ORIGINAL ARTICLE

Living kidney donation: a comparison of laparoscopic and conventional open operations

J R Waller, A L Hiley, E J Mullin, P S Veitch, M L Nicholson

Postgrad Med J 2002;**78**:153–157

Laparoscopic donor nephrectomy has the potential to lessen the burden placed on live kidney donors. This study describes the first British comparison of donor morbidity and recovery following conventional open donor nephrectomy (ODN) and laparoscopic donor nephrectomy (LDN).

An initial series of LDN (n=20) was compared to a historical control group of ODN (n=34). Laparoscopic operations were performed via a transperitoneal approach, the kidney being removed through a 6–12 cm Pfannensteil incision. Open operations were performed using a retroperitoneal flank approach with resection of the 12th rib. Postoperatively, donors were managed with a patient controlled analgesia system.

LDN was associated with shorter mean (SD) inpatient stay (6 (2) *v* 4 (1) days; p=0.0001) and lower parenteral narcotic requirements (morphine 179 (108) *v* 67 (54) mg; p=0.0001). Laparoscopic donors started driving their cars sooner (2 (1.5) *v* 6 (4) weeks; p=0.0001) and returned to work more quickly (5 (3) *v* 12 (6) weeks; p=0.0001) than open nephrectomy donors. There were no differences in recipient serum creatinine levels at three months post-transplant but two recipients of transplant kidneys retrieved laparoscopically (10%) developed ureteric obstruction, whereas this complication did not occur after ODN (p=0.13).

LDN is associated with less postoperative pain and a substantial improvement in donor recovery times. It is not yet clear whether or not the outcome of the recipient kidney transplants are the same after ODN and LDN and much more experience is required before the place of this new technique can be defined.

See end of article for authors' affiliations

Correspondence to: Professor M L Nicholson, University Division of Transplant Surgery, Leicester General Hospital NHS Trust, Gwendolen Road, Leicester LE5 4PW, UK; mln2@le.ac.uk

Submitted 25 July 2001
Accepted 1 October 2001

Kidney transplantation is widely accepted as the best form of renal replacement therapy, but has always been restricted by a shortage of suitable cadaveric organs. One response to this problem has been to increase transplantation using living donors, and in the last five years in the UK and Ireland the proportion of kidney transplants from live donors approximately doubled from 8% to 15% (UK Transplant Support Services Authority statistics). Live donors yield kidneys of the highest quality and it is not surprising that this type of kidney transplantation yields the best allograft survival results.[1] The price of this success is paid by the donor who must undergo a major surgical operation entirely for the benefit of another individual, albeit a loved one who has a debilitating chronic illness.

The traditional open approach for donor nephrectomy is through an extraperitoneal flank incision with or without resection of the twelfth rib. This leaves a significant wound, which may lead to a relatively prolonged recovery period.[2] There is no doubt that this represents a considerable disincentive to potential donors, particularly those who are in employment and have a young family to care for. Recent developments in minimal access surgery have meant that it is now possible to perform laparoscopically assisted donor nephrectomy[3] and it has been suggested that this technique will make living kidney donation a more attractive option. The first laparoscopic live donor nephrectomy in the UK was performed in Leicester in September 1998. The aims of this study were to compare the donor postoperative recovery rates and the initial outcome of the recipient transplant after conventional open and laparoscopic live donor nephrectomy.

PATIENTS AND METHODS

During the period 1994–2000, 54 live donor nephrectomies were performed at Leicester General Hospital. Between January 1994 and August 1998, kidneys were retrieved from live donors via a conventional open retroperitoneal flank approach that included resection of part of the 12th rib (open donor nephrectomy (ODN), n=34). The results of these open operations were compared to a consecutive series of 20 laparoscopic donor nephrectomies (LDNs) performed between September 1998 and December 2000. Data were obtained from a prospective computerised database, a retrospective review of the case notes, and telephone interviews carried out by the same interviewer. In the initial series of donors undergoing open nephrectomy, the renal vascular anatomy was assessed by digital subtraction angiography. From September 1998 this investigation was replaced by spiral computed tomographic angiography with three dimensional reconstruction of the arterial and venous anatomy.[4]

All the donors in this series were given a patient controlled analgesia system (PCAS) delivering 1 mg bolus doses of morphine with a lock-out period of five minutes. The PCAS was discontinued when the patient felt able to be managed by oral analgesics. Patients were asked to score their pain on an hourly basis using the following system: 0 no pain at rest and none on movement; 1 no pain at rest, slight pain on movement; 2 no pain at rest, moderate pain on movement; 3 some pain at rest, moderate pain on movement; 4 continuous pain at rest and severe pain on movement. The total time that the PCAS was in place was recorded in hours and the mean pain score was calculated by adding individual scores and dividing by the total number of observations.

