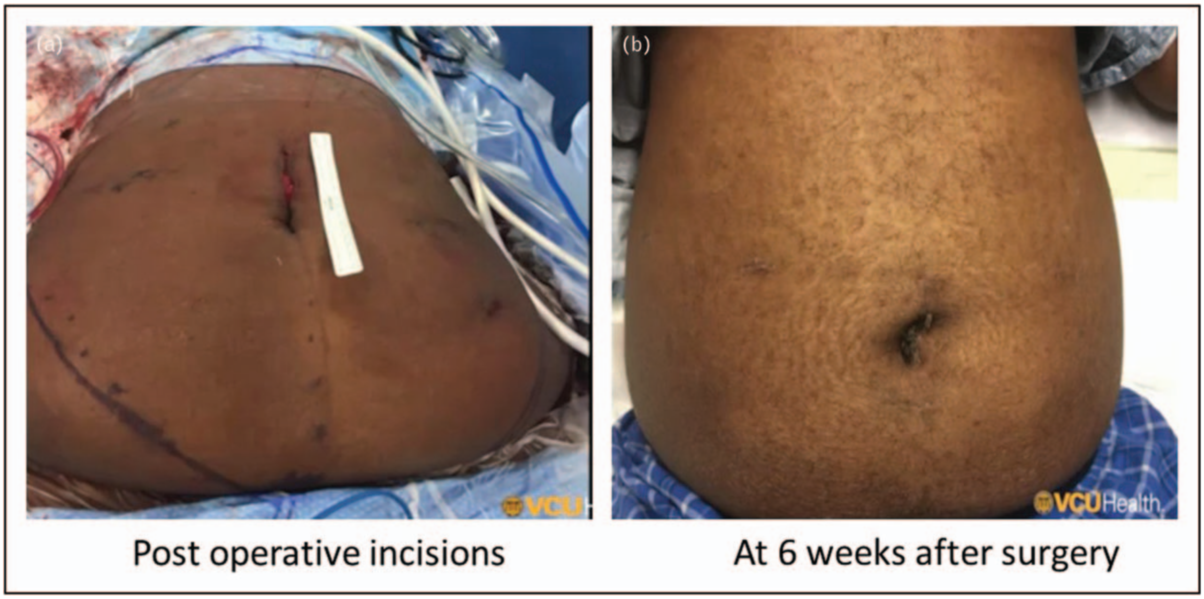
Ureteric anastomosis

RA: Renal Artery, RV: Renal vein , EIA: External iliac artery, EIV: External iliac vein

FIGURE 2. Vascular anastmosis during robotic-assisted kidney transplant.

examined in very limited studies [8▪▪,11,16]. The common variables that are studied include total ischemia time, cold ischemia time, warm ischemia time, rewarming time, EBL, creatinine postoperative trends, postoperative pain score and wound complications (Fig. 4).

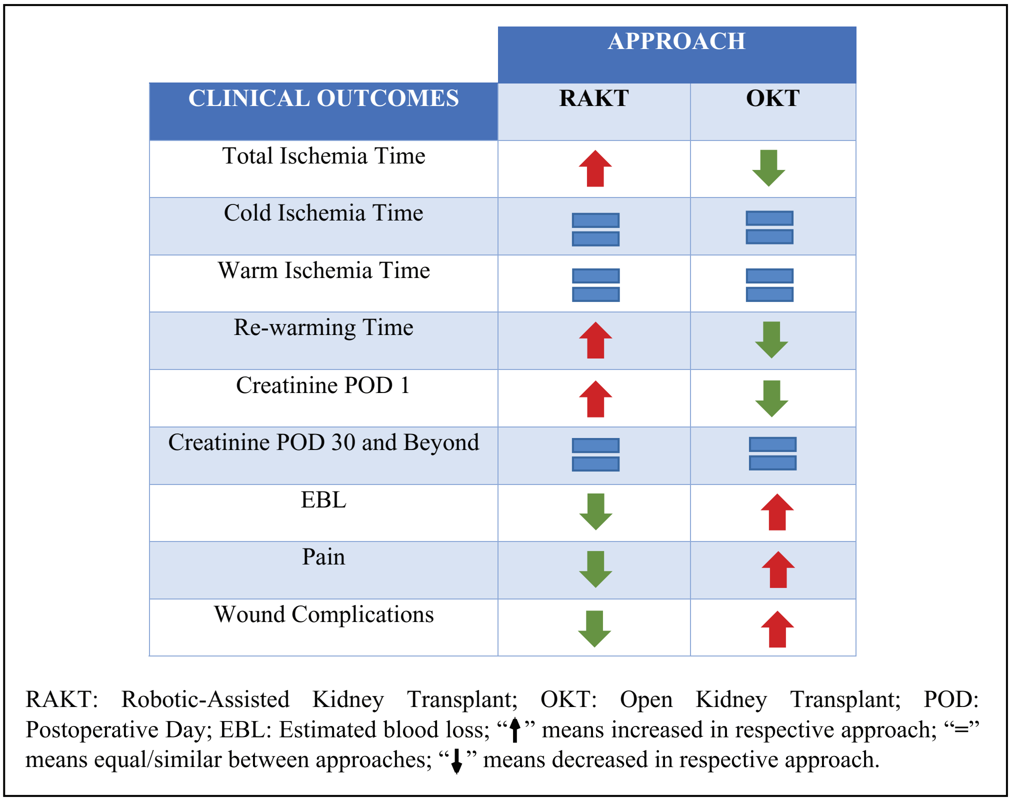
Tuğcu *et al.* performed a prospective study wherein they collected data on 40 OKT and 40 RAKT



