

Laparoscopic donor nephrectomy

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ABSTRACT

Living donor nephrectomy has been developed and promoted as a method to address the shortfall in kidneys available for transplantation. The classical method to procure a kidney from a living donor is the open donor nephrectomy performed through a flank lumbotomy incision. However, this classical method has negative short- and long-term side effects for the donor. These disincentives are a drawback for possible donors to donate a kidney. Therefore, transplant surgeons were stimulated to develop new and less invasive techniques. In this review several new open and laparoscopic techniques are described. Compared with open donor nephrectomy, laparoscopic donor nephrectomy has shown superior results in terms of postoperative pain, cosmetics, convalescence, and return to normal daily activities. No significant differences exist between the two approaches in terms of complication rates, cost-effectiveness and graft function. Nowadays, laparoscopic donor nephrectomy has become the preferred method for procuring kidney grafts of living donors in many centres.

KEYWORDS

Kidney transplantation, laparoscopy, minimally invasive surgical procedures, donor nephrectomy

INTRODUCTION

Living donor kidney transplantation is superior to deceased donor kidney transplantation because of better patient and graft survival rates, better cost-effectiveness and improved quality of life of the recipient.^{1,3} However, the donor needs to undergo a major surgical operation for the benefit of another individual. In living kidney donation there are several surgical techniques for taking a renal allograft from a living donor. The classical method to procure a kidney from a living donor is the open donor nephrectomy performed through a flank lumbotomy incision. In 1995,

Ratner *et al.* described the laparoscopic technique to perform a living donor nephrectomy.⁴ The minimally invasive aspect of this technique was an important factor leading to the fast spread of this technique in the surgical community and this became the preferred method for procuring kidney grafts from living donors in many centres. Laparoscopic donor nephrectomy seems to be at least as safe and efficacious as open donor nephrectomy.^{5,6} In the past years, several modifications to these two techniques of living donor nephrectomy have been described (*table 1*). Nowadays, the surgical technique of living donor nephrectomy varies greatly between transplant centres in European countries. An audit held in 2005 revealed that 40% of the living donor nephrectomies in Western Europe are performed laparoscopically.⁷ In 2003, the percentage of laparoscopies in the United States was approximately 67%.⁸

To date, evidence of level I studies comparing the different available techniques are scarce. In the beginning of laparoscopic donor nephrectomy, patient selection bias may have existed, especially in reports from centres in which both open and laparoscopic donor nephrectomy were performed. The more complex donors at that time could have undergone open procedures. Therefore meta-analyses are also polluted with this bias and conclusions should be drawn with caution. In this review we describe different

Table 1. *Surgical techniques for living kidney donation*

Open donor nephrectomy technique

- Classical lumbotomy
- Muscle-sparing mini-incision donor nephrectomy

Laparoscopic transperitoneal technique (*)

- Laparoscopic donor nephrectomy
- Hand-assisted laparoscopic donor nephrectomy

Endoscopic retroperitoneal technique (*)

- Endoscopic retroperitoneal donor nephrectomy
- Hand-assisted Endoscopic retroperitoneal donor nephrectomy

* These techniques can also be performed with robotic assistance.

surgical techniques and intraoperative and postoperative factors related to laparoscopic donor nephrectomy.

SURGICAL TECHNIQUES

Open donor nephrectomy

The open donor nephrectomy through the lumbotomy approach has been the classical method of procuring kidney grafts from living donors for many decades. This technique is safe, both for the donor and for the kidney, and it is the gold standard all new techniques are compared to.

