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Laparoscopic and open live donor nephrectomy: a cost/benefit study

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Abstract Recently, laparoscopic live-donor nephrectomy has been developed in order to increase organ donation. In this study we compare and review the records of 10 donors operated by open extraperitoneal approach and of 10 donors operated by a laparoscopic transperitoneal approach (LSC). Results show less use of postoperative parenteral narcotics in the LSC group (109 mg vs 272 mg; $P < 0.0005$) than in the extraperitoneal group. Morbidity was similar in both groups. There was no difference in postoperative stay. Allograft kidney function was similar in both groups until 6 months after donation. The use of disposable laparoscopic material bears an extra cost of 900 US$. We can thus conclude that laparoscopic live-donor nephrectomy is a safe procedure that significantly reduces postoperative pain, and is not detrimental to the allograft. The total cost of the laparoscopic procedure will be lower than that of the open approach if the length of postoperative stay is cut by 3 days.

Key words Laparoscopy · Kidney transplantation · Live-donor nephrectomy

Introduction

As one of the number of new strategies devised to increase the number of kidneys available for transplantation, the transplantation community is currently trying to promote live donation [10]. The most commonly applied method for live donor nephrectomy is by an extraperitoneal approach, with a flank incision. Reasons why potential living donors may be reluctant to donate a kidney, include the financial burden due to long hospitalisation and absence from work, the unwillingness to face considerable postoperative pain, and cosmetic considerations about the surgical wound. This has been the basis of the rationale for developing techniques of minimally invasive surgery for live donor nephrectomy. Two groups from Maryland have pioneered a transperitoneal laparoscopic approach for kidney harvesting, and have shown that their techniques are feasible and safe, and that they removed disincentives to live donation, since they produced shorter hospital stay and absence from work, lower postoperative pain, and smaller surgical wounds [5, 13, 14]. However, data regarding allograft function and costs are still lacking. Moreover, social and financial issues related to absence from work might not be as important in other countries as they are in the U.S.A. In this first European series of laparoscopic live donor nephrectomy, we present the technique we have developed and we compare its results with those obtained by a standard extraperitoneal approach. We concentrate on the costs and bene-

fits of the new technique, and on the issue of kidney allograft function.

Patients and methods

Study design

Medical and financial records of all donors and recipients who underwent live-donor nephrectomy and kidney transplantation at the Saint-Luc University Clinics in the 2-year period from May 1996 to April 1998 were retrospectively reviewed. Medical records of donors were reviewed for pre- and postoperative serum creatinin values, length of operation, perioperative blood loss and morbidity, postoperative analgesic requirements, and length of hospitalisation. The following allograft characteristics were collected from the donor's and recipient's medical records: warm ischemia time, delayed graft function or primary non-function, acute rejection episodes according to the Banff criteria [16], and serum creatinin values at 1 week, 1 month and 6 months. Warm ischemia the time was defined as time between ligation of the renal artery and start of perfusion of the kidney. For comparison of allograft function, we used the ratio of recipient creatinin clearance to postoperative donor creatinin clearance. Creatinin clearance was estimated using the Cockroft-Gault formula [2]. In order to perform a cost/benefit analysis, details of the invoicing in the donors' financial record were analyzed.

Patient selection

Laparoscopic live donor nephrectomy has been performed at the Saint-Luc University Clinics since February 1997. From that date on, all live donors were given formal information on the laparoscopic procedure, including explanations of the potential benefits of this approach, such as reduced postoperative pain, shorter recovery time, and cosmetic advantages for the surgical wound. Patients were also informed that this was a novel technique with, as yet, unavailable safety data. The possibility of an open conversion was also explained. All donors were given the choice between the laparoscopic and the open approach, and all of them elected to undergo laparoscopic kidney donation. All donors underwent the standard preoperative work-up. A preoperative arteriography was obtained for all donors, and the kidney with a single artery was selected for nephrectomy. If both kidneys had a normal arterial vascularisation, the left kidney was preferred because of the longer renal vein on that side.

