Published in final edited form as:
Am J Transplant. 2013 March ; 13(3): 721–728. doi:10.1111/ajt.12078.

Minimally Invasive Robotic Kidney Transplantation for Obese Patients Previously Denied Access to Transplantation

J. Oberholzer, MD[1], **P. Giulianotti, MD**[2], **K.K. Danielson, PhD**[1,5], **M. Spaggiari, MD**[1], **L. Bejarano Pineda, MD**[1], **F. Bianco, MD**[2], **I. Tzvetanov, MD**[1], **S. Ayloo, MD**[2], **H. Jeon, MD**[1], **R. Garcia-Roca, MD**[1], **J. Thielke, PharmD**[3], **I. Tang, MD**[4], **S. Akkina, MD**[4], **B. Becker, MD**[4], **K. Kinzer, BS**[1], **A. Patel, MBA**[1], and **E. Benedetti, MD**[1]

[1]Division of Transplantation, University of Illinois Hospital & Health Sciences System, University of Illinois at Chicago

[2]Division of Minimally Invasive and Robotic Surgery, Department of Surgery, University of Illinois Hospital & Health Sciences System, University of Illinois at Chicago

[3]Department of Pharmacy Practice, University of Illinois Hospital & Health Sciences System, University of Illinois at Chicago

[4]Division of Nephrology, Department of Medicine, University of Illinois Hospital & Health Sciences System, University of Illinois at Chicago

[5]Division of Epidemiology & Biostatistics, University of Illinois at Chicago

Abstract

Obese patients with end-stage renal disease (ESRD) are often excluded from kidney transplantation due to concerns about surgical site infections. To reduce infections, we developed a robotic kidney transplantation method for obese recipients. From June 2009-December 2011, a prospective cohort of 39 obese patients underwent robotic kidney transplantation at a single center. The outcomes of patients with at least six months of follow-up (n=28) were compared to a frequency-matched retrospective cohort of obese patients who underwent open kidney transplantation from 2004-2009 (n=28). The 28 robotic patients were predominately African-American (46.4%) or Hispanic (35.7%), with a mean age of 47.9±10.7 years, similar to the control group. BMI in the robotic group was 42.6±7.8 kg/m^2 compared to 38.1±5.4 kg/m^2 in the control group (p=0.02). There were no surgical site infections in the robotic group (0/28), while 28.6% (8/28) in the control group developed an infection (p=0.004). Six-month creatinine (1.5±0.4 vs. 1.6±0.6 mg/dL; p=0.47), and patient and graft survival (100%) were comparable between the two groups. Outcomes following robotic surgery compared favorably to conventional transplantation. Robotic surgery may therefore enable obese patients with ESRD to access kidney transplantation and may thereby reduce health disparities in groups with a high prevalence of obesity and ESRD.

Keywords

Robotic Surgery; Kidney Transplant; Obesity; Health Disparities

Corresponding Author: José Oberholzer, MD C. & B. Frese and G. Moss Professor of Surgery, Bioengineering, and Endocrinology Chief, Division of Transplantation University of Illinois Hospital & Health Sciences System 840 South Wood Street, CSB Rm 502 (MC 958) Chicago, IL 60612, USA Phone: +1 312 996 6771 Fax: +1 312 413 3483 jober@uic.edu.

Disclosures

The authors of this manuscript have no conflicts of interest to disclose as described by the *American Journal of Transplantation*.

Epidemiological data indicate that 20-50% of patients on dialysis for end-stage renal disease (ESRD) are obese (body mass index [BMI] ≥30 kg/m^2) (1). Obese patients with chronic renal failure have longer wait times until kidney transplantation (2) and inferior patient outcomes (3-7). In the US, for example, patients with a BMI <25 kg/m^2 have a median wait time of 39 months for a deceased donor kidney transplantation as compared to 59 months in patients with a BMI >40 kg/m^2 (2). Higher BMIs in kidney transplant recipients are associated with excess risk of surgical site infections (SSIs), which negatively impact graft survival (8). Obesity is also associated with comorbidities such as diabetes, although data on whether obesity increases mortality in kidney transplanted patients remains unclear (8,9). Provider perceptions of these risks accompanied by the expectation of some centers to give obese patients time to lose weight are the main reasons why a number of transplant centers are reluctant to list obese patients for transplantation (2,10). Unfortunately, many of these obese patients have diabetes and hypertension likely secondary to their obesity (11) and such patients who remain on dialysis have a very high mortality rate. The 5-year mortality rate for diabetic and hypertensive dialysis patients is 75 and 70%, respectively (1).