The donor is positioned in a lateral decubitus position on the operating table and is flexed at the level of the umbilicus to expose the flank fully. The open donor nephrectomy is carried out retroperitoneally through a 15 to 25 cm flank incision below the 12th rib. Resection of the distal part of the lowest rib is frequently applied to allow sufficient access to the kidney. After transection of the three layers of abdominal muscles, Gerota's fascia is exposed and the kidney is freed from the surrounding tissues. The renal vessels are isolated and the ureter with sufficient periureteral tissue is divided as distally as possible. After the renal vessels are ligated, it is possible to immediately extract the kidney from the operative field and start cold perfusion on the back-table. In this way the warm ischaemia time is very short. With this procedure there is limited risk of postoperative intraperitoneal complications, such as adhesions, intestinal perforations, splenic injuries or bowel obstructions. However, open donor nephrectomy significantly injures the abdominal wall resulting in significant postoperative pain, a long hospital stay, cosmetic problems and slow convalescence.⁹ In the long term, side effects include denervation of the abdominal wall, incisional hernias and less frequently intractable pain. These adverse events are a drawback for potential donors to donate a kidney. Therefore, in most centres, over the past decade the open donor nephrectomy has been replaced by less invasive techniques.

Minimally invasive open donor nephrectomy

After the introduction of the laparoscopic donor nephrectomy there was a stimulus for developing a minimally invasive modification of the classical open donor nephrectomy, and subsequently the muscle-sparing mini-incision donor nephrectomy was developed. This operation can be done via an anterior, flank or posterior approach with an incision of approximately 7 centimetres. With the donor placed in a lateral decubitus position and the operation table maximally flexed, a horizontal skin incision is made anterior to the 11th rib toward the umbilicus. The fascia and muscles of the abdominal wall are carefully split between the muscle fibres avoiding harm to the intercostal nerves between the internal oblique and transverse abdominal muscles. The peritoneum is displaced

medially and Gerota's fascia is opened on the lateral side of the kidney. The working space is limited, therefore long instruments are used. The kidney is meticulously dissected and arterial and venous structures are identified. After dissection, the ureter is divided and sutured distally. The renal artery and vein are clamped and ligated.

This approach provides the safety of the conventional open technique. This minimally invasive open donor nephrectomy results in reduced blood loss, hospital stay and incision-related complications compared with the classical open donor nephrectomy. There is only a marginal increase in operation time without compromising graft and recipient survival.¹⁰⁻¹² Lewis *et al.* performed a prospective study comparing traditional open, minimal-incision, and laparoscopic donor nephrectomy. Blood loss was significantly higher for open donor nephrectomy (842 ± 1439 , 260 ± 195 , $p < 0.0001$). Postoperative intravenous morphine requirements were twice as high after open donor nephrectomy than after the minimal-incision technique. Donors were able to do domestic tasks quicker after minimal-incision than after open donor nephrectomy (2 ± 1 vs 4 ± 3 , $p < 0.05$). No differences were found in recipient outcome.¹¹ However, on comparison with laparoscopic donor nephrectomy, minimal-incision donor nephrectomy resulted in slower recovery, more fatigue, a worse quality of life for the donor but with equal safety and function for donor and graft.¹³⁻¹⁵

LAPAROSCOPIC DONOR NEPHRECTOMY

The first laparoscopic donor nephrectomy was performed by Ratner and colleagues in 1995.⁴

With the donor placed in a lateral decubitus position and the operation table maximally flexed, 4 or 5 trocars are introduced. The abdomen is insufflated to 12 mmHg. The colon is mobilised and displaced medially. Gerota's fascia is opened and the renal vein and ureter, with sufficient periureteral tissue, are identified and dissected. The renal artery is identified. Branches of the adrenal, gonadal and lumbar veins are clipped and divided. The ureter is clipped distally and divided. Then, a low transverse suprapubic (Pfannenstiel) incision or midline incision is made creating a gate for extraction of the kidney later on. The renal artery and vein are divided using an endoscopic stapler or clips. The kidney is extracted through the extraction incision, and flushed with preservation fluid and stored on ice. Extraction of the kidney can be performed directly through the incision or by using a special endoscopic specimen retrieval bag.

