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Laparoscopic Living Donor Nephrectomy—Single-Center Initial Experience

Bartosz Małkiewicz [1,*], Dorota Kamińska [2], Maximilian Kobylański [1,*], Małgorzata Łątkowska [1], Wojciech Handzlik [1], Paweł Dębiński [3], Wojciech Krajewski [1], Oktawia Mazanowska [2], Paweł Poznański [2], Mirosław Banasik [2], Dariusz Patrzałek [4], Dariusz Janczak [4], Magdalena Krajewska [2], Romuald Zdrojowy [3] and Tomasz Szydełko [1]

[1] Department of Minimally Invasive and Robotic Urology, University Center of Excellence in Urology, Wroclaw Medical University, 50-566 Wroclaw, Poland
[2] Department of Nephrology and Transplantation Medicine, Wroclaw Medical University, 50-566 Wroclaw, Poland
[3] Department of Urology, University Center of Excellence in Urology, Wroclaw Medical University, 50-566 Wroclaw, Poland
[4] Department of Vascular, General and Transplantation Surgery, Wroclaw Medical University, 50-566 Wroclaw, Poland
* Correspondence: bartosz.malkiewicz@umw.edu.pl (B.M.); maxkobylanski@gmail.com (M.K.); Tel.: +48-506-158-136 (B.M.); +48-502-339-220 (M.K.)

Abstract: (1) Background: Donor nephrectomy for living donor kidney transplantation using minimally invasive techniques is a safe procedure that has been used for more than 20 years with excellent results. The total laparoscopic approach offers decreased postoperative pain, less incisional morbidity, and a shorter recovery time. (2) Methods: We present the results of a series of 43 laparoscopic donor nephrectomies performed in a single center. The procedures were performed in a systematic approach with transperitoneal access using four ports. The main renal artery and vein were ligated using a linear stapler fixed with an alternate triple row of titanium staples. The specimen was extracted in an endoscopic bag through an additional incision. (3) Results: All procedures were performed laparoscopically without conversion to open surgery. The average warm ischemia time was 4.73 min. In all recipients, immediate kidney allograft function was observed. (4) Conclusions: Total laparoscopic living donor nephrectomy is a safe procedure. It was performed successfully in all cases with a short surgical time, low morbidity, and 0% mortality.

Keywords: kidney transplantation; living donor; laparoscopy; warm ischemia time

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1. Introduction

Kidney transplantation is the most effective strategy for improving the survival and quality of life in patients with end-stage renal disease [1]. Living donor nephrectomy is a method that allows reducing the time on a waiting list for kidney transplant and in non-advanced cases to avoid the introduction of dialysis [2]. It is a special procedure as it is performed on healthy patients, unlike the traditional approach. Therefore, the safety and effectiveness of the surgery are crucial. Minimizing the complication rate, reducing the length of stay in hospital, faster recovery, and the return to normal professional activity are key to increase the number of donors for transplantation [3]. Since 1995, when Ratner and his team performed the first laparoscopic living donor nephrectomy (LLDN), this minimally invasive approach has become the standard method of organ retrieval for living donor kidney transplantation. In most centers, it has replaced conventional open donor nephrectomy (ODN) [4]. LLDN compared to ODN is characterized by a lower complication rate, faster convalescence, lower intraoperative blood loss, and a better cosmetic effect [5,6]. The aim of this study is to present an initial series of 43 laparoscopic living donor nephrectomies performed at a single center.

2. Materials and Methods

A prospective study enrolled all the patients undergoing laparoscopic kidney donation at the Department Minimally Invasive and Robotic Urology at the Wrocław Medical University. Patients were qualified according to a detailed protocol. During donor selection, patients underwent laboratory tests and imaging examination (i.e., chest X-ray/high-resolution computed tomography, abdominal ultrasound, abdominal computed axial tomography) [7]. Furthermore, kidney functional tests were performed, including estimated GFR, 24 h urine creatinine clearance, renoscintigraphy, as well as urinalysis [8,9]. Moreover, ECG, ABPM, and echocardiography were performed in all potential donors, together with endoscopic examinations, including gastroscopy and colonoscopy. Patients were consulted by various medical specialists and ultimately qualified by a qualifying board consisting of a nephrologist, a urologist, a transplant surgeon, and a clinical psychologist. All specified tests are presented in Table 1.