Abbreviations: LDN, laparoscopic donor nephrectomy; ODN, open donor nephrectomy; PCAS, patient controlled analgesia system

Laparoscopic operative technique

The operation was performed under general anaesthesia with the patient placed in a modified lateral decubitus position with a break in the table to open up the angle between the costal margin and the iliac crest. Three 12 mm and one 5 mm laparoscopic ports were introduced into the peritoneal cavity. The first 12 mm cannula was placed in the lower quadrant of the abdomen at the edge of the rectus sheath and level with the anterior superior iliac spine. The second and third 12 mm cannulas were placed in the midline above or below the umbilicus and two fingerbreadths below the xiphoid. The fourth 5 mm cannula was inserted after the colon had been mobilised and was placed midway between the costal margin and the iliac crest in the mid-axillary line. A pneumoperitoneum was established by placing a Veress needle in the incision for the iliac fossa port and insufflating the abdomen with carbon dioxide at a pressure of 15 mm Hg (2.0 kPa). A video laparoscope was introduced through the umbilical port and the epigastric and iliac fossa ports were used for the main dissecting instruments.

The operation began with mobilisation of the colon by incising the lateral peritoneal reflection from the splenic flexure to the pelvic inlet. The kidney was then exposed by opening the envelope of Gerota's fascia medially. The upper pole of the kidney was usually dissected first, leaving the lateral and inferior renal attachments in place to prevent the kidney from twisting on its pedicle. The ureter was then identified below the lower pole and the mesoureter preserved by identifying the gonadal vessels and including these in the mobilisation. This dissection was extended caudally to the iliac vessels at the pelvic inlet, where the distal end of the ureter was isolated, secured with an absorbable clip and divided; in the latter half of the series of LDN the ureter was divided using a vascular stapler.[5] The renal vein was then identified and its gonadal, lumbar, and adrenal tributaries were divided between metal clips. The renal artery was usually approached along its inferior margin with superior retraction of the renal vein. The artery was always carefully dissected to its origin from the aorta and topical papaverine was applied to relieve any vasospasm. The remaining posterior and lateral attachments to Gerota's fascia were then divided using diathermy scissors to completely free the kidney apart from its vascular pedicle.

A 6–12 cm Pfannensteil incision was made just above the pubis to expose the peritoneum, which was incised to allow introduction of an endocatch retrieval bag. The kidney was manoeuvred into the bag and the renal vessels were then divided. The renal artery was either transected using an endovascular stapling device or triple clipped flush with the aorta and divided distally with scissors. In two cases the donor kidney had two arteries and these were secured and divided sequentially. The renal vein was always divided using an endovascular stapler placed either proximal to the adrenal vein stump or between the gonadal and adrenal vein stumps. The retrieval bag with contained kidney was removed through the Pfannensteil incision. The kidney was placed in a bowl of iced preservation fluid and following excision of the venous staple line was flushed with 500 ml of preservation fluid held at 4°C. The Pfannensteil incision was closed with a non-absorbable suture and the pneumoperitoneum was re-established so that the stumps of the renal vessels and the whole renal bed could be checked for haemostasis. For right sided laparoscopic nephrectomy (n=2) a 6 cm transverse muscle cutting incision was made in the right upper quadrant. This allowed control of the vena cava with a partially occluding vascular clamp so that the full length of the relatively short right renal vein was available. This approach also allowed for direct removal of the kidney without the need for a retrieval bag.

