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Review Article

Minimally Invasive Techniques for Kidney Transplantation: A Systematic Review

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Abstract

Introduction: With the advancement in laparoscopic and robotic surgery, there is a push towards minimally invasive surgery. For kidney transplantation, minimally invasive techniques have been explored with intention to minimize the incision and thus to reduce the surgical trauma and associated pain or wound complications, improving recovery and cosmetic appearance. The aim of this review is to provide an update on the development of minimally invasive technique for kidney transplantation.

Methods: An electronic search of PubMed, Embase and Cochrane library database was conducted to identify the publications on surgical technique innovation for kidney transplantation by minimally invasive surgical technique between January, 1980 and September, 2016.

Results: There were 5 papers and abstracts reported kidney transplant by using a smaller incision from 5 to 9 cm in selected 142 patients. There were 6 papers and abstracts described laparoscopic kidney transplant in 89 recipients in total, whereas there were 10 papers and abstracts demonstrated the safety and feasibility of robotic kidney transplantation in 300 recipients. One group has in particular applied robotic surgery to the obese recipients for kidney transplantation.

Conclusion: Surgical technique innovation of minimally invasive technique for kidney transplantation is still at its early stage. The preclinical studies were conducted on the animals or human cadavers prior to application to the clinical human kidney transplantation. The technique challenge remains to minimize warm ischemic injury by improving proficiency of the vascular anastomosis under time pressure. The technique refinement is still needed to establish a better approach for kidney transplantation by minimally invasive technique.

Keywords: Kidney transplantation; Laparoscopic surgery; Robotic surgery; Minimally invasive technique

Introduction

Laparoscopic surgery has revolutionized the surgical approach with multiple benefits. Over the last three decades, it has been applied to all different types of surgery [1,2]. More sophisticated surgery can be performed by laparoscopic technique [3]. The invention of robotic system (da Vinci) has advanced the surgical technique and precipitate surgical technique innovation [4,5]. The surgeon can sit comfortably while performing complex surgery with lesser feeling of fatigue. With the advancement in laparoscopic and robotic surgery, there is a push towards minimally invasive surgery. As such, the conventional open surgery is being modified by using a smaller incision. In the field of kidney transplantation, laparoscopic live donor nephrectomy has been well accepted in the most transplant centers, whereas mini-incision for live donor nephrectomy has been developed. For kidney transplantation, minimally invasive techniques have been explored with intention to minimize the incision and thus to reduce the surgical trauma and associated pain or wound complications, improving recovery and cosmetic appearance. However, the technical challenge is to perform a quality vessel anastomosis under the time constraint to minimize the ischemic reperfusion injury of the kidney graft. The aim of this review is to provide an update on the development of minimally invasive technique for kidney transplantation and its clinical application.

Methods

An electronic search of PubMed, Embase and Cochrane library database was conducted to identify the publications on surgical technique innovation for kidney transplantation by minimally invasive surgical technique between January, 1980 and September, 2016. The terms "minimal incision + kidney transplantation", "Minimally invasive + kidney/renal transplantation"; "smaller incision + kidney/renal transplantation"; "laparoscopic kidney/renal transplant" and "robotic kidney/renal transplantation" were used. Cross-referencing was also conducted to find further publications on minimally invasive approach for kidney transplantation. English language reports were selected and reviewed.