Disadvantages of this technique include the steep and long learning curve, the risk of bowel injury from trocar insertion or during instrumentation, internal hernias or hernia through trocar sites and intestinal adhesions.¹⁶ Injuries to the lumbar vein, renal artery

and aorta, pneumomediastinum, splenic injury, and adrenal/retroperitoneal haematomas have been reported.¹⁷ Conversion rate from laparoscopic to open surgery is 1.8% (range 0 to 13.3%). Approximately half of the conversions to open are for bleeding or vascular injury.¹⁸

The laparoscopic technique results in a shorter vascular pedicle when compared with the open donor nephrectomy. The warm ischaemia time and operating time for laparoscopic donor nephrectomy is substantially longer than compared with open donor nephrectomy.

Simforoosh *et al.* reported the first randomised controlled trial between open and laparoscopic donor nephrectomy. They included 100 donors and reported no differences in complications and graft survival. Donors of the laparoscopic group were more satisfied and resumed their normal activities earlier.²

Recently, Nicholson *et al.* randomised 84 donors between open and laparoscopic donor nephrectomy (LDN). LDN results in less postoperative complications, less pain, shorter hospital stay, earlier return to employment without differences in renal function or allograft survival.¹⁹

Several meta-analysis compare open and laparoscopic donor nephrectomy.^{15,18} The overall results demonstrate that the laparoscopic technique is associated with a significantly shorter hospital stay, fewer postoperative analgesic requirements, improved cosmetics and a quicker return to work as compared with open donor nephrectomy. In addition, compared with the open technique, laparoscopic donor nephrectomy is associated with less donor morbidity and similar allograft function and overall safety, but with increased costs.¹⁸ Laparoscopic donor nephrectomy was compared with the mini-incision open donor nephrectomy in a study by Kok *et al.* In this randomised controlled trial comparing laparoscopic donor nephrectomy to mini-incision muscle splitting open donor nephrectomy, they reported longer warm ischaemia time (6 vs 3 min, $p < 0.001$), less blood loss (100 vs 240 ml, $p < 0.001$), less morphine (16 vs 25 mg, $p = 0.005$) and shorter hospital stay (3 vs 4 days, $p = 0.003$) in the laparoscopic group without a statistically significant difference in complication rate (intraoperatively 12 vs 6%, $p = 0.49$, postoperatively both 6%) and graft survival.¹³

Hand-assisted laparoscopic donor nephrectomy

Hand-assisted laparoscopic donor nephrectomy was first utilised to minimise the learning curve of the total laparoscopic donor nephrectomy. In addition, the hand port provides addition safety to laparoscopic donor nephrectomy, because rapid control of eventual massive blood loss from major blood vessels is possible due to the hand assistance. Different incisions for hand introduction have been described, such as a Pfannenstiel incision, a midline supraumbilical, periumbilical or infraumbilical incision. The hand port can be used partly or totally during the operation.

The hand-assisted laparoscopic donor nephrectomy is done transperitoneally.²⁰ After open dissection of the distal ureter and gonadal vein through a 7 to 8 centimetre Pfannenstiel incision the nondominant operator's hand is introduced through a hand port and two trocars are placed. The insufflation pressure is maximally 12 mmHg. The right or left colon is then mobilised. The renal vein and artery are identified and the kidney is mobilised from the surrounding tissue. After transecting the ureter distally, the renal artery is transected with metal clips or an endoscopic stapler which is used to transect the renal vein. The kidney is extracted through the Pfannenstiel incision and cold flushed and preserved with preservation fluid.