Laparoscopic operative technique

The technique we employed is derived from Gagner's technique for laparoscopic adrenalectomy [6]. Following induction of endotracheal general anaesthesia, the donor is placed in a lateral decubitus position, with the operating table flexed to extend the presenting flank, and with the arm extended and suspended. Naso-gastric suction tube, percutaneous bladder drainage, antibiotic prophylaxis and curarisation are used. The patient is draped so as to allow urgent subcostal or median laparotomy if necessary.

The operator stands facing the patient, with the camera operator cephalad to him, and the second assistant across the table. A video monitor stands at the head of the table, facing the operator. A total of 3–4 ports are necessary for the procedure (Fig. 1). The 12 mm camera port is first inserted, after a mini-laparotomy, on a horizontal line passing through the umbilicus, on the lateral border of the rectus abdominis muscle. A 14 mmHg carbon dioxide pneumoperitoneum is then insufflated. A first 10 mm dissection port (right hand of the operator for a left nephrectomy, left hand for a right nephrectomy) is placed on the same horizontal line, on the anterior axillary line. The second 10 mm dissection port is placed on the lateral border of the rectus abdominis muscle, immediately

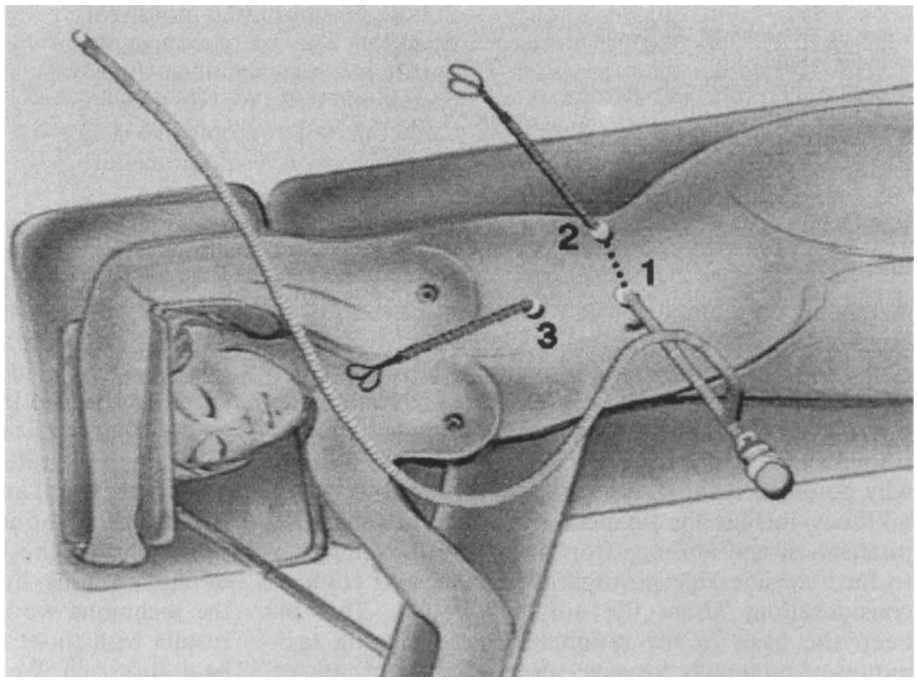

Fig. 1 View of the live donor placed in a lateral decubitus position. *Numbers* depict the position of the 3 ports, with the camera in port 1. After the laparoscopic stage of the intervention is completed, a transverse laparotomy is performed (*dotted line*), joining port holes 1 and 2

Table 1 Preoperative characteristics of 20 live kidney donors

	OPEN group ($n = 10$)	LSC group ($n = 10$)	P^a
Age[b]	41 (22–50)	45 (24–65)	n.s.
F/M sex ratio	9/1	5/5	< 0.02
BMI[b]	22.7 (18.7–28.8)	24.9 (18.1–29.5)	n.s.
Creatinin clearance (ml/min)[b]	89.9 (66.6–130.8)	75.1 (38.5–108.2)	< 0.05

[a] Fisher's exact test for categorical variables and unpaired Student's t-test for continuous variables
[b] Values expressed as median (range)

inferior to the border of the ribs. If necessary, a fourth 10 mm retraction port can be inserted on the mid-axillary line, a few centimetres cephalad to the first dissection port, or just inferior to the xyphoid process for a liver retraction in case of right nephrectomy.

