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A comparison of traditional open, minimal-incision donor nephrectomy and laparoscopic donor nephrectomy

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Abstract Laparoscopic donor nephrectomy (LDN) and minimal-incision donor nephrectomy (MILD) are less invasive procedures than the traditional open donor nephrectomy approach (ODN). This study compares donor and recipient outcome following those three different procedures. Sixty consecutive donor nephrectomies were studied ($n = 20$ in each group). Intra-operative variables, analgesic requirements, donor recovery, donor/recipient complications and allograft function were recorded prospectively. Operating and first warm ischaemia times were longer for LDN than for ODN and MILD (232 ± 35 vs 121 ± 24 vs 147 ± 27 min, $P < 0.001$; 4 ± 1 vs 2 ± 2 vs 2 ± 1 min, $P < 0.01$). Post-operative morphine requirements were significantly higher after ODN than after MILD and LDN (182 ± 113 vs 86 ± 48 vs 71 ± 45 mg; $P < 0.0001$). There was no episode of delayed graft function in this study. Donors returned to work quicker after LDN than after ODN and MILD (6 ± 2 vs 11 ± 5 vs 10 ± 7; $P = 0.055$). Donor and recipient complication rates and recipient allograft function were comparable. We concluded that MILD and LDN reduce postoperative pain and allow a faster recovery without compromising recipient outcome.

Keywords Live kidney donor · Nephrectomy · Laparoscopic nephrectomy · Minimal-incision nephrectomy · Open donor nephrectomy

Introduction

Renal transplants from living donors have many advantages. The planned nature of the operation provides an opportunity to optimise the welfare of both donor and recipient and avoids a long waiting time. Live-donor transplants also have the best allograft and patient survival rates [1]. A unique price has to be paid for these advantages, as donor nephrectomy exposes an otherwise healthy individual to the mortality and morbidity risks of major abdominal surgery, entirely for the benefit of someone else.

Traditional open donor nephrectomy is performed via an extraperitoneal loin incision, with resection of part, or all, of the twelfth rib. A variation of this technique is to make a more anterior, subcostal incision, leaving the twelfth rib intact (minimal-incision living-donor nephrectomy). This approach has been associated with less post-operative pain, shorter incision length, and faster recovery than in the traditional open procedure [2].

Laparoscopically assisted donor nephrectomy was introduced into clinical practice in 1995 [3], and this minimally invasive technique, along with the hand-assisted modification, has been associated with less post-operative pain, shorter hospitalisation and faster return to normal activities than in the open technique via a loin incision [4, 5, 6, 7, 8, 9, 10, 11]. The laparoscopic approach may remove some of the disincentives to donation and so increase donation rates [12, 13]. The aim of this study was to compare donor recovery rates and recipient allograft function after open donor nephrectomy with rib resection (ODN), minimal-incision living-donor nephrectomy (MILD), and laparoscopic donor nephrectomy (LDN).

Patients and methods

A consecutive series of 60 patients who underwent live-donor nephrectomy, performed between 1995 and 2002, was studied. The study comprised 20 patients in the ODN group, 20 in the MILD group, and 20 in the LDN group.

Between 1995 and 1998 all donor nephrectomies performed in Leicester were via the traditional open approach, with rib resection. The last 20 operations in this ODN series were compared with the first 20 MILD and LDN procedures performed in the period 1998–2002. The laparoscopic and minimal-incision procedures were introduced at a similar time. Donors were given informed consent on these two procedures and allowed to choose.

The donor work-up protocol included an isotope GFR measurement and either renal digital subtraction angiography (pre-1998) or spiral CT angiography to assess the renal vascular anatomy. The left kidney was removed preferentially, to provide longer vascular pedicles. In the presence of complicated vascular anatomy on the left and normal anatomy on the right, the right kidney was removed.