Results

A minimal incision for kidney transplantation

The conventional open kidney transplant has been well established

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since 1954. The incision is usually about 15-25 cm in length in lower abdomen. The Minimal Incision Kidney Transplantation (MIKT) was first described by Oyen, et al in 2006 [6]. A 7-9 cm transverse incision is made 3-5 cm above the inguinal ligament with the medial end 2-3 cm from the midline. The extra-peritoneal space is created as a pouch for housing the kidney graft. The iliac vessels are minimally dissected. It is emphasized that meticulous preparation of the kidney graft on the back table is essential as the kidney is sitting in a fitted position. It is a critical step to minimize the risk of bleeding after reperfusion of the kidney graft. In addition, it was described that the suture of the back wall of the vascular anastomoses is performed from the inside of the lumen. Ureteroneocystostomyis performed by using Lich-Gregoir technique without placement of a stent. In their initial 21 cases, there was no difference in terms of patient BMI 25.7kg/m^2 (21-32kg/m^2) in the MIKT group *vs.* 24.4kg/m^2 (18-33 kg/m^2) in the Conventional Open Kidney Transplant (COKT) group respectively. The average incision was8.1 cm in MIKT and 20.5 cm in COKT. The surgical time and length of hospital stay were significantly shorter in MIKT group in comparison with COKT. The kidney graft function was comparable between the two groups. The surgical complications including lymphocele, wound dehiscence, urinary tract obstruction were less in MIKT, although it was not statistically significant. Unsurprisingly, the analgesia consumption was also lesser in MIKT group, although it did not reach statistical significance. It was concluded that MIKT is feasible and safe. The wound complications may be reduced as a result of shorter incision and less dissection. Subsequently, this technique was adopted by Kim et al 7for17 young unmarried women (average age 26.5 ± 9.3 years) for live donor kidney transplant in comparison with COKT in 435 recipients (average age 43.6 ± 11 years, P< 0.001). The BMI was 18.72 ± 2.47 kg/m^2 in MIKT and 22.98 ± 3.76 kg/m^2 in COKT group respectively (P< 0.001) the incision was 9.5 ± 1.3 cm in length in MIKT group. However, there was no difference observed in terms of surgical time. The wound complications, graft function, and the kidney graft survival rate were comparable between the two groups.

In 2013, Kacar, et al. [8] reported a case control study for 86 kidney transplant recipients, 43 in each group of MIKT and COKT respectively. The mean operative time, the length of hospital stay and serum creatinine level were similar in both groups. The surgical complications were similar between two groups. It was recommended that MIKT seems to be a safe technique with less tissue trauma and pain for the recipients. Most recently, in 2016, Ostrowski M, et al. [9] (abstract TTS-2016) reported 41 cases of MIKT with incision 5-8 cm in comparison with 76 of COKT with incision 9-16 cm. It was noted that the analgesia consumption was lesser in MIKT group. The BMI was 23.5 kg/m^2 in MIKT group *vs.* 26.4 kg/m^2 in COKT group.

Interestingly, Mun, et al. [10] (Mun, Seong-pyo, J S R 2007) reported a video-assisted MIKT for 20 patients from January 2004 to March 2006. The video assistance was employed for the creation of extra peritoneal space and then facilitation of visualization for assistant surgeon during the procedure. The clinical variables were compared with COKT in 20 recipients. The incision was 7.8 cm in length that is significantly smaller than 21.2 cm in COKT group (P < 0.001). The analgesia consumption was lesser in MIKT than in COKT. The patients recovered and returned to work significantly quicker in MIKT than in COKT group. However, the operative time was similar for both groups in their report. Nevertheless, the application of this technique may not be suitable for obese patients or recipients who have iliac vessel disease.

In summary, the technique for MIKT is safe and feasible. The incision length with MIKT is smaller from 5 cm to 9 cm and therefore the analgesia consumption is less. The cosmetic appearance is superior. It seems that most studies employed MIKT for a selected group of recipients that were not obese. It was highlighted that the back table preparation is very important as the kidney is positioned in the extraperitoneal pouch such that it would be hard to flip kidney around for haemostasis check. The interest in this technique is growing amongst the surgical community due to technological advancement.

Laparoscopic technique for kidney transplantation

Laparoscopic kidney transplantation has not been endeavored until 2009. Rosales, et al. [11] performed the first case of kidney transplant by laparoscopic surgery from a living donor. A small 7 cm Pfannenstiel incision was made, through which the kidney graft was delivered to the iliac fossa. Three more ports were inserted in the right side of abdomen. The iliac vessels were dissected by incising the peritoneum. The renal vein and artery were anastomosed in end-to-side fashion to the external iliac vein and artery respectively. Ureteroneocystostomy was performed by using a modified Taguchi technique. The kidney graft was then placed at the extra-peritoneal space by closure of peritoneal window. Subsequently, Modi, et al. [12-14] reported 76 cases of laparoscopic kidney transplant by using a slightly different technique. The patient was placed on Trendlenberg position following general anaesthesia. A small incision (6-7 cm) was made at supra pubic region. This technique required four of 12 mm ports and *via* intraperitoneal approach. The peritoneum was incised open for dissection of the iliac vessels. The renal vein and artery were anastomosed in end-to-side fashion to the external iliac vein and artery respectively by using two separate 5-0 ploypropylene running sutures. The ureteroneocystostomy was done by modified Lich-Gregoir method by using 4-0 Polyglactin sutures without placement of ureteric stent. The kidney graft was placed at extra-peritoneal space by closing the retroperitoneal window. Meanwhile, Modi, et al. [15] have also advanced the technique by insertion of the kidney graft to the iliac fossa by vaginal access in 8 female recipients. Immediate graft function was achieved in all cases and was similar to randomly selected female patients who had open kidney transplant. The analgesia consumption was less in the study patients and cosmetic appearance was better. Furthermore, Abraham [16] presented 3 cases of laparoscopic kidney transplant at Annual Meeting of the American Urology Association, Atlanta, USA in May, 2012. No details of description of the technique were provided; but the dissection was *via* the intra-peritoneal approach and the kidney graft was placed at extra-peritoneal space by closure of retroperitoneal window.