On the left side, the retroperitoneal space is entered by reflecting the descending colon up to the left colonic angle medially. The splenorenal ligament is divided, as well as the diaphragmatic attachments of the spleen, as far as the greater curvature of the stomach. The spleen is thus allowed to "fall" medially by gravity. The ureter is dissected from the gonadic vessels as far as the iliac vessels distally, and toward the hilum proximally. The renal vein is found at the end of the gonadic vein, which has to be clipped and divided. The renal vein is dissected as far as its crossing of the aorta, which involves clipping and division of the adrenal vein. The renal artery appears behind the vein. Gerota's fascia is incised, and the surface of the kidney is progressively freed of the perirenal fat and the adrenal gland, starting at the upper pole, and working toward the lower pole, and the lateral and posterior aspects of the kidney. At this stage, the kidney is allowed to swing medially, and the renal artery is dissected toward the aorta on the posterior side of the pedicle. This ends the laparoscopic stage of the intervention.

A transverse laparotomy is performed, joining the first two port holes. This makes up an 8–12 cm surgical wound. Abdominal muscles are split longitudinally without transsecting muscular fibres. No systemic heparinisation is used before the extraction process. The ureter is clipped at its crossing of the iliac vessels and divided. The renal artery is ligated at its origin, or, if unpracticable, divided with a multifire endo-GIA 30 (or endo-TA 30) titanium vascular stapler (Auto Suture Co, Ascot, Berks., UK). Finally, the renal vein is divided as far as possible with a multifire endo-TA 30 titanium vascular stapler (Auto Suture Co). The kidney is quickly extracted from the abdominal cavity, immersed in iced saline, and flushed with University of Wisconsin preservation solution. Finally, the abdominal wound is closed.

On the right side, the operation begins with the division of the right hepatic triangular ligament. A fan-type liver retractor is inserted to reflect the right lobe anteriorly and medially. the posterior peritoneum is opened from the triangular ligament to the vena cava along the superior pole of the kidney. A Kocher's manoeuvre is performed, to recline the duodenum medially and expose the vena cava as far down as the renal vein. Access to the retroperitoneal space is completed by reflecting the ascending colon medially. The ureter is dissected from the gonadic vessels in the same manner as on the left side. On the right side, the renal vein is dissected from the vena cava onwards. The rest of the dissection is identical to that performed on the left.

In most cases, we used non-disposable laparoscopic material, with the exception of one medium-large titanium clip applier (Auto Suture Co, Ascot, Berks., UK), one pair of curved dissecting scissors (Auto Suture Co) and one endo-TA linear stapler. The open procedures were carried out with a retroperitoneal approach in the 10th intercostal space. All laparoscopic and open surgical procedures were performed by a single operator (JPS).

Patients

Twenty consecutive donors were operated during this period and analyzed. Ten donors were operated with an open approach (OPEN group), followed by ten more who were operated laparoscopically (LSC group). The groups were not identical for age, sex ratio and preoperative creatinin clearance, but were comparable for body mass index (Table 1).

Statistics

Comparisons between groups were made using unpaired Student's t-test for continuous variables and Fisher's exact test for categorical variables. Values of $P < 0.05$ were considered significant.