Donors were hydrated preoperatively by the intravenous administration of 1–2 litres of crystalloid solution. In addition, an internal jugular venous catheter was placed after the induction of anaesthesia in order to monitor intraoperative central venous pressure and to maintain this in the range 8–12 cm H_2O. The renal vein was inspected intermittently as an indirect measure of renal perfusion and relatively large volumes of crystalloid (3–6 litres) were administered to make sure that the renal vein remained well filled throughout the laparoscopic dissection. A diuresis was also stimulated immediately prior to division of the renal vessels and kidney retrieval by the administration of mannitol 0.5 g/kg intravenously. Donors received subcutaneous heparin preoperatively but systemic anticoagulation was not employed before clamping the renal vessels.

Table 1 Donor characteristics

	ODN (n=34)	LDN (n=20)
Sex (M:F)	12:22	8:12
Age (years)	44 (9)	44 (13)
Range	25–62	24–68
Weight (kg)	69 (12)	68 (13)
Range	45–92	56–90
Side of nephrectomy (L:R)	28:6	18:2

Values are raw numbers or mean (SD).

Kidneys were transplanted retroperitoneally into an iliac fossa. The renal vein was anastomosed end to side to the external iliac vein and the renal artery end to end to the divided internal iliac artery. In cases where dual renal arteries were present, the internal iliac artery was dissected beyond its bifurcation and the arteries were then anastomosed to suitably sized branches of this vessel. The ureter was anastomosed to the bladder as an extravesical onlay over a double J stent.

Data are presented as a group mean with the standard deviation and range. Differences between groups were evaluated by the Student's *t* test or the Mann-Whitney U test for continuous variables and Fisher's exact test for categorical variables. All tests were two tailed and statistical significance was taken as $p<0.05$.

RESULTS

Donor characteristics and complications

A comparison of donor characteristics is shown in table 1. In the LDN group, 18 left and two right nephrectomies were performed. All 20 LDNs were completed successfully and there was no requirement for conversion to the open operation or blood transfusion. Only one intraoperative technical problem was encountered in this initial series of LDNs. This occurred during division of a renal artery that had an early bifurcation into two equally sized branches. The endovascular stapler was used in this case and because this instrument has a diameter of 8 mm, the vast majority of the length of the main renal artery was taken up during application of the stapler. Transection of the artery left very little common trunk for anastomosis to the recipient internal iliac artery. A segment of recipient saphenous vein graft was therefore used to lengthen the donor renal artery before transplantation into the recipient.

There was no mortality in either group but two patients in each group suffered significant complications. In the ODN group, one donor required reoperation on the first postoperative evening for a reactionary haemorrhage that was found to be due to slippage of a ligature from the gonadal tributary of the left renal vein. Another open nephrectomy patient suffered a large left sided pneumothorax, which required the placement of an intercostal chest drain for a period of two days. Two patients in the LDN group had poor oxygen saturations in the immediate postoperative period and chest radiographs demonstrated unilateral pulmonary congestion. In both cases the LDN procedure had lasted for more than

Table 2 Postoperative analgesic requirements

	ODN (n=34)	LDN (n=20)	p Value
Total dose of morphine (mg)	179 (108)	67 (54)	0.0001
Range	41–384	3–190	
PCAS score (hourly mean)	1.7 (0.6)	1.1 (0.6)	0.0008
Range	0.6–2.67	0.1–2.0	
Total duration of PCAS (hours)	64 (18)	40 (13)	0.0001
Range	36–113	12–56	

Values are mean (SD).

Table 3 Donor postoperative recovery

	ODN (n=34)	LDN (n=20)	p Value
Actual return to work (weeks)	12 (6)	5 (3)	0.0001
Range	2–24	2–8	
Driving a car (weeks)	6 (4)	2 (1.5)	0.0001
Range	1–16	1–6	
Shopping (weeks)	5 (3)	2 (1.5)	0.0001
Range	1–14	1–6	
Exercising (weeks)	11 (7)	4 (2)	0.0001
Range	2–26	2–8	

Values are mean (SD).

three hours and the affected lung was the one which had been most dependent during the operation.

Intraoperative variables

The mean time spent in the operating theatre was approximately 60 minutes longer for LDN compared with ODN (215 *v* 155 min). The mean time between application of the arterial vascular clamp (or stapler) and the start of kidney cooling (the first warm time) was less than two minutes in the ODN group and nearly five minutes in the LDN group ($p<0.0001$).