A recent study demonstrated that obese patients who did not present with any SSIs had the same kidney transplant success rate as patients with a normal BMI (8). If surgical procedures could be developed that prevent SSIs and demonstrate successful outcomes, transplant centers may become less reluctant to list obese patients for kidney transplantation. Although any benefit would still have to be weighed against potential increased risks from obesity-related comorbidities. The prevalence of obesity and ESRD is higher among racial and ethnic minority populations, including African-Americans and Hispanics, compared to Non-Hispanic whites (12-15). These observations suggest developing kidney transplantation options for obese patients with ESRD may also help to reduce health disparities in racial and ethnic minorities.

We therefore developed a new, minimally invasive, robotic-assisted kidney transplantation method using a short epigastric incision. This method avoids any incision in the infection prone lower quadrants of the abdomen. We hypothesized a priori that the robotic approach would reduce SSIs and improve outcomes in obese kidney transplant patients. Herein, we present our experience and outcomes of the patients undergoing minimal invasive, robotic kidney transplantation at a single institution compared to patients who underwent the conventional open procedure.

MATERIALS and METHODS

Patients

From June 2009-December 2011, a prospective cohort of 39 obese patients with ESRD underwent robotic kidney transplantation at the University of Illinois Hospital & Health Sciences System. Twenty-eight of these patients completed a follow-up period of at least six months after transplant. We compared the post-transplant outcomes from these 28 patients with those of a retrospective cohort control group of 28 obese patients undergoing standard open kidney transplantation prior to June 2009 at our institution, also with at least six months of follow-up. They were frequency matched to the robotic surgery group on the following variables, listed in order of priority: BMI (30 kg/m^2 ≤ BMI < 35 kg/m^2 [obese], or BMI ≥35 kg/m^2 [morbidly obese]); race (patient reported Non-Hispanic white, Hispanic, African-American); ABO incompatibility (yes/no); cross-match positivity (yes/no); gender (male/female); age; living/deceased donation; underlying disease; and pre-transplant dialysis (yes/no). Patient characteristics are described in Table 1.

The pre-transplant work up for all patients regardless of surgical procedure followed Center of Medicare and Medicaid Services guidelines. Historically, our institution had never

excluded any patient from transplantation based on body weight if the pre-transplant workup did not show any formal contraindications. However, the average BMI of the control group was significantly lower than the robotic group, since we were not able to find equally obese patients in the control group. The immunological status of the recipient was not used to select patients. Kidney transplantation was offered to presensitized patients, patients undergoing desensitization in the presence of a positive cross-match or ABO incompatibility to their prospective living donors, as well as patients with a history of previous kidney transplantation. The institutional review board at the University of Illinois at Chicago approved this chart review (IRB Protocol 2011-1104).

Surgical Technique

Robotic kidney transplants were performed as previously described (16). Hand-assisted clamping of the iliac artery and vein during the anastomosis, at least during the early case experiences, provided additional safety in case of any vascular accident. However, with increasing experience, robotic vascular clamps for clamping the external iliac vessels were used. All patients were started intraoperatively on intravenous heparin infusion at a standard rate of 300 units/hour and maintained on heparin until discharge. Living donations were performed robotically as previously described (17).

Immunosuppression

Patients who were African-American, re-transplant, cross-match positive, and/or ABO incompatible underwent the high risk protocol consisting of induction with rabbit antithymocyte globulin (ATG), and maintenance immunosuppression by a combination of tacrolimus, mycophenolate mofetil (MMF), and a rapid steroid taper completed by post operative day (POD) 6. In addition, positive crossmatch and ABO incompatible patients underwent a desensitization protocol with plasmapheresis (PP) and intravenous immunoglobulins (IVIg) as previously described (18). In positive cross-match patients, steroids were tapered rapidly to the dose of 10 mg of prednisone by POD 5 and maintained at that dose thereafter. ABO incompatible recipients underwent laparoscopic spleenectomy during the same procedure as previously described (19). Transplant recipients who were Hispanic or Non Hispanic white and negative cross-match underwent the low risk protocol consisting of induction with 20 mg Basiliximab, with the first dose given at the induction of anesthesia and the second on POD 4. Maintenance immunosuppression included a combination of tacrolimus and MMF, and a rapid steroid taper completed by POD 6.

SSI Criteria

The established criteria by the Center for Disease Control and Prevention were used to define SSI. This includes a surgeon diagnosis of infection, a positive fluid culture from the wound, and purulent exudate drainage from the surgical site. The wounds were classified as incisional superficial or incisional deep according to the soft tissue involvement (20).

Statistical Analysis

Means and frequencies were used to describe the patient characteristics. Medical costs were adjusted to 2011 prices (21). As the robotic group (n=28) and control group (n=28) were frequency matched (not pair matched), comparisons between the groups were performed using the Chi-square test for categorical variables, with Yates' correction or Fisher's exact test when appropriate, and the unpaired t-test for continuous variables. The primary outcomes of interest were wound complications and SSIs. Tests were two-tailed and statistical significance was set at $p<0.05$. Statistical analysis was performed by IBM SPSS 19.0 (Armonk, NY) and SAS version 9.2 (Cary, NC).