Table 1. Living kidney donor qualification protocol.

Laboratory tests	blood morphology coagulation parameters liver tests kidney tests autoimmune diseases tests infectious diseases tests
Imaging examinations	chest X-Ray/HRCT abdominal ultrasound abdominal CAT scan
Kidney functional tests	estimated GFR 24 h urine creatinine clearance renoscintigraphy urinalysis
Kidney structural examination	abdominal ultrasound abdominal CAT scan renoscintigraphy
Endoscopic examinations	gastroscopy colonoscopy (as per local health screening criteria)
Specialized medical consultations	nephrologist urologist ophthalmologist cardiologist transplant surgeon others if necessary
Others	ECG ABPM echocardiography
Psychological assessment	clinical psychologist
Qualifying board	nephrologist urologist transplant surgeon clinical psychologist

Abbreviations: HRCT—high-resolution computed tomography, CAT—computed axial tomography, GFR—glomerular filtration rate, ECG—electrocardiography, ABPM—arterial blood pressure measurement.

The anatomy and number of renal vessels were assessed by high-resolution angiography or 3D computed tomography. In the case of equivalent renal function, the extraction of the left kidney was preferred to minimize the risk of transplant failure (due to the length of the vessels for veno-arterial anastomoses). The laparoscopic nephrectomies were performed by 2 urologists, the first of whom performed 29 procedures and the second 14 procedures.

Patients were positioned on their right side in 45° flexion. In the case of right kidney retrieval, the patient was positioned similarly, but on his/her left side. The procedures were performed by the transperitoneal approach. In order to obtain pneumoperitoneum, a 2 cm Hasson minilaparotomy was performed. The first to be introduced was a 12 mm umbilical trocar, and a pneumothorax was obtained with a pressure of 12 cm H_2O. Three more trocars (two 5 mm and one 12 mm) were placed under the control of 10mm laparoscopic optics. A 5 mm trocar was inserted in the mid-clavicular line halfway between the navel and the xiphoid process. The 12 mm trocar was inserted below the navel, laterally to the edge of the rectus abdominis muscle. The last 5 mm trocar was inserted in the anterior axillary line, under the rib edge. The colon was released in the middle. The ureter was localized and released to the junction with the iliac vessels. Using ultrasound and bipolar energy (Thunderbeat, Olympus, Japan), as well as a bipolar grasper and titanium clips, the kidney was completely dissected from the adipose tissue. A Pfannenstiel cut 5–9 cm long was made. If the patient had previously undergone surgery in the lower abdomen, the incision was made in the line of the scar. The Endo Catch^{TM} bag was inserted through the cut. Next, the ureter was clipped and then cut with scissors. In the next stage, the renal artery was closed with the Multifire Endo TA^{TM} stapler, applying three rows of 30 mm staples, and then, it was cut parallel to the staple line. The renal vein was fit in the same way. The use of a one-sided stapler allows obtaining maximally long graft vessels, which facilitates implantation. If there were small accessory renal arteries, they were closed with titanium clips. The prepared kidney was placed in a pre-inserted Endo Catch^{TM} bag. A 5 mm drain was left in the retroperitoneal space and inserted through the incision of the remaining 5 mm trocar. The trocars were removed and the incisions closed.

We collected data as follows: (1) demographics: age, sex, BMI, ECOG Performance Status, Karnofsky Performance Status; (2) intraoperative: operation time, WIT, drainage time, intraoperative blood loss, number of renal arteries and veins in the retrieved kidneys; (3) post-operative: length of hospital stay, length of follow-up, creatinine at discharge time, creatinine at the last follow-up visit.

3. Results

From 2014 to March 2021, 43 procedures of laparoscopic kidney donation from a living donor were performed. The mean age of the donors was 53 years (range: 32–69 years), and among them, there were 23 females and 20 males. The mean BMI was 26 kg/m^2 (range: 19.4–33.3 kg/m^2); the mean ECOG Performance Status was 0; the mean Karnofsky Performance Status was 100. Laboratory tests were performed preoperatively and on the first postoperative day, including hemoglobin concentration, creatinine levels, and eGFR, which were measured at 14.1 and 12.5 g/dL, 0.92 and 1.35 mg/dL, and 79 and 51 mL/min/1.73 m^2, respectively. Patient demographics and laboratory test results are presented in Table 2.