Postoperative recovery (tables 2 and 3)

There were no differences in the time to resumption of oral fluids, but patients in the LDN group resumed a solid diet approximately one day earlier. The mean (SD) duration of inpatient stay was significantly shorter after LDN (4.1 (1.0) *v* 6.0 (1.8) days; $p=0.0006$). Two patients in the LDN group were discharged home on the second postoperative day, compared with a shortest stay of four days after ODN. Parenteral analgesic requirements, pain scores, and total duration of PCAS use were all significantly lower after LDN (table 2).

LDN was associated with a quicker return to normal activities (table 3). Donors undergoing the laparoscopic procedure returned to work and started driving, shopping, and exercising earlier than donors undergoing the conventional open operation. For each of these parameters the recovery period was shortened by at least 50% after laparoscopic surgery.

Two patients suffered long term incisional pain after ODN and were referred to the pain clinic. This complication was not seen after LDN. There was no significant difference in the six week postnephrectomy serum creatinine in the donors undergoing ODN (96 (18) μmol/l) and LDN (102 (15) μmol/l) groups.

Recipient allograft results

One transplant performed after ODN was complicated by primary non-function due to an on-table arterial thrombosis which occurred 15 minutes after revascularisation. The recipient had very severe atheroma of the iliac arteries and the sudden arterial occlusion was thought to be due to embolism of an atheromatous plaque. The kidney was initially revascularised successfully but the recipient suffered a cardiorespiratory arrest on the third postoperative day. Although the patient was successfully resuscitated the transplant kidney was found to be thrombosed. Delayed graft function requiring a period of dialysis occurred in a further two transplants performed after ODN (2/34, 6%). There was no primary non-function in transplants from LDN and the transplant which required reconstruction of the renal artery using a reversed saphenous vein graft yielded a serum creatinine of 165 μmol/l at six months.

While there were no urological complications in transplants after ODN, there were two ureteric complications in the LDN group (10%; $p=0.13$). One patient developed ureteric obstruction 12 weeks after transplantation and an antegrade pyelogram demonstrated severe stenosis of the transplant ureter from the bladder proximally over a distance of 8 cm. This patient had been treated with three courses of antirejection therapy (including antithymocyte globulin) in the first six weeks after transplantation. A native uretero-transplant pyelostomy was performed to reconstruct the transplant ureter but further obstruction developed three months later. Re-exploration demonstrated complete fibrosis of the remaining transplant ureter and pelvis back to the level of the renal sinus; the patient is currently being managed with a percutaneous nephrostomy. The second urological problem was an anastomotic ureteric stenosis in a transplant recipient with an ileal conduit that had been created 20 years previously. A preoperative contrast study suggested that the conduit was healthy, but at operation it was found to be narrowed and fibrotic. A percutaneous nephrostomy was performed and the stenosis was then successfully treated by percutaneous balloon dilatation.

Delayed graft function occurred in one of the 20 transplants performed after LDN (5%) and 2/34 (6%) transplants from ODN (NS). Acute rejection was diagnosed in 15/34 transplants after ODN (44%) and 9/20 transplants after LDN (45%). Post-transplant serum creatinine fell more slowly in the LDN transplants initially compared with ODN transplants. But by day 14 the serum creatinine levels were similar (129 (15) *v* 130 (14) μmol/l) and there was no significant difference at six months follow up (137 (18) *v* 125 (11) μmol/l). The actual one year graft survival rate of transplants retrieved by ODN was 33/34 (97%) and 19/20 (95%) for transplants retrieved by LDN.

DISCUSSION

This study suggests that laparoscopic donor nephrectomy has a number of advantages over the conventional open operation.

The severity and duration of postoperative pain is decreased, hospitalisation is shorter, and return to normal activities and employment is quicker after the laparoscopic operation. The principal concern with laparoscopic nephrectomy is that the kidney will be damaged during retrieval and that as a consequence, morbidity may be transferred from the donor to the recipient. LDN should therefore only gain general acceptance if it can be clearly demonstrated that the operation can be performed without adversely influencing the outcome of the recipient transplant.