All donors received 2 l of crystalloid fluid intravenously in the 12 h preceding their nephrectomy to improve renal perfusion during the procedure. Consultant surgeons carried out all donor nephrectomies, and consultant anaesthetists administered the general anaesthetics. The intra-operative central venous pressure was maintained at 8–12 cmH_2O by administration of intravenous crystalloid fluid. Blood loss was assessed by measurement of the content of the suction reservoir and by the weighing of swabs at the end of each operation but was not recorded in the early part of the ODN series. Post-operatively, patients' treatment was managed by a patient-controlled analgesia system (PCAS), which delivered intravenous morphine in 1 mg boluses with a 5 min lock-out period. This was discontinued when it was felt that the patient could be maintained on oral analgesia alone. Patients were allowed to eat and drink when they felt able and were discharged home when comfortable, ambulatory and able to eat solid foods.

At the time of discharge donors were advised to return to normal activities as soon as they felt able. Donors were discharged with a simple diary sheet on which to record when they returned to the following activities: domestic tasks such as caring for the home and shopping; driving; exercising; feeling that they were able to return to work; actual return to work. The donors were reviewed in a dedicated follow-up clinic 6 weeks after discharge from hospital.

The procedures

All the nephrectomy operations in this series were performed by two consultant surgeons working together. ODN was performed via a muscle-cutting flank incision with the patient in the lateral decubitus position and the operating table broken to open the angle between the iliac crest and the costal margin. The twelfth rib was exposed and partially or completely excised, and Gerota's fascia was identified in the extraperitoneal space and dissected away from the kidney. The ureter was identified at the lower pole and dissected distally to the pelvic brim along with the gonadal vein in order to preserve the meso-ureter. The ureter was ligated with an absorbable tie and divided. The renal vein was then dissected free, and its tributaries were identified and divided. The renal artery was dissected back to its origin from the aorta. The artery and vein were clamped and divided to remove the kidney. The renal artery stump was double ligated and oversewn with 5/0 polypropylene. The renal vein stump was oversewn with 5/0 polypropylene. The muscle layers were closed with a continuous 1 nylon suture, and the skin was closed with a sub-cuticular absorbable suture. The incision was infiltrated with 0.25% bupivacaine.

MILD was performed through a muscle-cutting flank incision running from the tip of the twelfth rib towards the umbilicus. The incisions ranged from 10–15 cm in length. The rest of the operation was carried out in the same way as the ODN procedure including the use of wound infiltration with 0.25% bupivacaine. A fixed retraction system (Omnitract, http://www.meddis.co.uk) was used during MILD nephrectomy.

Laparoscopic nephrectomy was performed via a transperitoneal approach, with the patient in a modified lateral decubitus position and a table break to open the space between the iliac crest and the costal margin. A pneumoperitoneum was established by the placing of a Veress needle through the incision for the iliac fossa port and insufflation of the peritoneal cavity with carbon dioxide to a pressure of 10–12 mmHg. Three 12 mm ports were placed in the midline above the umbilicus, two fingerbreadths below the xiphisternum and in the left iliac fossa at the edge of the rectus sheath at the level of the iliac crest. A fourth 5 mm port was inserted in the mid-axillary line, midway between the costal margin and the iliac crest. The umbilical port was used to house the video laparoscope; the epigastric and iliac ports were used for dissection instruments and the 5 mm port was used for retraction.

The colon was mobilised by dissection of the splenic flexure and division of the lateral peritoneal reflection. The left colon was then medialised to expose Gerota's fascia, which was incised to expose the underlying kidney. The ureter was dissected first, care being taken to include the gonadal vein during mobilisation in order to maintain a good margin of peri-ureteric tissue. Initially, the ureteric and gonadal vein dissection was followed cranially, in order to allow clear identification of the junction of the gonadal and renal veins. The ureter was then dissected to the pelvic brim where it was divided with an endovascular stapling device. The renal vein was then dissected free, and its gonadal, lumbar and adrenal tributaries were secured with metal clips and divided. The renal artery was dissected back to its origin from the aorta. The remaining fascial attachments were divided to free the kidney.

The renal artery and vein were divided by an endovascular stapling device, and the kidney was removed via an endocatch retrieval bag (Tyco Healthcare, Gosport, UK) introduced through a short supra-pubic Pfannensteil incision. This incision was closed with a non-absorbable continuous suture to the rectus sheath and a sub-cuticular absorbable suture to the skin. Port sites were closed with interrupted absorbable sutures to the muscle/fascia and non-absorbable interrupted skin sutures. The Pfannensteil and port site incisions were infiltrated with 0.25% bupivacaine at the end of the procedure.