Post operative incisions

At 6 weeks after surgery

FIGURE 3. Incision after robotic-assisted kidney transplant.



CLINICAL OUTCOMES	APPROACH	
	RAKT	OKT
Total Ischemia Time	↑	↓
Cold Ischemia Time	=	=
Warm Ischemia Time	=	=
Re-warming Time	↑	↓
Creatinine POD 1	↑	↓
Creatinine POD 30 and Beyond	=	=
EBL	↓	↑
Pain	↓	↑
Wound Complications	↓	↑

RAKT: Robotic-Assisted Kidney Transplant; OKT: Open Kidney Transplant; POD: Postoperative Day; EBL: Estimated blood loss; "↑" means increased in respective approach; "=" means equal/similar between approaches; "↓" means decreased in respective approach.

FIGURE 4. Comparative analysis of robotic-assisted kidney transplant vs. open kidney transplant in nonobese patients.

cases [11]. They showed that RAKT had increased total ischemia and rewarming times than OKT but no difference in cold ischemia or warm ischemia times independently. EBL and postoperative pain were significantly decreased in RAKT, a common trend that was observed in robotic cases compared to open in various other studies. Similarly, a study by Pein *et al.* showed increased rewarming times and total ischemia times with no differences in creatinine postoperatively in comparing 21 RAKT and 21 OKT patients [16]. These findings were further emphasized by recently published prospective study of 55 RAKT and 152 OKT by Maheshwari *et al.* Interestingly, 3 months serum creatinine levels were similar in both groups and no difference in outcome was noted [8▪▪]. However, in the early postoperative period, there was a delayed fall in creatinine observed in the study by Maheshwari *et al.* that was not observed in the studies by Tuğcu *et al.* or Pein *et al.* In addition, all studies showed that there were fewer wound infection/complications in the RAKT group than in the OKT group because of location and size of incision.

To address the issue of rewarming during implantation in RAKT, the regional hypothermia concept was published by Menon *et al.* [14]. In this technique, the pelvic bed is cooled to 18–20°C with the introduction of 180–240 ml of ice slush via modified syringes. Here at VCU, we place the kidney in an ice jacket before placing the kidney intraperitoneally (Fig. 2a). Although safety, short-term patient and graft outcomes of RAKT have been well established, no data have been published on long-term results. Most studies report on short-term follow-up but a recently published study by Tzvetanov *et al.* with 10 years of follow-up confirmed safety of this procedure with excellent outcomes [17▪▪]. These comparative studies confirm that RAKT is a promising approach with key advantages, including fewer wound complications, decreased EBL and early recovery improved pain scores. Unfortunately, no randomized control trials exist and would need to be done to truly elicit the advantage and disadvantages of RAKT vs. OKT.