LDN was first performed in 1995.[3] Since then a small number of studies from the United States have shown that LDN is technically feasible and can be performed safely.[6–9] Our findings broadly agree with the comparative published series which found that LDN was associated with significantly reduced postoperative pain and recuperation times which were between one and two thirds shorter than those for ODN.[6 7] The main weaknesses of the studies performed so far are that they have used historical control groups and some of the data relating to recovery was compiled retrospectively by personal or telephone interviews. These criticisms apply equally to the present study, although all the data relating to the laparoscopic procedure and approximately 60% of the ODN data were recorded prospectively. Indices of postoperative recovery such as the time taken to return to work present difficulties in interpretation as they are influenced by several factors including the attitudes of the patients themselves as well as their surgeons, family doctors, and employers. It is striking, however, that the mean time off work after LDN (5 (3) weeks) is comparable to that after laparoscopic cholecystectomy.[10]

The open nephrectomy operations in this series involved partial resection of the 12th rib. As there is a marked difference in the size of the wound required for this open operation and the laparoscopic procedure, the postoperative recovery data are not surprising. Other open approaches to the kidneys such as a retroperitoneal loin approach without rib resection and anterior transperitoneal approaches are also used, but in the absence of prospective comparisons it is not known whether or not a particular operative approach is less painful or associated with an improved recovery time. What is clear is that all of these procedures leave a significant wound, which is likely to present an important disincentive to becoming a donor.[2]

Transplant kidneys removed laparoscopically were associated with a slower initial fall in recipient serum creatinine compared with ODN transplants. This feature, which has previously been noted,[9 11] may result from the longer warm ischaemic period to which laparoscopically dissected kidneys are exposed during retrieval of the organ from the abdomen. An alternative explanation is that the raised intra-abdominal pressure required to maintain a pneumoperitoneum causes a decrease in renal blood flow and urine output during the relatively prolonged period required to complete a laparoscopic nephrectomy.[12 13] Whatever the cause, transplants from LDN and ODN have equal renal function in the longer term. This is consistent with the available evidence suggesting that significant renal injury occurs only after quite prolonged warm ischaemia.[14]

The reporting of a higher incidence of ureteral complications after the early experience of LDN is of some concern.[5] Technical errors during kidney retrieval may compromise the ureteric blood supply of a transplant kidney as this is derived exclusively from the renal artery. The ureteric branch of the renal artery runs through a "golden triangle" bounded by the renal hilum, the lower pole of the kidney, and the lower medial border of the renal vein; this area must be carefully protected during both open and laparoscopic dissections. Vascular injury may also occur at a lower level if the ureter is stripped of its surrounding connective tissue. One way of avoiding this is to dissect the ureter and gonadal vessels together, and it has been suggested that this technical modification reduces the incidence of ureteric complications after laparoscopic retrieval.[5 8] The two ureteric complications noted in the present series were not thought to be due to vascular injuries at the time of laparoscopic dissection. The first case involved a progressively evolving fibrotic ureteric stenotic process which followed a series of severe acute rejection episodes and the second case occurred after implantation of the transplant ureter into a rather fibrotic ileal conduit.

LDN is technically challenging and is also unique among minimal access operations in that the organ being removed must not be damaged in any way. The dissection of the renal vessels is the most demanding phase of LDN and short, thin walled tributaries of the renal vein can be difficult to deal with. Preoperative imaging by high resolution spiral computed tomographic angiography can be particularly helpful in this respect.[4 15] The three dimensional reconstructions provided by this imaging modality allow the surgeon to build up a preoperative picture of the renal anatomy and to be aware of the exact position of potentially hazardous features, such as a posterior lumbar tributary of the renal vein, before they are encountered.

LDN will inevitably be associated with a significant surgical learning curve and it is important that the procedure is only carried out by surgeons with experience of advanced laparoscopic techniques; we have found that working as a team of two consultant surgeons greatly facilitates the process. Technical modifications such as gasless laparoscopy and the use of devices which allow a hand to be introduced into the abdominal cavity in order to help with retraction[16] may also widen the applicability of LDN. In this technique, a pneumoperitoneum is created as before but the surgeon then introduces one hand into the abdominal cavity through a specially designed airtight sleeve, but also uses laparoscopic instruments to dissect the kidney. The introduction of a hand allows an improved tactile sense and this may facilitate the dissection of important structures such as the renal vessels and may possibly reduce the total operating time.