Right laparoscopic donor nephrectomies required a modified approach to secure the renal vein. In these patients ($n=3$), a 6–8 cm transverse incision was made in the right upper quadrant, and the vena cava was controlled with a side-biting vascular clamp. This allowed the full length of the relatively short right renal vein to be removed with a thin cuff of vena cava. The caval defect was closed with a double layer of continuous 5/0 polypropylene sutures. In these patients, the kidney was retrieved directly through the right upper quadrant incision without the use of the endocatch system.

After removal, the kidney was placed in a bowl of iced hyperosmolar citrate solution and then perfused with 500 ml of the same solution cooled to 4°C. The first warm time was recorded as the time between the clamping of the renal artery and the commencement of the flushing with cold preservation solution.

In all donor groups, topical papaverine was applied to the renal artery prior to division, to relieve any vasospasm.

The same consultant surgeon performed all the kidney transplantations. The iliac vessels were approached extraperitoneally through a muscle-cutting incision in the iliac fossa. The renal vein was anastomosed end-to-side to the external iliac vein with continuous 5/0 polypropylene sutures, and the artery was anastomosed end-to-end to the divided internal iliac artery with interrupted 6/0 polypropylene. In those cases with multiple arteries, suitable branches of the internal iliac artery were utilised for anastomosis. The spatulate end of the ureter was anastomosed to the bladder as an extravesical onlay over a 4.8 French, double J stent.

Donor follow-up

All donors are seen 6 weeks after surgery and yearly thereafter. Follow-up comprises clinical examination, urinalysis for proteinuria and blood pressure and serum creatinine measurement.

Data analysis

The data are presented as raw numbers or as a group mean ± SD. Continuous data were analysed by one-way analysis of variance (ANOVA). Where significant differences were demonstrated between the three groups, post-tests were performed with the Tukey–Kramer multiple comparisons test. Categorical data were analysed by χ^2 test or Fisher's exact test.

Results

Donor characteristics

Donor characteristics are shown in Table 1. There were no significant differences in donor age, gender, weight or side of nephrectomy between the three groups.

Intra-operative variables

Table 2 displays the intra-operative variables. The operating time for the laparoscopic approach was significantly longer than that of the other two groups. The first warm-ischaemia time was significantly longer in the laparoscopic group but was limited to a mean of only 4 min compared with 2 min in both open groups. Intraoperative blood loss was higher for ODN but this did not reach statistical significance.

Table 1 Demographic distribution of donors. Values are means ± SD

Characteristic	ODN	MILD	LDN	P Value
Age (years)	45 ± 10	43 ± 10	43 ± 13	0.798
Female/male	14/6	12/8	11/9	0.610
Weight (kg)	68 ± 10	73 ± 11	71 ± 13	0.488
Left/right kidney	17/3	15/5	17/3	0.641

Table 2 Intra-operative variables. Values are means ± SD

Variable	ODN	MILD	LDN
Operating time (min)	121 ± 24	147 ± 27	232 ± 35[a]
First warm-ischaemia time (min)	2 ± 2	2 ± 1	4 ± 1[a]
Blood loss (ml)	842 ± 1439	260 ± 195	340 ± 185

[a] $P < 0.001$ vs ODN and MILD

Hospital recovery and analgesia

Hospital recovery and analgesia are depicted in Table 3. There was no significant difference between groups in time taken to oral fluids, but the time taken to recommence solid food was significantly longer in the ODN group. In-patient stay was significantly shorter in the LDN group (4.4 ± 1.8 days) than in both the ODN (6.6 ± 1.6 days) and the MILD (6 ± 1.1 days) groups. Postoperative intravenous morphine requirements were twice as high after ODN than after both MILD and LDN. The duration of use of the PCA system was significantly shorter in the LDN group than in both the open groups.

Outpatient recovery

Table 4 shows outpatient recovery. Twelve patients were not employed and, therefore, did not give values for actual return to work. Seven did not drive, and six did not participate in any regular exercise. Two male donors did not participate in domestic tasks at home. LDN was associated with a quicker return to normal activities than was ODN. Donors in the laparoscopic group returned to work and started driving, performing domestic tasks in the home and exercising earlier than donors in the ODN group. When compared with the MILD group, LDN patients started driving and exercising and returned to work more quickly.