RESULTS

Patient Characteristics (Table 1)

The majority of the patients were African-American (46.4%) or Hispanic (35.7%), with a mean age of 47.9±10.7 and 49.8±10.8 years for the robotic and control group, respectively (p=0.51). The control group had a significantly lower average BMI than the robotic transplant group (38.1±5.4 kg/m^2 vs. 42.6±7.8 kg/m^2, respectively; p=0.02), but the proportion of patients who were obese/morbidly obese was comparable between the two groups. The leading causes of kidney failure were hypertension, diabetes, or the combination in the robotic (60.7%) and control group (82.1%).

Intra-operative Outcomes (Table 2)

Two of the 28 patients in both groups underwent deceased donor kidney transplantation; the remaining patients had a suitable living donor. The presence of donor vascular anomalies required a vascular reconstruction during the graft bench preparation for two (7.1%) and five (23.8%) patients in the robotic and control group (p=0.12), respectively. There were no significant differences in mean cold and warm ischemia times (robotic group: 2.8 and 47.7 minutes; controls: 2.0 and 49.2 minutes; p≥0.48). Only one control patient required an intraoperative blood transfusion. The majority of patients in both groups received induction and maintenance therapy with thymoglobulin (n=21, 75%) and tacrolimus (n=23, 82.1%).

Post-transplant Outcomes (Table 3)

In the robotic group, one patient required hemodialysis within the first week after transplantation (delayed graft function). Seven patients (25%) in the robotic group underwent kidney biopsy for rejection suspicion as indicated by decreased urine output and an elevation in serum creatinine >25% in the absence of other causes. Considering the intraperitoneal location of the graft in robotic recipients, the kidney biopsies were performed laparoscopically. In one case, the renal allograft was covered by adhesive bands and an open procedure via a small McBurney incision for the biopsy was considered safer. Rejection occurred in seven (25%) and five (17.9%) patients in the robotic and control group, respectively. Acute cellular rejection (ACR) was confirmed in four patients in the robotic group (Banff score 2A [n=1] or 1B [n=3]) and three controls (Banff score 1A [n=1] or undetermined [n=2]) (22). All the patients were treated with a good response. Antibody mediated rejection (AMR) was confirmed in four robotic patients, including one mixed form; and confirmed in two controls.

The creatinine value at discharge was significantly higher in the robotic group (p=0.04), but at six months follow-up creatinine values were similar (1.5±0.4 vs.1.6±0.6 mg/dL; p=0.47). The control group presented wound complications in eight patients (28.6%) compared to one patient in the robotic group (3.6%; p=0.02). The one wound complication in the robotic group was a small subcutaneous hematoma with subsequent superficial wound dehiscence secondary to Coumadin treatment. All eight complications in controls were SSI's classified as incisional-superficial (Table 4); the proportion of SSIs in the controls was significantly higher than the robotic group (0%; p=0.004). Four controls with wound infections were readmitted for initial treatment and the majority continued treatment for infection in an outpatient setting.

The mean total hospital days over six months follow up was 14.3±10.2 in the robotic group and 15.8±17.3 in the control group (p=0.69). Medical complications during the follow up included new onset post-transplant diabetes mellitus (n=3 robotic), pulmonary embolism (n=1 robotic and n=2 controls), and stroke (n=1 robotic and n=1 controls). Six-month readmission rate, reoperation rate, and graft (100%) and patient survival (100%) were

comparable between the two groups. However, hospital costs for the transplant admission (p=0.02) and total hospital costs over the six months following transplant (p=0.04) were significantly higher in the robotic group compared to controls.

DISCUSSION

Since the first case reported by our team (16), the minimally invasive robotic approach to kidney transplantation has been offered to most obese patients with a high risk of wound infection and post-surgical complications. Herein, we present outcomes from the first cohort of fully robotic kidney transplants in obese recipients, aimed at reducing SSIs and improving both graft and patient survival. No SSIs and only one wound complication was observed in this very challenging sample of 28 obese patients. The absence of SSIs in the robotic group was a significant improvement on the rate of SSIs (28.6%) in the control group; the SSI rate in the control group was consistent with previous reports (8). Robotic kidney transplant therefore offers an attractive alternative to dialysis for obese renal failure patients, and may help to reduce health disparities due to ESRD in populations with a higher prevalence of obesity.