Results

Laparoscopic nephrectomy was attempted on 10 patients and successfully performed in all of them. In each group 7 patients had the left- and 3 had the right kidney removed. No intraoperative vascular or ureteral injury occurred during procurement in any group. The only incident noted was an arterial spasm that hindered and delayed satisfactory perfusion of the kidney for a few seconds in the LSC group. Intraoperative blood losses, estimated by the fall in serum haemoglobin concentration after the intervention were similar in both groups. No patients required blood transfusion in either group. Average operating time was about 1 h longer in the LSC group. Warm ischemia times were similar in both groups.

Analgesics requirements expressed as duration of parenteral narcotic use and total dose of morphine equivalents administered, were much higher in the OPEN group. Only one significant complication was observed in the LSC group (abdominal wall hematoma) and none in the OPEN group. Length of postoperative hospital stay was similar in both groups, but 4 patients were discharged before the 7th postoperative day in the LSC group. Intraoperative and postoperative donor characteristics are shown on Table 2.

Postoperative function of the allograft was similar in both groups (Table 3). No primary non-function or delayed graft function were observed. As expected from preoperative donors' characteristics, creatinin clearances 1 week after surgery were higher in both donor and recipient in the LSC group, as compared to the OPEN group. However, recipient to donor creatinin clearance ratios were identical in both groups 1 week, 1 month and 6 months after transplantation. Occurrence and severity (according to Banff criteria) of biopsy-proven

Table 2 Intra- and postoperative characteristics of 20 live kidney donors

	OPEN group ($n = 10$)	LSC group ($n = 10$)	P^a
Operative time (min)[b]	150 (115–180)	218 (175–260)	< 0.00001
Haemoglobin fall (g/dl)[b]	1.75 (0–3.4)	1.80 (0.5–2.5)	n.s.
Warm ischemia time (min)[b]	4.3 (3–7)	5.0 (3–7)	n.s.
Parenteral narcotics (h)[b]	68 (44–82)	43 (18–55)	< 0.00001
Parenteral narcotics (mg)[c]	265 (80–546)	88 (26–284)	< 0.0005
Morbidity (patients)	0	1	n.s.
Postoperative stay (days)[b]	9 (8–10)	11 (6–16)	n.s.

[a] Fisher's exact test for categorical variables and unpaired Student's t-test for continuous variables
[b] Values are expressed as median (range)
[c] Milligrams of morphine equivalents

Table 3 Postoperative course of 20 kidney allografts

	OPEN group ($n = 10$)	LSC group ($n = 10$)	P^a
Creatinin clearance index, 1 week[b]	1.10 (0.72–1.37)	1.07 (0.52–1.66)	n.s.
Creatinin clearance index, 1 month[b]	0.94 (0.59–1.48)	0.89 (0.52–1.72)	n.s.
Creatinin clearance index, 6 month[b]	0.77 (0.54–1.42)	0.85 (0.47–1.50)	n.s.
Banff I acute rejection episodes	3	3	n.s.
Banff II acute rejection episodes	1	1	n.s.
Patients with acute rejection[c]	3	3	n.s.

[a] Fisher's exact test for categorical variables and unpaired Student's t-test for continuous variables
[b] Creatinin clearance (Cr cl) indexes represent the ratio of recipient Cr cl values at the time considered to donor Cr cl values at 1 week after surgery. A value of 1.0 represents equal clearance in the graft and in the donor's residual kidney. Values are expressed as median (range)
[c] One patient in each group had 2 rejection episodes

Table 4 Costs of live donor nephrectomy[a]

	Open procedure	Laparoscopic procedure
Procedure costs[b]	50'000.– (1'500.–)	50'000.– (1'500.–)
Drugs[c]	7'000.– (200.–)	7'000.– (200.–)
Laparoscopic disposable material[d]	– (–)	30'000.– (900.–)
Hospital room	13'000.–/day (400.–/day)	13'000.–/day (400.–/day)

[a] Prices are expressed in Belgian Francs, with approximate corresponding US$ values in parentheses
[b] Including surgery and anaesthesia, operating room costs, preoperative arteriography and other radiological examinations and laboratory
[c] All drugs, including perfusions and postoperative analgesia
[d] Including 1 exemplary each of: curved dissecting scissors, medium-large titanium clip applier, and endo-TA linear stapler

acute rejection episodes requiring treatment was similar in both groups. All allografts are still functioning at the time of writing.