Table 2. Patient demographics and laboratory test results.

Parameter	**Value**	
Age, mean (range), years	53 (32–69)	
Sex, women/men	23/20	
BMI, mean (range), kg/m^2	26 (19.4–33.3)	
ECOG Performance Status, mean	0	
Karnofsky Performance Status, mean	100	
Laboratory tests	Preoperative	Postoperative (1 day)
Hemoglobin, mean, g/dL	14.1	12.5
Creatinine, mean, mg/dL	0.92	1.35
eGFR *, mean, mL/min/1.73 m^2	79	51

* MDRD formula.

The mean duration of surgery was 154 min with a tendency to shorten during subsequent operations. Among the organs retrieved, 42 were left kidneys, and in one case, a right nephrectomy was performed. All procedures were performed laparoscopically without conversion to open surgery. The average warm ischemia time was 4.73 min. The mean drainage time was 2.81 days. Among the graft vascular anomalies, 2 and 3 renal arteries were present in 12 and 3 patients, respectively. An additional renal vein was found in two donors. In one case, a single vein had a retroaortic variation. Due to the existing anomalies, the essential vascular graft reconstructions were performed in five cases. The peri- and postoperative transfusion rate was 0%. The average blood loss was less than 100 mL. The intraoperative data are presented in Table 3.

Table 3. Intraoperative data.

Parameter	Value
Operation time, mean ± SD, minutes	154 ± 32
WIT *, mean ± SD, minutes	4.73 ± 1.69
Drainage time, mean ± SD, days	2.81 ± 1.66
Intraoperative blood loss, mean, mL	81.40
Left kidneys donated for transplantation (%)	98
Number of renal arteries (%):	
1	65
2	30
3	5
Number of renal veins (%):	
1	95
2	5

* WIT—warm ischemia time.

No ureteral, bowel, or mesenteric injuries occurred. In only one case, the removed kidney was not transplanted due to an intraoperatively diagnosed tumor with a diameter of <1 cm in the distal part of the ureter. A perioperative histopathological examination revealed low-grade urothelial carcinoma. Overall, in three cases, there were complications. Among the intraoperative complications, there was damage to the cisterna chyli, which resulted in lymphorrhea. It was stopped by the use of TachoSil®. Another intraoperative complication was bleeding from the lumbar vein with a 300 mL blood loss. The only postoperative complication was lymphorrhea, which resulted in a prolonged drainage in one of the initial cases. All of the complications occurred in different patients and independently of the progression of the learning curve of the two operators.

The mean length of hospital stay was 4.73 days. The mean follow-up of donors was 2.49 years (range, 0.5–5 years). The mean serum creatinine concentration of donors at the discharge time and at the last follow-up visit was 1.32 mg/dL and 1.26 mg/dL, respectively. Information on the postoperative period is provided in Table 4.

Table 4. Postoperative data.

Parameter	Value
Hospital stay, mean ± SD, days	4.73 ± 1.85
Follow-up, mean (range) ± SD, years	2.49 (0.5–5) ± 1.26
Creatinine at the discharge time, mean, mg/dL	1.32 ± 0.22
Creatinine at the last follow-up visit, mean, mg/dL	1.26 ± 0.21

The learning curve presented in Figure 1 was drawn for both operators. It illustrates the shortening of the time of the procedures along with the acquisition of experience in performing laparoscopic nephrectomy. Complications were classified according to the modified Clavien classification, which is used to assess complications in living kidney donors (modification according to Kocak) [10].