Table 3 Donor in-patient recovery. Values are means ± SD

Variable	ODN	MILD	LDN
Time to oral fluids (days)	1 ± 0.4	1 ± 0	1 ± 0.2
Time to food (days)	3.5 ± 1.5[a]	2.3 ± 1	2.4 ± 0.8
In-patient stay (days)	6.6 ± 1.6	6 ± 1.1[c]	4.4 ± 1.8[d]
Total morphine (mg)	182 ± 113	86 ± 48[b]	71 ± 45[d]
Duration of PCA (h)	55 ± 18	53 ± 14	41 ± 12[e]

[a] $P < 0.05$ compared with MILD and LDN
[b] $P < 0.01$ compared with ODN
[c] $P < 0.01$ compared with LDN
[d] $P < 0.001$ compared with ODN
[e] $P < 0.05$ compared with ODN and MILD

Table 4 Donor outpatient recovery. Values shown are means ± SD

Activity (weeks)	ODN	MILD	LDN
Felt able to return to work	12 ± 8	7 ± 6	5 ± 2[a]
Actual return to work	11 ± 5	10 ± 7	6 ± 2
Driving	5 ± 4	4 ± 1	2 ± 1[a]
Domestic tasks	4 ± 3	2 ± 1[b]	2 ± 1
Exercise	13 ± 14	5 ± 2	4 ± 1[b]

[a] $P < 0.01$ compared with ODN
[b] $P < 0.05$ compared with ODN

Donor complications

There were no significant differences in the overall rate of donor complications following the three different operations. Eight complications occurred in the LDN group: unilateral pulmonary oedema in the dependant lung ($n = 2$); chest infection ($n = 2$); post-operative ileus; renal bed collection (treated conservatively); adhesional pain; and urinary retention. None of the laparoscopic procedures required conversion to an open operation. There was a total of seven complications in the ODN group: haemorrhage from the ovarian vein, which required emergency laparotomy and blood transfusion; wound pain secondary to a suture granuloma; hypertension; persistently raised serum creatinine; proteinuria; wound "bulge". Seven complications occurred in the MILD group: post-operative anaemia that required blood transfusion; chest infection (n = 2); persistently raised serum creatinine ($n = 2$); prolonged wound pain; wound "bulge".

Recipient complications

There were no significant differences in the overall recipient complication rate. One transplant from the LDN group was poorly perfused on clamp release due to a dissection of the transplant artery. The kidney was explanted and flushed with cold hyperosmolar citrate solution. The dissected segment of renal artery was then excised and reconstructed with a saphenous vein graft. The transplant functioned immediately, and the serum creatinine fell to the normal range on the fourth postoperative day. There were no other early vascular complications in the series. Two patients subsequently developed transplant renal artery stenosis and required percutaneous transluminal angioplasty with stenting. These were both short peri-anastomotic stenoses that occurred after MILD and LDN.

To date, three ureteric stenoses have occurred (5%), two following LDN and one following MILD. The first case after LDN was thought to be secondary to an episode of vascular rejection treated by ATG. The whole length of the ureter was found to be markedly strictured

9 weeks after this early rejection episode. This was initially treated by anastomosis of the ipsilateral native ureter to the donor renal pelvis, but this anastomosis leaked due to necrosis of the renal pelvis and a Boari flap reconstruction was then performed. Further stricturing occurred 3 months later, and the patient's condition has subsequently been managed with a percutaneous nephrostomy for a total of 44 months. The second case after LDN developed 4 weeks post-transplantation in a patient with an ileal conduit. The stenosis developed at the ureter–conduit anastomosis and was very localised. This was successfully treated by balloon ureteroplasty. The two cases that occurred in the LDN series led to a change in the laparoscopic technique for harvesting the ureter. This entailed a wider excision margin, with the gonadal vein's being taken en-bloc. Since this modification, no further ureteric complications have occurred in LDN recipients.