ROBOTIC-ASSISTED KIDNEY TRANSPLANT IN OBESE PATIENTS

Surgery in obese patients comes with many challenges and this is especially true when performing a kidney transplant in patients with ESRD. Obesity is a significant risk factor for increased morbidity and mortality from cardiovascular disease, diabetes and even kidney disease. Given their body habitus, ESRD patients with obesity are at an increased risk of poor surgical outcomes [9]. Operating in an obese patient

Table 2. Summary of studies examing outcomes of robotic-assisted kidney transplant

Ref.	Year	Region	No. of patients	Patient characteristics	Major results
Prudhomme *et al.* [10]	2020	Germany	169	Nonobese and obese	Similar renal function across BMI subgroups, similar functional graft outcomes
Maheshwari *et al.* [8■■]	2020	India	55	Nonobese	RAKT reduced EBL, initial delay in fall of creatinine with normalization at 3 months
Pein *et al.* [16]	2019	Germany	21	Nonobese	100% patient and graft survival, reduced hospital stay 14 vs. 20 day for RAKT and OKT, respectively
Tzvetanov *et al.* [17■■]	2019	USA	239	Obese	Wound complications occurred in 3.8% of obese patients. Graft survival at 1 year and 3 years was 98 and 93%, respectively.
Tuğcu *et al.* [11]	2017	Turkey	40	Nonobese	RAKT shorter drain withdrawal time, less postoperative pain and fewer complication compared with OKT
Breda	2017	Europe	120	Nonobese	No comparison with OKT, complication rate 15%
Garcia-Roca *et al.* [18]	2015	USA	67	Obese	Decreased wound infections, decreased incidence of thrombosis and similar graft survival rates RAKT vs. OKT
Menon *et al.* [14]	2014	USA/India	50	Nonobese	RAKT with regional hypothermia with ice slush can limit rewarming time and improve graft outcomes

with a deep pelvis can be very challenging and require a larger incision to access the vasculature for the anastomosis. The anastomosis time can be significantly higher and increased risk of wound dehiscence and infection in comparison to standard OKT. However, many studies have demonstrated the utility of robotic approach in this unique population.

Since the pioneering report by Giulianotti *et al.* [7], multiple groups have shown positive outcomes in the obese patient undergoing RAKT compared to the OKT approach. Oberholzer *et al.* performed a retrospective study comparing 28 RAKTs to 28 OKTs and found wound complication/infections were higher in the OKT group (3.6 vs. 28.6%, respectively) [9]. Garcia-Roca *et al.* showed that obese RAKT group had less wound complications, less graft rejection, fewer graft thromboses and similar creatinine postoperatively compared with the obese OKT group [18].

In a more recent single-centre retrospective study, 239 living and deceased donor RAKTs were compared across multiple BMI subgroups over a 10-year period [17■■]. Wound complications occurred in 3.8%, occurring more in patients with BMI more than 50. In addition, patient survival at 1-year and 3-year posttransplant in both RAKTs arms were similar to reported data in the UNOS databank for living and deceased donors. Similar trends were observed by Prudhomme *et al.* in a study of 169 living donor RAKTs in obese patients [10]. However, in their study, obese patient initially had a delay in the normalization of the creatinine compared with non-overweight patients but observed no difference by postoperative day 7. Various studies that have shown benefits are summarized in Table 2 [8■■,10,11, 14,16–19].

Most transplant centres across the world deny obese patient for transplantation because of the increased risk of complications and poor outcomes. Limited supply and increasing demand warrants judicious use of transplant organs. Taken together, these results are truly promising. Obese patient without transplantation have poor outcomes. As the number of patients with ESRD increases especially in the obese population, it is imperative that improvements in kidney transplantation are made in order to offer this population a solution. RAKT has the potential to decrease the barriers to access of transplantation in this patient population and improve patient outcomes and satisfaction. Still, more prospective data and randomized control studies are needed to directly compare the advantage and disadvantages of RAKT and OKT.

BARRIER TO THE IMPLEMENTATION OF ROBOTIC-ASSISTED KIDNEY TRANSPLANT AND TRAINING

It is well known that robotic surgery requires an increased level of technical skill, team approach and the financial resources to support this approach. However, robotic surgery does have its disadvantages, which include absence of tactile feedback, steep learning curve and high financial burden compared with open surgery. One barrier for residents and established surgeons without formal robotic training is time allowed for skill acquisition. Simulation is a well established tool for surgical skill acquisition in robotic techniques and a critical part of the resident training programme, which is often accomplished by the use of virtual simulators, animal models and cadaveric models [20]. However, these models do not always realistically simulate the critical parts of surgery, and moreover, they are associated with high costs and regulated availability [21].