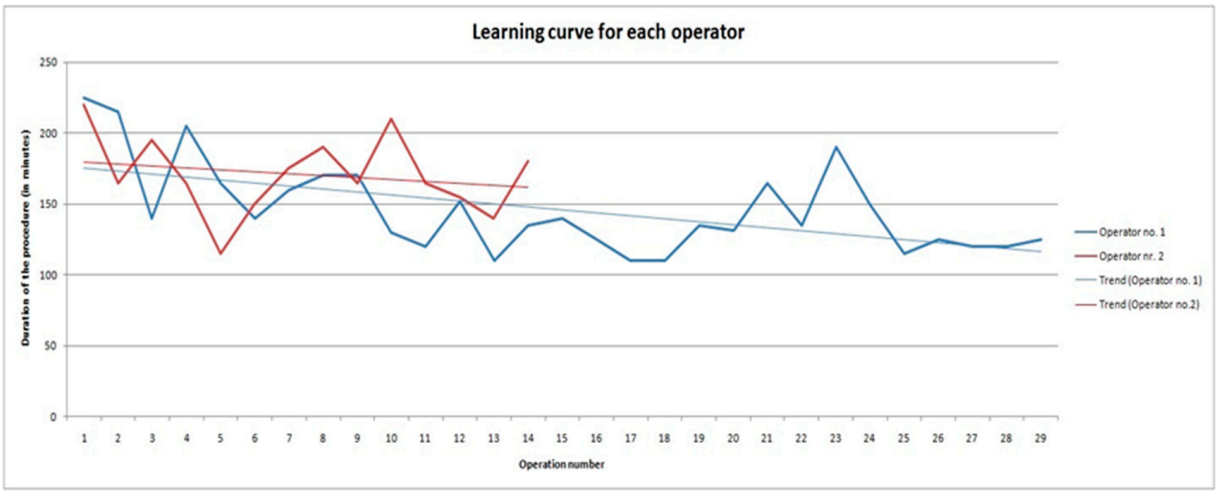

Figure 1. Learning curve for each operator.

Among the donated kidneys, two of them were part of a cross-transplant, which took place in February 2019. The number of procedures in individual years was, respectively: 3 in 2014, 5 in 2015, 7 in 2016, 14 in 2017, 4 in 2018, 7 in 2019, 2 in 2020, and 1 in 2021. In 12-month observations, all 43 grafts were functioning properly, as evidenced in normal levels of the renal parameters.

4. Discussion

The LLDN technique has become the standard procedure for transplanting kidneys from living donors. It is characterized by lower intraoperative blood loss, a lower incidence of complications, faster convalescence, and a better cosmetic effect. The above-mentioned advantages prove the superiority of the minimally invasive technique over the open procedure [11].

Among the surgical methods used to collect a kidney for transplantation, apart from the classic open method (ODN), there are laparoscopic techniques—transperitoneal laparoscopy (LDN), transperitoneal laparoscopy with manual assistance (HALDN), retroperitoneoscopy (RDN), and retroperitoneoscopy with manual assistance (HARDN). In the case of a series of procedures performed in our center, the applied surgical method was transperitoneal laparoscopy, which resulted from the operators' previous experience with this technique. In LDN procedures, the frequency of conversion to ODN procedures ranges from 0–13%, depending on the center [12]. Our operators' extensive experience in laparoscopic kidney surgery enabled all 43 LLDN procedures to be performed without the need for conversion.

The optimal variant for an inexperienced operator in LLDN is left-sided nephrectomy with a single artery and a single renal vein. Laparoscopic right kidney transplantation is a more difficult procedure. In our opinion, this does not result from the need to operate near the liver or inferior vena cava, but from the presence of shorter kidney vessels, which make graft transplantation difficult. However, with the introduction of new techniques for the formation of vascular anastomoses, right-sided LLDN does not constitute a contraindication [13]. In the case of procedures performed in our center, 42 transplants were left kidneys, whereas 1 was a right kidney. When selecting a kidney from a living donor, we were guided by the length of the vessels. Patient enrollment showed that, in all cases, the vessels on the left side were of the same length or longer than those on the right side. Moreover, due to less experience in LLDN procedures and to minimize the risk of transplant failure, the choice of the left kidney was preferred.

The warm ischemia time (WIT) of the transplanted kidney reflects ischemia under normothermic conditions—this is the period from the closure of the renal artery or arteries until the organ is cooled with a perfusion fluid at a temperature of 4–6 °C. Organ ischemia

leads to a rapid depletion of the reserves of high-energy compounds, such as ATP, and changes in cellular metabolism to anaerobic metabolism. Unfavorable biochemical changes accumulate, leading to organ damage, in particular to renal tubular epithelial cells, which may lead to acute noninflammatory renal failure after transplantation (ATN—acute tubular necrosis) [14]. In the event of a prolonged WIT, there is a risk of delayed graft function in the transplanted organ. Therefore, any action that may minimize WIT in LLDN procedures should be taken. The optimal duration of WIT is in the range of 2 to 3 min [15]. The literature reports no effect of WIT <10 min on delaying renal transplant function [16]. In the case of our patients, the average WIT was 4.73 min, and this value did not negatively affect the graft's functioning [17]. We did not observe any correlation between the reduction of the duration of the operation in the course of subsequent laparoscopic procedures and the simultaneous reduction of the duration of the WIT.