The third case, a long, distal, ureteric stricture, occurred 3 months after transplantation of a kidney removed by MILD nephrectomy. We treated this by performing a uretero-ureretostomy between the native and transplant ureters.

Early graft function

There were no episodes of primary non-function or delayed graft function in this series. Recipient serum creatinine values were higher after LDN than after both MILD and ODN, but there were no statistically significant differences between the three groups at any time point up to 1 year post-transplantation (Fig. 1).

Allograft rejection

Overall and steroid-resistant rejection rates are displayed in Table 5. The high rate of steroid-resistant rejection in laparoscopically derived kidneys is likely to be due to the greater number of poorly matched HLA-DR pairs in this group.

Graft losses

One recipient in the laparoscopic group underwent a laparotomy for small-bowel perforation 5 days post-transplantation. This was followed by a period of anuria secondary to severe acute tubular necrosis, and the transplant developed accelerated chronic allograft nephropathy (CAN) leading to graft loss 6 months later. Five further graft losses have now occurred (two after LDN, two after MILD, one after ODN). The earliest of these was at 21 months secondary to recurrent focal segmental glomerulosclerosis; the latest was at 68 months secondary to CAN. The other causes of graft failure were: recurrent IgA nephropathy; accelerated CAN secondary to polyoma virus; CAN following an early acute rejection episode treated with ATG and OKT3.

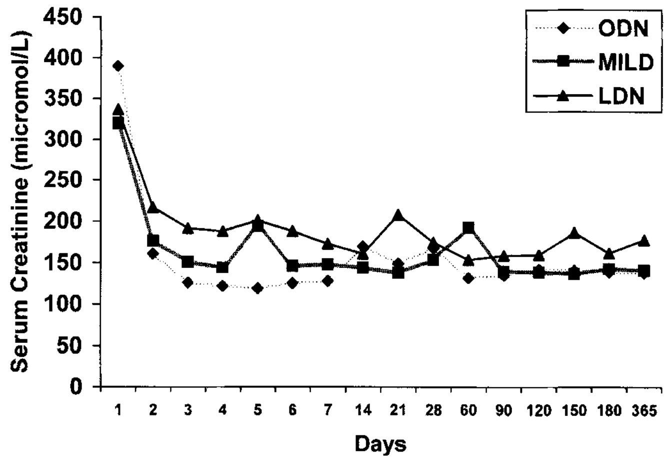

Fig. 1 Comparison of allograft function between groups over the first 12 months post-transplantation

Discussion

This is the first study to compare donor recovery and recipient outcome after LDN and two different open nephrectomy procedures. Laparoscopic donor nephrectomy has several advantages when compared with traditional open nephrectomy with rib resection. LDN patients required less postoperative analgesia, were discharged from hospital earlier and returned to normal activities, including employment, more quickly. The laparoscopic approach also had advantages over minimal-incision donor nephrectomy, including earlier discharge from hospital and quicker return to work. Donors who underwent MILD required less postoperative analgesia and a shorter in-patient stay than the ODN group.

The laparoscopic procedure had a number of disadvantages. The mean operation time for LDN was nearly 4 h, compared with less than 2.5 h for both ODN and MILD. The first warm-ischaemia time was also longer for LDN than for the open operations, although this did not have any adverse consequences in terms of early allograft function. Concerns remain about the effect of the longer warm-ischaemia time in laparoscopic donors;

Table 5 Rejection rates

Parameter	ODN	MILD	LDN	*P*
Rejection (yes/no)	11/9 (55%)	12/8 (60%)	13/7 (65%)	0.81
Steroid-resistant (yes/no)	9/2 (18%)	1/10 (10%)	6/7 (46%)	0.09

a deleterious effect of warm ischaemia on renal function might have been observed if patient numbers had been greater.

The overall complication rates of the three types of nephrectomy were not significantly different, but there were differences in the types of complications occurring. There were no conversions in the LDN series and no requirement for blood transfusion. The two cases of unilateral pulmonary oedema were thought to have been related to the per-operative administration of several litres of intravenous crystalloid fluid. This initial protocol was developed in an attempt to maintain adequate renal perfusion in the face of a prolonged pneumoperitoneum held at 15 mmHg but has now been abandoned in favour of a less aggressive fluid regimen. One patient in each group suffered a postoperative haemorrhage. The episode following LDN was a small collection in the renal bed, which was treated conservatively. In the ODN and MILD groups the single episodes of bleeding were more serious and required an emergency laparotomy with blood transfusion, and a blood transfusion alone, respectively. After both of the open operations one patient developed evidence of wound herniation, manifested as significant bulging of the wound. Whilst this complication was not seen following LDN, one patient in this group was admitted with abdominal pain ascribed to adhesions.