Lynch et al. found obesity to be an independent risk factor for SSIs (8), and wound complications have been estimated to range from 20-30% in obese recipients and up to 40% for morbidly obese patients (BMI>40 kg/m^2) (8,23). The higher incidence of wound complications in obese patients has been proposed to be related to greater dead space above the fascia, longer operative times, need for a larger incision, and a higher prevalence of diabetes. In our robotic series, 16 of 28 (57.1%) recipients had a BMI>40 and 32.1% had diabetes prior to transplant. Results of our robotic group are therefore comforting in terms of wound complications and SSI occurrence. However, we did encounter one non-infectious wound complication presenting in the form of a subcutaneous hematoma with subsequent superficial wound dehiscence secondary to Coumadin treatment. Our hypothesis that minimally invasive, robotic kidney transplantation would reduce the risk of wound infections was therefore confirmed. Overall we attribute the achievement of significantly fewer SSIs to replacing the large supra-inguinal incision in a highly colonized area, necessary to access the external iliac vessels in open kidney transplantation, with a 7cm periumbilical incision for insertion of the kidney graft.

Obesity is also related to general post-surgical complications (24). Gore et al. (25) found that BMI impacts early and long term transplant outcomes by increasing the days of hospitalization and the incidence of delayed graft function. In our case series, there was only one patient with delayed graft function in the robotic group, and the minimally invasive approach allowed for early mobilization and rehabilitation of these otherwise rather immobile obese patients. Three recipients in the robotic group had a prolonged hospitalization (over 14 days), compared with four patients in the control group. Readmissions and reoperation rate were also similar between the two groups.

Notable issues that occurred in the other 11 patients not included in the current analysis due to less than 6-months of follow up included one death from fulminant line sepsis on POD 9, after a complication-free surgery and immediate graft function. Another patient with a BMI of 54.5 kg/m^2 developed a median incisional hernia 1.5 months after transplantation and required an abdominoplastic hernia repair. Two of the 39 patients (5.1%) initially started robotically were converted to the standard open procedure. In both cases, conversion to open surgery was indicated by the presence of severe adhesions. One of them developed a wound hematoma that needed drainage and wound healing by secondary intention. Beyond any doubt, this is a very morbid patient population, and the surgery and post-transplant follow-up can be complicated.

There is substantial evidence that obesity is a risk factor for rejection. The analysis performed by Gore et al. (25) found a significant independent association of morbid obesity with increased acute rejection, and decreased overall graft survival. In our series of 28 robotic and control patients, we observed seven cases of biopsy-proven rejection (25%) in the robotic group: three ACR, three AMR, and one mixed ACR+AMR; compared with five cases biopsy-proven rejection (17.9 %) in the control group: three ACR and two AMR. No patient or graft was lost in either the robotic or control groups during follow-up.

There are some issues to consider with regard to the new robotic technology for kidney transplant. First, we observed a significantly lower serum creatinine at discharge in the controls than in the robotic surgery group. The average warm ischemia time was longer in the current analysis of obese patients compared to the average for non-obese patients at our center (30-35 minutes). However, mean warm ischemia time was comparable between the robotic (47.7 minutes) and open (49.2 minutes) techniques and prolonged time likely does not explain the higher discharge creatinine in the robotic group. Therefore, we have to consider a possible influence of prolonged pneumoperitoneum on the early graft function, as previously suggested (26). However, at six months post-robotic transplantation, kidney function was not different from the open group.

Second, the Achilles heel of robotic kidney transplantation is the intraperitoneal location of the graft, which in conjunction with the obesity of patients, potentially increases the risk for complications related to standard ultrasonography-guided percutaneous kidney graft biopsy. For this case series, we chose to perform kidney graft biopsies by laparoscopy, though with increased experience, in the future, many of these patients may undergo percutaneous kidney graft biopsy. This greater barrier to kidney graft biopsy could lead to increased treatment on a presumptive basis, therefore biasing these patients toward better or worse acute rejection outcomes depending on the data considered for the analysis, biopsy reports, or treatments for rejection.

Third, the increased technical complexities of the procedure will also likely limit the initial implementation of the new surgical procedure to select academic centers. However, these centers are often located in highly urban areas with larger minority populations who could benefit from the procedure. After our initial experience standardizing the procedure and eliminating logistical limitations with extensive training of the staff and surgeons, the robotic procedure is now available in our center at all times for both living and cadaveric donors. The primary technical restriction to performing the robotic surgery is extensive peripheral vascular disease in the recipient and significant atherosclerosis in the graft vessels with a cadaveric donor.

Fourth, the medical costs were significantly higher for the robotic surgical technique compared to the open technique. As hospital days and outcomes were comparable, if not better in terms of SSIs, for the robotic group and controls, the higher costs are a function of the robotic surgical system. However, the higher costs will have to be balanced against the cost of keeping obese renal failure patients on dialysis.