Potential disadvantages are higher costs because of the hand port, a worse ergonomic position for the surgeon during operation, a higher rate of wound infections and increased traumatic injury to the transplant as a consequence of manipulation. Conversion to open surgery is 2.97% in the hand-assisted group.²¹ The most common causes for conversion to open surgery include intraoperative haemorrhage or vascular injury, difficult kidney exposure or an obese donor, vascular staple malfunction, adhesions and loss of pneumoperitoneum. Potential advantages of hand-assisted laparoscopic donor nephrectomy over conventional laparoscopy include the ability to use tactile feedback, less kidney traction, rapid control of bleeding, fast kidney removal and shorter warm ischaemic periods.^{21,22} Kokkinos *et al.* performed a meta-analysis which compared the total laparoscopic donor nephrectomy with the hand-assisted laparoscopic donor nephrectomy. They reported a significantly shorter warm ischaemic time, operation time and less blood loss for the hand-assistance technique. The hand-assisted technique also had a reduced intraoperative and postoperative complication rate when compared with the total laparoscopic technique, but these differences failed to reach statistical significance.²¹

In addition, the introduction of hand-assisted laparoscopic donor nephrectomy broadens the indications for laparoscopic living donor nephrectomy to include obese donors and donors who have had previous abdominal surgery.²³ Wolf *et al.* reported 47% less analgesic use ($p = 0.004$), 35% shorter hospital stay ($p = 0.0001$), 33% more rapid return to non-strenuous activity ($p = 0.006$), 23% earlier return to work ($p = 0.037$), and 73% less pain six weeks postoperatively ($p = 0.004$) in the hand-assisted laparoscopy group compared with the open donor group.²⁴ Bargmann *et al.* showed no difference between the hand-assisted laparoscopy group and totally laparoscopy group in a randomised controlled trial regarding intra and postoperative complications.²²

Retroperitoneoscopic donor nephrectomy

To limit and prevent possible intra-abdominal manipulation of the transperitoneal laparoscopic techniques, the retroperitoneal endoscopic donor

nephrectomy was developed. During this technique the peritoneal cavity is not opened. The technique has been described with and without hand assistance. The donor is placed in the full lateral position, and the retroperitoneal space is created using a balloon or the operators hand and maintained by carbon dioxide (CO₂) insufflation with a pressure of 12 mmHg. Dissection of Gerota's fascia, perirenal tissue and vascular structures are performed as described above. Potential disadvantages are emphysema such as pneumomediastinum, pneumothorax and pneumopericardium and gas embolism. Three comparative studies from Sweden comparing hand-assisted retroperitoneoscopic with laparoscopic donor nephrectomy revealed no differences in intraoperative and postoperative outcome for donor and recipient.²⁵⁻²⁷ However, data on hand-assisted retroperitoneoscopic donor nephrectomy are scarce and more prospective data on this technique are needed.

Robotic-assisted donor nephrectomy

Horgan *et al.* described their first series of 12 patients undergoing robotic hand-assisted laparoscopic donor nephrectomy and compared it with the standard laparoscopic donor nephrectomy.²⁸ Robotic-assisted donor nephrectomy can be performed with or without hand assistance. The Da Vinci robotic system has three components: a console, a control tower and the surgical arm cart. The donor nephrectomy is performed with the patient placed in a decubitus position. The operating table is flexed to maximise the exposure of the kidney during the procedure. Four trocars are placed in the left or right side of the abdomen to allow placement of three articulated robotic arms, the robotic camera, and the standard laparoscopic instrument used for retraction and dissection during the procedure. The left or right colon is mobilised medially to expose the kidney. Dissection of Gerota's fascia, perirenal tissue and vascular structures are performed as described above.

There is only one small study comparing the robot-assisted donor nephrectomy to the open donor nephrectomy revealing no differences in intraoperative and postoperative outcome for donor and recipient.²⁹ This current lack of data has to be filled with prospective studies.

The advantage of this technique is the movement of the articulated arm of the robot reproduces the action of the human wrist, which provides more free mobility. A potential disadvantage is the costs.