It appears that the engagement of laparoscopic technique for kidney transplant has been progressing gradually. Our group [17,18] has developed a laparoscopic technique by extra-peritoneal approach on the human cadavers and subsequently applied to a clinical kidney transplant by using this innovative technique. The patient has been followed-up 3 years with no surgical complications. The kidney graft function is satisfactory with creatinine level at 103 μmol/L (Abstract TTS2016) [19].

Robotic technique for kidney transplantation

Employment of robotic technique for human kidney transplant was first conducted by Hoznek, et al. [20] in 2002 using da Vinci system. The patient was placed on supine position under general anaesthesia with legs on lithotomy position allowing placement of the surgical cart. The open wound was made at the left iliac fossa, through which the robotic arms were inserted. The procedure was conducted by operating under da Vinci system with an assistant helping through the open wound for hemostasis and retraction of the suture line. The patient recovered well and the kidney graft function was reported to be satisfactory.

It took approximately eight years to see another case report of kidney transplantation by robotic surgery. Giulianotti, et al. [21] from the University of Illinois reported a robotic kidney transplant in a morbidly obese patient (BMI 41 kg/m^2) *via* a minimal midline incision 7 cm in length. The patient was placed in the left decubitus position with the right flank up. The da Vinci System was docked into the place on the patient's right side. A Lap Disc was inserted over the incision to maintain the pneumoperitoneum. Two 12 mm ports and two 7 mm ports were required for the 3-D scope, two robotic instruments and assistance respectively. The dissection of the iliac vessels was performed *via* the transperitoneal approach. The renal vein and renal artery were anastomosed in end-to-side fashion to external iliac vein and artery respectively with running 6-0 Gore-Tex sutures. Ureteroneocystostomy was done by using continuous 6-0 Polydioxanone Suture (PDS). The kidney graft was placed in the intra-peritoneal cavity. The patient recovered well with immediate kidney graft function. This group has been focusing on innovating robotic surgical techniques for kidney transplantation in the obese recipients. By 2013, they [22] reported a matched cohort study of robotic kidney transplantation in obese patients. There was no surgical site infection in 28 (0/28) recipients in robotic group while there were 28.6% in the control group patients (8/28) developed surgical site infection ($p = 0.004$). During 6 months follow-up, the patient and graft survival were comparable between the two groups. It was concluded that robotic surgery for kidney transplantation may ease the access to kidney transplant for obese patients. Otherwise, these obese recipients may be excluded for kidney transplant as a result of concerns of surgical complications. Most recently, (Garcia-Roca R Transplantation 2016 may 15) they [23] reviewed the living donor kidney transplant recipients with BMI≥ 40 using the United Network of Organ Sharing (UNOS) database during 5 years period from September 2009 to December, 2014. There were 67 recipients who had kidney transplant by robotic surgery versus 545 cases by conventional open kidney transplant. The 1-year patient and graft survival rates were similar between two groups. The kidney graft function was also comparable at 6, 12 and 36 months between the two groups. It was noted that the BMI was relatively higher in robotic group. The graft loss due to thrombosis was 0% in robotic group while it was 1.3% in conventional open surgical group. It was concluded that robotic surgery offers similar patient and graft survival without additional surgical complications in the morbidly obese patient.