The current analysis has some weaknesses. The mean follow-up for the robotic surgery group is one year. However, there is extensive evidence in the literature that 6-month creatinine is predictive of long-term graft survival (27). The control group was also not concurrent to the robotic surgery group. This resulted in a higher BMI in the robotic group compared to controls, as the robotic procedure was performed more recently and was offered to all obese patients after training and standardization allowing more obese patients with ESRD to be transplanted. However, the same group of surgeons and staff were involved in all of the surgeries presented in both groups, with similar protocols for antibiotic

and aseptic management in the operating room and immunosuppressive therapy and patient management after transplant. The incidence of complications in either group did not vary over time indicating the lower incidence of SSIs in the robotic group is likely not due to greater experience over time. The study was not a randomized controlled trial because such a design would be impractical based on the unwillingness of patients to be assigned to a open technique control group after features of both procedures were explained, considering the shorter recovery time and cosmetic appearance with the robotic technique. Further, the inability to blind patients and providers to treatment group would limit comparisons.

From a public health perspective, the question could be raised whether patients should lose weight before undergoing transplantation. The low success rate of medical weight loss has been extensively discussed in the medical literature (28); and randomized trials of bariatric surgery indicate that 12 months following the procedure, approximately 30-65% of excess weight remains (29). Considering the significant 6-month (5-10%), one-year (10-17%), and two-year (18-29%) mortality on dialysis for patients age 20 to 64 years (1), it is evident that these patients face a battle against the clock and simply may not have enough time left to normalize their body weight before kidney transplantation. Pursuing weight loss would increase the pre-transplant mortality for patients presenting with a living donor. In the case of cadaveric donation, pre-transplant weight loss for newly listed patients or patients with little wait time may make sense, and is the strategy at our center and many others. Therefore, with the majority of our patients presenting with a living donor, we chose an approach that would first offer the kidney transplant, and subsequently guide our patients through weight loss and hypertension and diabetes management. In light of evidence that obese patients with no SSIs had the same kidney transplant success rate as patients with a normal BMI (8), weight loss and co-morbidity management after robotic transplant may further improve outcomes. Ongoing follow-up is underway to determine long-term graft and patient survival.

While in most instances the rationale for minimally invasive surgery is based on reduced postoperative discomfort and improved cosmetic appearance, robotic technology in this case allowed surgeons at our center to offer transplantation to a population that has been found to have a greater likelihood of being bypassed for kidney transplantation compared to non-obese patients (2). The robotic technique may also help to reduce health disparities due to ESRD in populations with a higher prevalence of obesity. Now that the robotic technique is consistently used for kidney transplant in obese patients at our center, future research can determine the impact robotic surgery may have on changing wait times, access to transplantation, co-morbidities, quality of life, and survival.

Acknowledgments

There were no sources of funding. The results were previously presented orally (abstract 157) at the American Transplant Congress 2012.

Abbreviations

ESRD	end-stage renal disease
SSI	surgical site infection
ATG	antithymocyte globulin
MMF	mycophenolate mofetil
POD	post-operative day
PP	plasmapheresis

IVIg	intravenous immunoglobulins
ACR	acute cellular rejection
AMR	antibody mediated rejection
SD	standard deviation
FSGS	focal segmental glomerulosclerosis
CAD	coronary artery disease
CVD	cerebrovascular disease
PAV	peripheral arterial disease
CMV	cytomegalovirus