One strategy to combat this limitation is the use of 3D printed models to recapitulate key parts of the procedure such as the vascular anastomosis in RAKT. One study generated 3D printed hybrid models of recipient and donor anatomy to simulate this vascular anastomosis step [22]. A computed tomography (CT) scan was used to generate an anatomically accurate model of the recipient pelvis, kidney and renal vasculature and deceased donor iliac vessels were harvested allowing surgeons to practice this critical step in a technically challenging procedure. This simulation tool would permit surgeons to have patient-specific training especially in the setting of challenging anatomy, as one would be able to practice on a geometrically and spatially accurate model of the recipient's operative field. However, although this strategy is promising, it is limited, as access to deceased donor iliac vasculature may be not be feasible in many facilities and it does not represent a perfused state of the anatomy as one will encounter in the actual surgery.

Interestingly, a more recent study by Saba *et al.* demonstrated that hydrogels could be used to simulate perfused vascular and ureterovesical anastomoses. Similar to the previous study, CT scans of donors and recipients were obtained, and 3D printed models were created with various polyvinyl alcohol gels to recapitulate a perfused state [23▪]. Metric including total anastomosis time, minutes for arterial, venous and ureterovesical anastomosis were all within the published time for competency or the mastery range.

However, the learning curve is surmountable, as surgeons with previous robotic experience who performed as few as 12 RAKTs demonstrated improved incision to closure times [16]. Recently presented data from our institution showed significant improvement in suturing (anastomosis) time after the 13th RAKT case, which helps in establishing a number of learning curve cases for new incoming transplant surgeons [24]. Given that RAKT is still in its infancy, this technique should be reserved for centers with significant robotic experience.

These studies demonstrate that 3D-print technology has the potential to aid in overcoming the learning curve in robotic surgery [25▪]. In fact, the use of 3D-print and 3D-virtual technologies is becoming more wildly used in the management of urologic disease [25▪]. These technologies can be used in surgical planning, resident education/training and even patient counselling offering an array of benefits that could potentially improve patient outcomes and management. However, randomized studies need to be performed with larger cohorts of surgeons to truly demonstrate the utility of 3D-print models vs. standard simulation techniques. In addition, access to 3D printing and virtual facilities may be limited for training programme for various reasons including financial which would make implementation of this simulation strategy challenging.

CONCLUSION

The RAKT approach is very promising and has some advantages over the OKT approach. RAKT is emerging and getting more widely accepted, as it has similar patient and graft survival outcomes as OKT. The RAKT approach provides improved visualization of the vascular anastomosis as well as decreased incidence of wound complications in the obese patient population.

However, although robotic surgery is highly popularized, it takes a level of technical skill to overcome the learning curve, which might be difficult to obtain without the right resources. Therefore, the RAKT technique should be used by experienced robotic surgeons. Nevertheless, new 3D-printing and virtual technologies may allow surgeons to overcome the learning curve as well as practice in patient-specific manner with geometrically and spatially accurate model of the recipient's operative field. Larger powered prospective and randomized studies are still needed to fully understand the long-term benefits of RAKT vs. OKT.

Acknowledgements

We acknowledge Virginia Commonwealth University Health System, Urology and Transplant departments.

Financial support and sponsorship

None.

Conflicts of interest

None.

REFERENCES AND RECOMMENDED READING

Papers of particular interest, published within the annual period of review, have been highlighted as:

■ of special interest
■■ of outstanding interest

1. Saran R, Robinson B, Abbott KC, *et al.* US Renal Data System 2019 Annual Data Report: epidemiology of kidney disease in the United States. Am J Kidney Dis 2020; 75:A6.
2. Barker CF, Markmann JF. Historical overview of transplantation. Cold Spring Harbor Perspect Med 2013; 3:a014977.
3. Ng ZQ, Lim W, He B. Outcomes of kidney transplantation by using the technique of renal artery anastomosis first. Cureus 2018; 10:1–11.
4. Lanfranco AR, Castellanos AE, Desai JP, *et al.* Robotic surgery: a current perspective. Ann Surg 2004; 239:14.
5. Wagenaar S, Nederhoed JH, Hoksbergen AW, *et al.* Minimally invasive, laparoscopic, and robotic-assisted techniques versus open techniques for kidney transplant recipients: a systematic review. Eur Urol 2017; 72:205–217.
6. Hoznek A, Zaki SK, Samadi DB, *et al.* Robotic assisted kidney transplantation: an initial experience. J Urol 2002; 167:1604–1606. ■■

First prospective study of RAKT vs. OKT during the same time period with midterm follow-up.