An important advantage of this study is that all the data, including information relating to recovery, were collected prospectively. The series describes the natural development of the local live-donor programme, and there was no selection of donors for LDN in accord with such criteria as weight and body habitus.

The main limitation of this study is that it was nonrandomised. In addition, the indices of donor recovery used were subjective and were difficult to interpret, as so many factors, including the attitudes of the donors themselves and their hospital and family doctors, affected them. The time taken to return to work showed considerable variability and was likely to have been influenced by the type of work done (sedentary or manual; self employed or not) as well as the personality type of the donor and the attitudes and policies of their employers. Donors were asked to record when they felt able to return to full-time work, as well as their actual return to work, in an attempt for us to take account of some of these influences. After LDN, donors returned to full-time employment in a mean time of 6 weeks, and it is striking that this is comparable to the recovery from laparoscopic cholecystectomy [14].

The findings of the present study are in broad agreement with other published studies that compare LDN with open nephrectomy [4, 5, 6, 7, 8, 9, 10, 11]. These all show that LDN led to significantly reduced postoperative pain and quicker donor recovery rates. The main weakness of all these studies is that the comparative open nephrectomy control groups were historical and some of the donor recovery data was collected in retrospect. The findings relating to the comparison of MILD and ODN are also in agreement with the paper by Yang et al. [2], who demonstrated no difference in operating time or in-patient stay but a shorter duration of narcotic use in the MILD group.

LDN requires advanced laparoscopic skills and has not yet been introduced widely into surgical practice in the UK [15]. Modification of the technique to include a device that allows a hand to be introduced into the abdomen (hand-assisted or "handoscopy") may widen the applicability of LDN. The only published randomised, controlled, trial compares the hand-assisted laparoscopic technique with an open flank incision without rib resection [10]. The hand-assisted approach was associated with less post-operative pain, shorter in-patient stay and a quicker recovery time. This procedure is a distinct entity from the laparoscopic assisted approach, and further studies are required to compare laparoscopic nephrectomy, minimal-incision donor nephrectomy, and hand-assisted laparoscopic nephrectomy, as all three appear to have advantages over the standard open donor nephrectomy with rib resection [2, 4, 5, 6, 7, 8, 9, 10, 11].

There has been some concern that LDN leads to a higher urological complication rate in the subsequent recipient transplant [16, 17]. The transplant ureter is particularly susceptible to ischaemic injury, as its sole blood supply is the ureteric branch of the renal artery, which can easily be damaged during the donor operation. This may be particularly the case in the laparoscopic procedure, and it has been suggested that the risk of vascular injury to the ureter is reduced if the gonadal vein and the ureter are mobilised together to provide a generous margin of peri-ureteric tissue [16, 17].

LDN will not prove to be an advance if it simply transfers morbidity from the donor to the recipient. Its success must, therefore, also be gauged by the results of the subsequent transplant. Some studies have shown that LDN leads to a slower fall in recipient serum creatinine than to that in ODN transplants [18, 19]. This has been attributed to a longer first warm-ischaemia time and a fall in donor intraoperative renal blood flow and urine output secondary to a prolonged pneumoperitoneum [20]. All 60 live-donor renal transplants in this series demonstrated initial graft function, and there were no statistically significant differences in post-transplantation renal function following the three nephrectomy techniques used in this series.

This study suggests that laparoscopic donor nephrectomy is safe for the donor and does not significantly increase morbidity in the recipient. The benefits of LDN include reduced post-operative pain and shorter in-patient stay and recovery times. Open donor nephrectomy, performed through a limited incision and without rib resection (MILD), also confers significant advantages on the donor when compared with open nephrectomy with rib resection and merits further investigation alongside the developing laparoscopic procedures.

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