REFERENCES

1. U.S. Renal Data System. USRDS 2011 Annual Data Report: Atlas of Chronic Kidney Disease and End-Stage Renal Disease in the United States. National Institutes of Health; National Institute of Diabetes and Digestive and Kidney Diseases; Bethesda, MD: 2011.
2. Segev DL, Simpkins CE, Thompson RE, Locke JE, Warren DS, Montgomery RA. Obesity impacts access to kidney transplantation. J Am Soc Nephrol. 2008; 19:349–55. [PubMed: 18094366]
3. Modlin CS, Flechner SM, Goormastic M, Goldfarb DA, Papajcik D, Mastroianni B, et al. Should obese patients lose weight before receiving a kidney transplant? Transplantation. 1997; 64:599–604. [PubMed: 9293872]
4. Meier-Kriesche HU, Vaghela M, Thambuganipalle R, Friedman G, Jacobs M, Kaplan B. The effect of body mass index on long-term renal allograft survival. Transplantation. 1999; 68:1294–7. [PubMed: 10573066]
5. Pischon T, Sharma AM. Obesity as a risk factor in renal transplant patients. Nephrol Dial Transplant. 2001; 16:14–7. [PubMed: 11208986]
6. Meier-Kriesche HU, Arndorfer JA, Kaplan B. The impact of body mass index on renal transplant outcomes: a significant independent risk factor for graft failure and patient death. Transplantation. 2002; 73:70–4. [PubMed: 11792981]
7. Meier-Kriesche HU, Kaplan B. Waiting time on dialysis as the strongest modifiable risk factor for renal transplant outcomes: a paired donor kidney analysis. Transplantation. 2002; 74:1377–81. [PubMed: 12451234]
8. Lynch RJ, Ranney DN, Shijie C, Lee DS, Samala N, Englesbe MJ. Obesity, surgical site infection, and outcome following renal transplantation. Ann Surg. 2009; 250:1014–20. [PubMed: 19779327]
9. Aalten J, Christiaans MH, de Fijter H, Hené R, van der Heijde JH, et al. The influence of obesity on short- and long-term graft and patient survival after renal transplantation. Transpl Int. 2006; 19:901–7. [PubMed: 17018125]
10. Pham PT, Pham PA, Pham PC, Parikh S, Danovitch G. Evaluation of adult kidney transplant candidates. Semin Dial. 2010; 23:595–605. [PubMed: 21175834]
11. Sugerman HJ, Wolfe LG, Sica DA, Clore JN. Diabetes and hypertension in severe obesity and effects of gastric bypass-induced weight loss. Ann Surg. 2003; 237:751–8. [PubMed: 12796570]
12. Institute of Medicine. Unequal treatment: confronting racial and ethnic disparities in health care. The National Academies Press; Washington, D.C.: 2002.
13. Coresh J, Selvin E, Stevens LA, Manzi J, Kusek JW, Eggers P, et al. Prevalence of chronic kidney disease in the United States. JAMA. 2007; 298:2038–47. [PubMed: 17986697]
14. Mehrotra R, Kermah D, Fried L, Adler S, Norris K. Racial differences in mortality among those with CKD. J Am Soc Nephrol. 2008; 19:1403–10. [PubMed: 18385428]
15. US Centers for Disease Control. [February 12, 2012] Fact sheet: health disparities in obesity 2011. http://www.cdc.gov/minorityhealth/reports/CHDIR11/FactSheets/Obesity.pdf.

16. Giulianotti P, Gorodner V, Sbrana F, Tzetanov I, Jeon H, Bianco F, et al. Robotic transabdominal kidney transplantation in a morbidly obese patient. Am J Transplant. 2010; 10:1478–82. [PubMed: 20486912]

17. Gorodner V, Horgan S, Galvani C, Manzelli A, Oberholzer J, Sankary H, et al. Routine left robotic-assisted laparoscopic donor nephrectomy is safe and effective regardless of the presence of vascular anomalies. Transpl Intern. 2006; 19:636–40.

18. Thielke JJ, West-Thielke PM, Herren HL, Bareato U, Ommert T, Vidanovic V, et al. Living donor kidney transplantation across positive crossmatch: the University of Illinois at Chicago experience. Transplantation. 2009; 87:268–73. [PubMed: 19155983]

19. Grim SA, Pham T, Thielke J, Sankary H, Oberholzer J, Benedetti E, et al. Infectious complications associated with the use of rituximab for ABO-incompatible and positive cross-match renal transplant recipients. Clin Transplant. 2007; 21:628–32. [PubMed: 17845637]

20. Horan TC, Gaynes RP, Martone WJ, Jarvis WR, Emori TG. CDC definitions of nosocomial surgical site infections, 1992: a modification of CDC definitions of surgical wound infections. Infect Control Hosp Epidemiol. 1992; 13:606–608. [PubMed: 1334988]

21. CPI Inflation Calculator. Bureau of Labor Statistics. United States Department of Labor. Visited October 2012. http://www.bls.gov/data/inflation_calculator.htm

22. Solez K, Colvin RB, Racusen LC, Sis B, Halloran PF, Birk PE, et al. Banff ’05 meeting report: differential diagnosis of chronic allograft injury and elimination of chronic allograft nephropathy (‘CAN’). Am J Transplant. 2007; 7:518–26. [PubMed: 17352710]

23. Marks WH, Florence LS, Chapman PH, Precht AF, Perkinson DT. Morbid obesity is not a contraindication to kidney transplantation. Am J Surg. 2004; 187:635–8. [PubMed: 15135681]

24. Patel S, Cassuto J, Orloff M, Tsoulfas G, Zand M, Kashyap R, et al. Minimizing morbidity of organ donation: analysis of factors for perioperative complications after living-donor nephrectomy in the United States. Transplantation. 2008; 85:561–5. [PubMed: 18347535]

25. Gore JL, Pham PT, Danovitch GM, Wilkinson AH, Rosenthal JT, Lipshutz GS, et al. Obesity and outcome following renal transplantation. Am J Transplant. 2006; 6:357–363. [PubMed: 16426321]