INTRAOPERATIVE FACTORS

Left or right kidney

There is an ongoing discussion whether right or left donor nephrectomy is to be preferred. Most centres prefer to use the left kidney for living kidney donation

because the renal vein is longer, which is advantageous during implantation.³⁰⁻³² However, some surgeons prefer the right kidney because it is easier to recover than the left kidney and the risk of splenic laceration is decreased.³³ A single-centre randomised controlled trial revealed no differences between left- and right-sided donor nephrectomy in donor hospital stay, donor quality of life, donor and acceptor complication rates, or graft survival. However, operation time for hand-assisted laparoscopic donor nephrectomy of the right kidney was significantly shorter (150 min, range 92 to 219) than that of hand-assisted laparoscopic donor nephrectomy of the left kidney (180 min, range 117 to 266, 95% confidence interval (CI) 3.93 to 46.38, $p=0.021$).³⁴ Right hand-assisted laparoscopic donor nephrectomy is justified if both kidneys have similar anatomy.

Multiple renal arteries and veins

Multiple renal arteries are present in 12 to 33%.^{35,36} In earlier studies the implantation of kidneys with multiple arteries has been associated with an increased incidence of vascular and urological complications, such as thrombosis and ureteral ischaemia, and was considered a relative contraindication by some.^{36,37} However, more recent reports state that renal transplantation can be performed safely in case of multiple arteries.³⁸⁻⁴⁰ Special care has to be taken with the lower kidney pole accessory renal arteries as they often provide substantial blood supply to the renal pelvis and ureter in a transplanted kidney and otherwise giving urological complications.

Multiple renal veins are present in 5 to 10% of the donors.^{35,36} Most of the small calibre accessory renal veins can safely be ligated, but occasionally reconstruction to gain length of a short right renal vein or repair of a damaged vein makes additional venous reconstruction necessary. It can be concluded that regardless of which technique (open or laparoscopic) used multiple vessels are not a contraindication.

WARM ISCHAEMIA TIME AND OPERATING TIME

Warm ischaemia time is the time the kidney remains at body temperature after its blood supply has been cut off but before cold perfusion is started. Compared with laparoscopic donor nephrectomy, open donor nephrectomy has a shorter warm ischaemia time by 102 seconds (95% CI 102.01 to 155.15, $p<0.001$).¹⁸ Warm ischaemia time was shorter by 75 seconds in the hand-assisted group compared with the laparoscopic donor nephrectomy (95% CI 2.84 to 116.14, $p<0.001$).²¹ In general, especially in the early years laparoscopic techniques had a longer warm ischaemia time than the open techniques but the hand assistance

and organ-retrieval bags have reduced these long warm ischaemia times. Nowadays, because of these adjuncts to laparoscopic techniques the warm ischaemia time is almost identical to open techniques. On the other hand, there is no clinically demonstrated negative effect on kidney function if the warm ischaemia time is less than 10 minutes, which is the case in almost all laparoscopic series.⁴¹

The open donor nephrectomy compared with the laparoscopic donor nephrectomy has a shorter operative time by 52 minutes (95% CI 39.73 to 64.12, $p=0.001$).¹⁸ The hand-assisted group was on average quicker by 30 minutes compared with the laparoscopic donor nephrectomy (95% CI 3.84 to 56.22; $p=0.02$).²¹ A recent systematic review stated that there appears to be sufficient evidence to conclude that both renal function and renal blood flow are decreased during pneumoperitoneum. The magnitude of the decrease is dependent on factors, such as preoperative renal function, level of hydration, level of pneumoperitoneum, patient positioning, and duration of pneumoperitoneum.⁴²