Cost analysis is summarised on Table 4. The total cost in our hospital for the open procedure is BEF 57'000.– and BEF 87'000.– for the laparoscopic procedure. An additional BEF 13'000.–/day is charged for the hospital room in both groups. In order to achieve lower costs in the LSC group, length of hospitalisation has to be 3 days shorter.

Discussion

Minimally invasive surgical techniques for kidney harvesting have been recently developed in order to increase the number of live donors. A transperitoneal laparoscopic approach has been pioneered by 2 groups from Maryland [5, 13], and has been a consequence of the laparoscopic techniques developed for diseased kidney removal [1] and the demonstration of the feasibility of laparoscopic kidney harvesting on a porcine model [7]. A modified open live-donor nephrectomy technique, via a mini-subcostal incision has been developed by other groups [9] (Leone et al, Annual Meeting of the American Society of Transplant Surgeons, Chicago, 1998). Attempts at developing a retroperitoneoscopic approach have also been reported, but to a much smaller extent so far [18, 20].

The latest reports by Ratner et al. and Flowers et al. have validated laparoscopic live donor nephrectomy for the transplantation community, in respect of safety and a smoother postoperative course for the donor [5,

13]. However, some questions about costs and quality of the allograft are still left unanswered. This study presents the first European results on that subject, and addresses the latter issues.

The ethics of live donation imply that the morbidity of the procedure should be as low as possible, and that there should be no mortality. In particular, the figures for the laparoscopic procedure should not exceed the low morbidity and mortality < 0.1 % reported for open live donor nephrectomy [3, 19]. In this series, the safety of the technique seemed to be equivalent in both groups. Only one minor complication occurred, in a patient from the LSC group (parietal hematoma), and was related to the open part of the procedure rather than to the laparoscopic part. However, as outlined by Ratner [13], who advocates the establishment of an international registry, in view of the very low morbidity of the procedure, large numbers of patients would have to be analyzed if one were to demonstrate differences or equivalence in the morbidity of the two approaches. Blood losses, assessed by the fall of hematocrit in the two days before and after the operation, were minimal and identical in both groups, contradicting other reports of lower blood losses in the LSC group. The different methods used for intraoperative bleeding assessment make it difficult to compare the results and understand the reasons for that difference.

A transperitoneal, rather than retroperitoneal, route has been chosen for our technique of laparoscopic kidney harvesting. The retroperitoneal approach greatly reduces working space, and would prolong operative time. One might argue that the transperitoneal approach carries a higher risk of adhesions or damage to intra-abdominal organs. Such complications have not been reported by the American groups [5, 13]. Additionally, by analogy with laparoscopic adrenalectomy, no differences in long-term morbidity have been observed for the two techniques [4, 6]. The length of our incision is somewhat larger than what has been reported by other groups [5, 13]. However, the shorter, midline incision they use, necessitates the use of a bag for kidney extraction. We feel that this procedure squeezes the organ, and carries an increased risk of damage. In order to reduce the risk of injury, we prefer to make a slightly larger incision, as close as possible to the kidney.

The most obvious advantage of the laparoscopic approach for the donor was that of less postoperative pain. Both the total amount of parenteral narcotics administered and the duration of parenteral administration were greatly reduced in the laparoscopic group. Interestingly, the length of postoperative hospitalisation was not decreased in the laparoscopic group. The much reduced financial and social pressure for short in-hospital recovery and absence from work that is seen in Europe, as compared to the United States, is the most likely explanation for this finding. In Belgium, the donors' hospitalization costs are totally covered by the recipients' insurance. Absence from work is totally covered by the employer and the mutual insurance company. In effect, many of the donors from the laparoscopic group elected to remain in hospital as long as the recipient was hospitalised. On the other hand, a few donors from the laparoscopic group (4/10) left as early as postoperative day 6, whereas no donor from the open group left before postoperative day 8. In any case, it will take a tremendous change in the way of life in Belgium, before laparoscopic donors are discharged from hospital 1–2 days after surgery, as reported elsewhere.