26. London ET, Ho HS, Neuhaus AM, Wolfe BM, Rudich SM, Perez RV. Effect of intravascular volume expansion on renal function during prolonged CO2 pneumoperitoneum. Ann Surg. 2000; 231:195–201. [PubMed: 10674610]

27. First MR. Renal function as a predictor of long-term graft survival in renal transplant patients. Nephrol Dial Transplant. 2003; 18(suppl 1):i3–6. [PubMed: 12738756]

28. Wu T, Gao X, Chen M, vanDan RM. Long-term effectiveness of diet-plus-exercise interventions vs. diet-only interventions for weight loss: a meta-analysis. Obes Rev. 2009; 10:313–23. [PubMed: 19175510]

29. Franco JVA, Ruiz PA, Palermo M, Gagner M. A review of studies comparing three laparoscopic procedures in bariatric surgery: sleeve gastrectomy, roux-en-y gastric bypass and adjustable gastric banding. Obes Surg. 2011; 21:1458–68. [PubMed: 21455833]

Table 1

Robotic Kidney Transplant and Control Patient Characteristics

	Robotic Transplant (n=28)	Controls (n=28)	*P* value
Demographics			
Age (years), mean (SD)	47.9 (10.7)	49.8 (10.8)	0.51
Gender (male), No. (%)	13 (46.4)	11 (39.3)	0.59
Race (African American/Hispanic/White), No. (%)	13/10/5 (46.4/35.7/17.9)	13/10/5 (46.4/35.7/17.9)	
Clinical			
BMI (kg/m^2), mean (SD)	42.6 (7.8)	38.1 (5.4)	0.02
Obese (30≤BMI<35)/Morbidly Obese (BMI≥35), No. (%)	6/22 (21.4/78.6)	6/22 (21.4/78.6)	
Creatinine pre-transplant (mg/dl), mean (SD)	7.6 (3.5)	6.3 (2.5)	0.11
Dialysis, No. (%)	19 (67.9)	20 (71.4)	0.77
Duration on dialysis (months; n=17/17), mean (SD)	32.0 (34.7)	15.6 (11.8)	0.08
Crossmatch positive, No. (%)	7 (25.0)	7 (25.0)	
ABO incompatible, No. (%)	1 (3.6)	1 (3.6)	
Co-morbidities			
CAD, No. (%)	9 (32.1)	9 (32.1)	
CVD, No. (%)	1 (3.6)	4 (14.3)	0.35
PAV, No. (%)	2 (7.1)	4 (14.3)	0.67
Asthma/sleep apnea, No. (%)	5 (17.9)	3 (10.7)	0.71
Congestive heart failure, No. (%)	2 (7.1)	2 (7.1)	
Cause of Kidney Failure			
Diabetes, No. (%)	7 (25.0)	2 (7.1)	0.14
Hypertension, No. (%)	8 (28.6)	11 (39.3)	0.40
Diabetes + Hypertension, No. (%)	2 (7.1)	10 (35.7)	0.009
FSGS, No. (%)	2 (7.1)	1 (3.6)	0.99
Graft failure/re-transplant, No. (%)	2 (7.1)	0	0.49
Lupus nephritis, No. (%)	1 (3.6)	0	0.99
Obstructive uropathy, No. (%)	1 (3.6)	0	0.99
Analgesic nephropathy, No. (%)	1 (3.6)	0	0.99
Wegener's granulomatis, No. (%)	1 (3.6)	0	0.99
Post-infectious crescentic glomerulonephritis, No. (%)	1 (3.6)	0	0.99
Alport's syndrome, No. (%)	0	1 (3.6)	0.99
Hemolytic uremic syndrome, No. (%)	0	1 (3.6)	0.99
Hypertension + nephrotic syndrome, No. (%)	0	1 (3.6)	0.99
Unknown, No. (%)	2 (7.1)	1 (3.6)	0.99

SD, standard deviation; BMI, body mass index; CAD, coronary artery disease; CVD, cerebrovascular disease; PAV, peripheral arterial disease; FSGS, focal segmental glomerulosclerosis