In conclusion, the early experience of LDN clearly suggests that this technique has the potential to become a major advance in renal transplantation. Enthusiasm for the use of laparoscopic assisted live donor nephrectomy is increasing around the world but this new procedure cannot be supported purely on the basis of audit data and comparison with historical control groups. Further studies are awaited and consideration should be given to planning carefully designed randomised trials of the different nephrectomy techniques.

ACKNOWLEDGEMENTS

Dr Lloyd Ratner MD first showed us how to perform laparoscopic nephrectomy and we would like to thank him for his thoughtful advice and encouragement. We would also like to thank Mrs Carol Barr for diligently collecting much of the data presented.

Authors' affiliations

J R Waller, A L Hiley, E J Mullin, P S Veitch, M L Nicholson, University Division of Transplant Surgery, Leicester General Hospital, UK

REFERENCES

1 **UNOS and the Division of Transplantation**, Bureau of Health Resources and Services Administration. *Annual report of the US scientific registry of transplant recipients and organ procurement and transplantation network-transplant data: 1988–1994.* Rockville, MD: US Department of Health and Human Services.
2 **Shaffer D**, Sahyoun AI, Madras PN, *et al.* Two hundred consecutive living-donor nephrectomies. *Arch Surg* 1998;**133**:426–31.
3 **Ratner LE**, Ciseck LJ, Moore RG, *et al.* Laparoscopic live donor nephrectomy. *Transplantation* 1995;**60**:1047–9.
4 **Alfrey EJ**, Rubin GD, Kuo PC, *et al.* The use of spiral computed tomography in the evaluation of living donors for kidney transplantation. *Transplantation* 1995;**59**:643–5.

5 **Philosophe B**, Kuo PC, Schweitzer EJ, *et al*. Laparoscopic versus open donor nephrectomy. *Transplantation* 1999;**68**:497–502.
6 **Ratner LE**, Kavoussi LR, Sroka M, *et al*. Laparoscopic assisted live donor nephrectomy - a comparison with the open approach. *Transplantation* 1997;**63**:229–33.
7 **Flowers JL**, Jacobs S, Cho E, *et al*. Comparison of open and laparoscopic live donor nephrectomy. *Ann Surg* 1997;**226**:483–90.
8 **Sasaki T**, Finelli F, Barhyte D, *et al*. Is laparoscopic donor nephrectomy here to stay? *Am J Surg* 1999;**177**:368–70.
9 **Nogueira JM**, Cangro CB, Fink JC, *et al*. A comparison of recipient renal outcomes with laparoscopic versus open live donor nephrectomy. *Transplantation* 1999;**67**:722–8.
10 **Majeed AE**, Troy G, Nicholl JP, *et al*. Randomised, prospective, single-blind comparison of laparoscopic versus small-incision cholecystectomy. *Lancet* 1996;**347**:989–94.
11 **Ratner LR**, Montgomery RA, Kavoussi LR. Laparoscopic live donor nephrectomy: the four year Johns Hopkins University experience. *Nephrol Dial Transplant* 1999;**14**:2090–3.
12 **Harman PK**, Kron IL, McLachlan HD, *et al*. Elevated intra-abdominal pressure and renal function. *Ann Surg* 1982;**196**:594–7.
13 **Kirsch AJ**, Hensle TW, Chang DT, *et al*. Renal effects of CO_2 insufflation: oliguria and acute renal dysfunction in a rat pneumoperitoneum model. *Urology* 1994;**43**:453–9.
14 **Thoren O**. Ischaemia time and time for onset of graft function after cadaveric kidney transplantation. *Scand J Urol Nephrol* 1976;**38S**:33–8.
15 **Rubin GD**, Alfrey EJ, Dake MD, *et al*. Assessment of living renal donors with spiral CT. *Radiology* 1995;**195**:457–62.
16 **Slakey DP**, Wood JC, Hender D, *et al*. Laparoscopic living donor nephrectomy. Advantages of the hand assisted method. *Transplantation* 1999;**68**:581–3.