7. Giulianotti P, Gorodner V, Sbrana F, *et al.* Robotic transabdominal kidney transplantation in a morbidly obese patient. Am J Transplant 2010; 10:1478–1482.
8. Maheshwari R, Qadri SY, Rakhul L, *et al.* Prospective nonrandomized comparison between open and robot-assisted kidney transplantation: analysis of midterm functional outcomes. J Endourol 2020; 34:939–945. ■■

First prospective study of RAKT versus OKT during the same time period with midterm follow-up

9. Oberholzer J, Giulianotti P, Danielson K, et al. Minimally invasive robotic kidney transplantation for obese patients previously denied access to transplantation. American Journal of Transplantation: official journal of the American Society of Transplantation and the American Society of Transplant Surgeons. 2013; 13: 721.
10. Prudhomme T, Beauval JB, Lesourd M, *et al.* Robotic-assisted kidney transplantation in obese recipients compared to non-obese recipients: the European experience. World J Urol 2020; 1–12.
11. Tuğcu V, ener NC, ahin S, *et al.* Robot-assisted kidney transplantation: comparison of the first 40 cases of open vs robot-assisted transplantations by a single surgeon. BJU Int 2018; 121:275–280.
12. Boggi U, Vistoli F, Signori S, *et al.* Robotic renal transplantation: first European case. Transpl Int 2011; 24:213–218.
13. Tsai MK, Lee CY, Yang CY, *et al.* Robot-assisted renal transplantation in the retroperitoneum. Transpl Int 2014; 27:452–457.
14. Menon M, Abaza R, Sood A, *et al.* Robotic kidney transplantation with regional hypothermia: evolution of a novel procedure utilizing the IDEAL guidelines (IDEAL phase 0 and 1). Eur Urol 2014; 65:1001–1009.
15. Vignolini G, Sessa F, Greco I, *et al.* Intraoperative assessment of ureteral and graft reperfusion during robotic kidney transplantation with indocyanine green fluorescence videography. Minerva Urol Nefrol 2019; 71:79–84.
16. Pein U, Girndt M, Markau S, *et al.* Minimally invasive robotic versus conventional open living donor kidney transplantation. World J Urol 2019; 1–8.
17. Tzvetanov IG, Spaggiari M, Tulla KA, *et al.* Robotic kidney transplantation in the obese patient: 10-year experience from a single center. Am J Transplant 2020; 20:430–440. ■■

This is the largest cohort to date of robotic assisted kidney transplants with the longest follow-up (10 years) which examined outcomes in mutiple BMI subtypes including obese patients, demonstrating that RAKT results in few wound complications in the obese population.

18. Garcia-Roca R, RGarcia-Aroz S, Tzvetanov I, *et al.* Single center experience with robotic kidney transplantation for recipients with BMI of 40 kg/m^2 or greater: a comparison with the UNOS registry. Transplantation 2017; 101:191–196.
19. Breda A, Territo A, Gausa L, *et al.* Robot-assisted kidney transplantation: the European experience. Eur Urol 2018; 73:273–281.
20. Schreuder HW, Wolswijk R, Zweemer RP, *et al.* Training and learning robotic surgery, time for a more structured approach: a systematic review. BJOG: Int J Obstet & Gynaecol 2012; 119:137–149.
21. Gilbody J, Prasthofer A, Ho K, *et al.* The use and effectiveness of cadaveric workshops in higher surgical training: a systematic review. Ann R Coll Surg Engl 2011; 93:347–352.
22. Uwechue R, Gogalniceanu P, Kessaris N, *et al.* A novel 3D-printed hybrid simulation model for robotic-assisted kidney transplantation (RAKT). J Robot Surg 2018; 12:541–544.
23. Saba P, Belfast E, Melnyk R, *et al.* Development of a high-fidelity robotic assisted kidney transplant (RAKT) simulation platform using 3D printing and hydrogel casting technologies. J Endourol 2020; 1–19. ■

This paper highlights the use of 3D-printing technology to recapituatelate a perfused nonbioharzardous platform for RAKT simulation training that may help overcome the robotic learning curve

24. Khan A, Bhati C, Reichman T, *et al.* Complete robotic-assisted kidney transplantation: our initial experience [abstract]. Am J Transplant 2019; 19:53–54.
25. Checcucci E, Amparore D, Fiori C, *et al.* 3D imaging applications for robotic urologic surgery: an ESUT YAUWP review. World J Urol 2020; 38:869–881. ■

A review on current applications of 3D imaging in robotic urologic surgery.