As part of the series of procedures performed in our center, we also did not notice any significant, life-threatening intra- and post-operative complications. The intraoperative complications included an accidental incision of the lumbar vein, which resulted in loss of about 300 mL of blood and was effectively treated at the time of detection. In addition, in two cases, there was a partial degloving of the kidney capsule due to dense adhesions of perirenal adipose tissue, which, however, did not affect the functioning of the graft. In one case, an operator damaged the cisterna chyli, which led to intraoperative lymphorrhea, successfully managed with TachoSil®. On the other hand, in the postoperative period, another patient developed lymphorrhea caused by the drain being kept for too long. It was one of the first donors operated on in our center, and drainage was left for 12 days for fear of postoperative lymphorrhea. In retrospect, this period was too long, and the prolonged maintenance of the drain after a few days induced proper lymphorrhea in this patient, which eventually stopped spontaneously.

All of the donated kidneys were implanted in recipients, except in one case. One patient's kidney was laparoscopically collected, but still, intraoperatively, a nodular thickening was found in the distal part of the ureter. Histopathological examination performed after nephrectomy revealed the occurrence of a lesion of the urothelial carcinoma type, which was the reason for abandoning further kidney transplantation, and the donor was informed about this fact and referred for further oncological diagnostics.

The division of laparoscopic procedures in urology, proposed in 2001, based on the degree of their difficulty, shows the challenge of living donor kidney transplantation [18]. The authors of the classification distinguished three criteria—technical difficulty, operative risk, degree of attention—based on which they classified the radical nephrectomy procedure as a difficult procedure (13 out of 21 points) and the nephrectomy procedure in a living donor as a very difficult procedure (16 out of 21 points). In LLDN, the learning curve is higher compared to, e.g., radical nephrectomy. In the early stages of the learning curve, the surgical technique becomes difficult, and the duration of the procedure is extended. Many authors report a longer duration of LLDN treatments than ODN [19]. The procedures that took place in our center were performed by two urologists who specialize in laparoscopic kidney surgery. Therefore, only the first transplants took longer, most likely due to the stressful situation posed by the use of a new surgical technique, especially in living donor patients. Along with the experience gained in this field, the length of operations has shortened, comparable to the time interval described in the literature [20].

Due to the minimally invasive nature of the LLDN technique, as well as the associated lower postoperative pain and shorter recovery time after surgery, a shorter hospital stay (LOS) is expected [21]. The mean LOS for our patients was 4.73 days. Although almost all donors could have been discharged home earlier, our center offers the opportunity to stay longer and remain in touch with transplant recipients.

In a series of 43 kidneys transplanted using the LLDN method, one cross-transplant took place, which was the first kidney cross-transplant performed in our center and the fifth in Poland. Two kidneys were simultaneously collected by laparoscopy and implanted in recipients unrelated to the donors.

Kidney transplants from living donors in Poland are still rare. According to the Poltransplant registry, 52 kidney transplants from living donors were performed in 2019, which, with 907 transplants from deceased donors, constitutes only 5% of the total [22]. This ratio of kidneys retrieved from living donors compared to organs retrieved from deceased donors has not changed significantly in recent years. The number of transplants carried out in our center significantly decreased to 2 in 2020 and 1 by March 2021, probably due to the SARS-CoV-2 pandemic.

5. Conclusions

Laparoscopic living donor kidney transplantation is a safe method, and it is a preferable alternative to the open method. LLDN is effective and successful and can be performed with a relatively short treatment time, a low complication rate, and a zero mortality rate. The standardization in the scope of the procedure performed increases the effectiveness and safety of the procedure, as well as reduces the risk of complications for donors. The encouraging results of our preliminary series on the use of minimally invasive techniques should positively impact the rate of kidney donation in Poland, which is still insufficient as compared to the number of patients on the waiting list.

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