An important issue raised by the laparoscopic technique is that of the safety of the graft. Reasons for concern are threefold. Firstly, the laparoscopic operation is technically challenging and is characterised by a long learning curve. This aspect exposes the kidney parenchyma, the renal vessels, and the ureter to a risk of lesions [5, 13]. Secondly, experimental data are available that demonstrate that the increased intra-abdominal pressure of the pneumoperitoneum decreases renal blood flow, which diminishes glomerular filtration, and may provoke acute tubular necrosis [8, 11]. However, there is no clinical relevance of these findings so far, in terms of deleterious effects on the allograft. Thirdly, warm ischemia time tends to be longer than in the open procedure, because of a more delicate and difficult extraction of the kidney.

No significant lesion to the kidney or to any of its hilar components was observed in our series. In particular, we did not have the high rate of ureteral lesions reported by the University of Maryland group (Philosophe et al, Annual Meeting of the American Society of Transplant Surgeons, Chicago, 1998). The only notable incident was a short-duration arterial vasospasm of the renal artery, without further consequence for the graft. The small size of our series prevents us from drawing conclusions on the causality of laparoscopic dissection or increased intra-abdominal pressure on the occurrence of arterial spasms. Warm ischemia time was similar in both groups. The fact that we extract the kidney manually, without making use of a sac explains the equal rapidity of extraction in both procedures.

In this series, we systematically preferred to harvest the left kidney if possible, but, because of the renal vascular anatomy, we performed a right nephrectomy in 3 cases without incident. The shorter renal vein on that side, and the risk of lesion to the inferior vena cava, have refrained the pioneering groups from performing right nephrectomy so far. We demonstrate in this paper the high safety of the procedure, which is in fact easier to perform than on the left side. The use of an endo-TA, rather than an endo-GIA, device allows stapling the renal vein right at its junction with the vena cava, thus gaining a few extra millimetres thanks to the lacking line of staples.

All allografts from both groups had immediate kidney function. Since donors from the LSC group had significantly lower creatinin clearance values, both before and after kidney harvesting, we had to make use of a recipient-to-donor creatinin clearance ratio, in order to be able to compare results. No detrimental effect of the laparoscopic procedure on kidney allograft function was identified at 1 week, 1 month and 6 months after transplantation, in comparison to the OPEN group. Moreover, the number and severity of episodes of acute rejection requiring therapy was equal in both groups. Two recent communications deal with this issue of renal allograft function, one of them reporting similar function in both groups [15]. However, another team reports significantly poorer initial function in the laparoscopic group [12], illustrating the potential detrimental effects on the graft of the procedure.

At our hospital, there is a difference in fixed costs of BEF 30'000.– (US$ 900.–) extra for patients operated under laparoscopic conditions, due to the use of disposable material. As the hospital room is charged BEF 13'000.– per day (US$ 400.–), this difference can be balanced if patients operated by laparoscopy cut their hospital stay by 3 days, when compared with patients who undergo the open procedure. This was the case in our series in 4 laparoscopic patients, which demonstrates that lower costs can indeed be achieved in this group, if individual patients are discharged according to medical, rather than socio-affective criteria [17].

Laparoscopic nephrectomy is a safe procedure both for the donor and for the short-term allograft function. Due to the novelty of the technique, data long-term allografts are still lacking, but should be available in a few years. Its potential advantages expressed as duration and amount of postoperative narcotic use, hospital stay and costs, including disposable material, should be compared to the standard extraperitoneal approach, and balanced with the local social way of life.

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