To convert creatinine (mg/dl) to SI units (umol/L), multiply by 88.4

Table 2

Robotic Kidney Transplant and Control Patient Intra-operative Outcomes

	Robotic Transplant (n=28)	Controls (n=28)	*P* value
Surgery			
Cold ischemia time (hours; n=28/18), mean (SD)	2.8 (3.6)	2.0 (4.5)	0.48
Warm ischemia time (minutes; n=28/19), mean (SD)	47.7 (7.8)	49.2 (25.2)	0.77
Blood loss (mls; n=27/20), mean (SD)	110.2 (75.2)	120.8 (102.4)	0.69
Intra-operative blood transfusion, No. (%)	0	1 (3.6)	0.99
Intra-operative vascular complication, No. (%)	0	2 (7.1)	0.49
Induction: Thymoglobulin/Basiliximab/Daclizumab, No. (%)	21/7/0 (75.0/25.0/0)	21/2/5 (75.0/7.1/17.9)	0.02
Maintenance: Tacrolimus/Neoral/Sirolimus/Tacrolimus +Sirolimus/Tacrolimus+MMF, No. (%)	23/3/0/0/2 (82.1/10.7/0/0/7.1)	23/3/1/1/0 (82.1/10.7/3.6/3.6/0)	0.41
Donor			
Living donor, No. (%)	26 (92.9)	26 (92.9)	
Related donor (n=26/26), No. (%)	20 (76.9)	17 (65.4)	0.36
Robotic donor nephrectomy (n=26/26), No. (%)	26 (100)	26 (100)	
Age (years; n=27/26), mean (SD)	32.3 (10.1)	34.3 (11.8)	0.52
Gender (male; n=28/26), No. (%)	16 (57.1)	9 (34.6)	0.10
BMI (kg/m^2; n=20/26), mean (SD)	29.4 (7.1)	30.7 (5.9)	0.52
Vascular anomalies (n=28/21), No. (%)	2 (7.1)	5 (23.8)	0.12

SD, standard deviation; MMF, mycophenolate mofetil; BMI, body mass index

Table 3

Robotic Kidney Transplant and Control Patient 6-month Outcomes

	Robotic Transplant (n=28)	Controls (n=28)	*P* value
Surgical Outcomes			
Delayed graft function, No. (%)	1 (3.6)	0	0.99
Surgical biopsy*, No. (%)	7 (25.0)	0	0.01
Wound complications, No. (%)	1 (3.6)	8 (28.6)	0.02
Wound infections, No. (%)	0	8 (28.6)	0.004
Creatinine at discharge (mg/dl), mean (SD)	2.0 (1.4)	1.4 (0.5)	0.04
Creatinine at 6 months (mg/dl), mean (SD)	1.5 (0.4)	1.6 (0.6)	0.47
Graft survival at 6 months, No. (%)	28 (100)	28 (100)	
Patient survival at 6 months, No. (%)	28 (100)	28 (100)	
Resource Utilization			
Hospital days for transplant, mean (SD)	8.2 (4.5)	8.1 (5.3)	0.98
Total hospital days over 6 months, mean (SD)	14.3 (10.2)	15.8 (17.3)	0.69
Readmission over 6 months, mean (SD)	1.6 (2.0)	1.5 (1.5)	0.82
Reoperation over 6 months, No. (%)	0	1 (3.6)	0.99
Hospital costs for transplant ($; n=28/25), mean (SD)	75,148	60,552	0.02
Total hospital costs over 6 months ($), mean (SD)	86,272	66,487	0.04
Total follow-up (months), mean (SD)	12.0 (6.0)	35.7 (17.2)	<0.001
Co-morbidities			
Incident diabetes mellitus, No. (%)	3 (10.7)	0	0.24
Polyoma virus infection, No. (%)	2 (7.1)	1 (3.6)	0.99
Pulmonary embolism, No. (%)	1 (3.6)	2 (7.1)	0.99
Stroke, No. (%)	1 (3.6)	1 (3.6)	
CMV viremia, No. (%)	1 (3.6)	0	0.99
Fungal pneumonia, No. (%)	1 (3.6)	0	0.99
Septic shock, No. (%)	1 (3.6)	0	0.99
Rejection			
ACR, No. (%)	3 (10.7)	3 (10.7)	
AMR, No. (%)	3 (10.7)	2 (7.1)	0.99
ACR + AMR, No. (%)	1 (3.6)	0 (0)	0.99
Splenectomy, No. (%)	3 (10.7)	0 (0)	0.24

CMV, cytomegalovirus; ACR, acute cellular rejection; AMR, antibody mediated rejection

To convert creatinine (mg/dl) to SI units (umol/L), multiply by 88.4

*Surgical biopsies were performed by laparoscopic technique and one was converted to open procedure by a mini McBurney incision directly over the graft.

Table 4

Control Patient Wound Complication Characteristics (n=8)

SSI, No. (%)	8 (100)
SSI incisional-superficial, No. (%)	8 (100)
Treatment	
Readmission for wound complication, No. (%)	4 (50.0)
Operative intervention, No. (%)	2 (25.0)
Treated as outpatient, No. (%)	7 (87.5)
Wound Healing	
Primary intention, No. (%)	0
Secondary intention, No. (%)	7 (87.5)
Tertiary intention, No. (%)	1 (12.5)

SSI, surgical site infection