In the meantime, there were other reports of robotic kidney transplantation around the world. In Europe, Boggi, et al [24] reported a robotic kidney transplant from a live donor by using a slightly different technique from the abovementioned. The recipient was on a supine position with the right flank slightly elevated and 15 degree Trendelenburg position. Four ports were required with two of 12 mm ports, one 11 mm port and one 8 mm port. A 7 cm incision was made at supra pubic region and a Lap Disc was placed over the incision, in which one of these two 12 mm port was inserted. The da Vinci System was docked into the patient's right side. The dissection of the iliac vessels was *via* the intra-peritoneal approach. The renal vein and artery were anastomosed in end-to-side fashion to the common iliac vein and artery respectively by using two short 6-0 expanded polytetrafluoroethylene (ePTFE) sutures. However, in their report, the ureteroneocystostomy was done through the supra pubic incision by an open approach. The kidney graft was placed at the extra-peritoneal space by closure the window of the peritoneum. The patient recovered uneventfully with immediate kidney graft function.

Modi et al (abstract TTS-2016) [25] reported a large cohort of 180 robotic kidney transplants in comparison with 243 open kidney transplants. Four patients in robotic group required conversion to open surgery due to either venous bleeding or arterial thrombosis. The patient and graft survival were comparable between the two groups. The eGFR was similar in both groups. However, the blood loss and the analgesia consumption were significantly less in robotic group when compared to open group ($P< 0.001$; $P <0.01$). Modi et al (abstract TTS-2016) [25] have also advanced the robotic kidney transplant by insertion of the kidney graft *via* vagina in 19 selected female patients. In comparison with 39 female patients who had open kidney transplant, there was no difference in terms of the patient and graft survival. The eGFR was similar in both groups. The analgesia consumption was significantly less ($P< 0.01$) in the study group and the cosmetically better as well.

Menon et al and Sood, et al. [26,27] have applied regional hypothermia during robotic kidney transplantation to minimize warm ischemic injury to the kidney graft . They also intended to introduce the IDEAL (Innovation, Development, Exploration, Assessment, Long-term study) model for safe introduction of a new surgical technique and to determine the learning curve. From their study it was concluded that there was little or no learning phase for the robotic-trained surgeon, whereas there was a significant learning phase for non-robotic trained surgeon. It is arguable that the lack of kidney transplant experience did not significantly affect the learning curve.

Tsai, et al. [28] reported a modified technique of robotic kidney transplant *via* extra-peritoneal approach by a minimal incision (7.7±1.04 cm) along the line for conventional open surgery in 10 recipients with 6 cases from living donor. There was no requirement of pneumoperitoneum with abdominal wall lifting. The endoscope was inserted to the working space through open incision while two working instruments were placed through the Robotic port. The average anastomotic time was 67.4 ± 22.3 minutes and operation time was 257.8 ± 52.7 minutes. The immediate kidney graft function was achieved in nine cases and there was one delayed graft function due to prolonged warm ischemic time at the donor surgery.

Furthermore, some case reports described various conditions such as a dual-kidney transplant was performed successfully by robotic surgery *via* a 7 cm incision [29]. A kidney auto-transplantation was performed without extraction of the kidney graft by Gordon, et al. [30].

Conclusion

It seems that more cases of kidney transplantation have been performed by robotic surgery than laparoscopic surgery in the context of minimally invasive technique. The challenge remains to perform vascular anastomosis under the time constraint. The most concerning aspect is additional warm ischemic injury due to possible prolonged vessel anastomotic time. Robotic surgery has the advantage where the vascular anastomosis was felt easier to perform as a result of 3D vision and the 7-degree movement of instrument while laparoscopic surgery is limited in the finer movement of the instrument. It is expected that the variation of the technique from each report exists. However, minimally invasive surgery for kidney transplantation can be done safely after under taking the proper training. In the future, the innovation is still necessitated to discover a better approach and therefore to facilitate the vessel anastomosis. In addition, the technique by extra peritoneal approach would be more beneficial as this would avoid violating the intraperitoneal cavity and organs. As such it will allow the patient resume the peritoneal dialysis after the kidney graft failure. Once the technique approach is established, kidney transplantation by minimally invasive technique can be well conducted as a standard practice. A format of mentorship can be structured for safe introduction of this innovative technique without compromising the recipient's outcomes.

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