Older donors

Due to the increasing organ shortage, more and more transplant centres are retrieving kidneys from older donors. Excellent results in younger donors encouraged them. With increased age more comorbidity such as hypertension and diabetes is manifested. Transplantation of kidneys from older donors has been associated with early hyperfiltration renal injury and shortened graft survival.^{43,44} The use of older living donors remains controversial because of the physiological decline in glomerular filtration rate beginning in the third decade of life and an increased risk of surgical complications for the older kidney donor.^{45,46} Garg *et al.* assessed a systematic review on proteinuria and reduced kidney function in living kidney donors.⁴⁷ They revealed that older age at the time of donation was associated with both lower pre- and post-donation glomerular filtration rate (GFR). However, the change in GFR after donation was not statistically associated with donor age at the time of donation. Boudville *et al.* performed a systematic review on hypertension after kidney donation and revealed a 5 mmHg increase in blood pressure within five to ten years after donation over that anticipated with normal ageing.⁴⁸ Age usually older than 60 years and older age at the time of donation were prognostic features associated with larger increases in blood pressure. The United Kingdom guidelines for living donor kidney transplantation stated that age alone is not an absolute contraindication to donation but the medical assessment of older donors (>60 years) must be particularly rigorous to ensure that they are suitable. Both donor and recipient should be made aware that the older donor may be at greater risk of perioperative complications and that the function and possibly the long-term survival of the graft may be compromised.⁴⁹

However, studies have demonstrated similar graft survival rates of older and younger kidney donors.⁵⁰⁻⁵³ Several studies revealed no differences in complication rates between older and younger donors.^{54,56} In a prospective study surgical outcome and the quality of life were examined in older living donors, defined as 55 years and older. There were no significant differences in intraoperative and postoperative complication rates or in the one-year graft survival rate between younger and older donors. Elderly donors ($n=34$) had both significantly lower postoperative pain at rest at day 1 compared with the younger group ($p=0.019$) and a lower total pain score in the analysis for the whole follow-up period ($p=0.002$).

Obese donors

More and more transplant centres are faced with obese donors. However, obesity is recognised as an independent cardiovascular risk factor and has also been shown to be a significant risk factor for complications following major surgery, including living kidney donation.^{57,58} Recently, obesity has been recognised as an independent risk factor for end-stage renal disease.⁵⁹ Compared with persons who had normal weight, obese persons had an increased adjusted relative risk for end-stage renal disease. In a retrospective study of 73 patients, Praga *et al.* reported that 13 out of 14 (92%) obese donors (BMI >30) developed proteinuria and renal impairment after a mean follow-up of ten years compared with 12% of nonobese donors.⁶⁰ A retrospective study involving 5304 donors revealed no differences in readmission and reoperation rates between normal and obese donors. Higher BMI was associated with higher blood pressure ($p<0.01$). At six months, decline in estimated glomerular filtration rate from baseline ($p=0.63$) and percent change in creatinine ($p=0.11$) did not differ significantly across groups. Delayed graft function was more common among recipients of kidneys from very obese donors (odds ratio 2.16, CI 1.20 to 3.89, $p<0.01$).⁶¹ Nevertheless, obese donors are accepted in donor selection programmes. The United Kingdom guidelines for living donor kidney transplantation describe that obese patients should undergo careful preoperative evaluation to exclude cardiovascular, respiratory and renal disease. They should be counselled regarding the increased perioperative risk and potential long-term risk of renal disease and advised to lose weight prior to donation and encouraged to adopt a healthy lifestyle.⁴⁹

A randomised controlled trial comparing two mini-incision techniques and judging the impact on the quality of life, pain, and safety of living kidney donors, revealed significantly longer incision length as well as higher blood loss in obese donors.⁶² Open surgical nephrectomy in obese subjects is associated with higher rates of postoperative complications, primarily wound related.⁵⁸ A prospective study revealed a lower conversion rate in obese female

donors compared with obese male donors, due to different distribution of fatty tissue.⁶³ At this moment data are lacking on whether hand-assisted laparoscopic donor nephrectomy or total laparoscopic donor nephrectomy has additional advantages in kidney retrieval from obese donors.

POSTOPERATIVE FACTORS

Complications

The described mortality risk for open and laparoscopic nephrectomy is 0.03%.^{8,64} The complication rate of donor nephrectomy is approximately 10%.^{6,18} Major complications, defined as Clavien⁶⁵ grade ≥ 3 , are rare, ranging from 2.9 to 5.8%.⁶⁶⁻⁶⁸ By comparison, pulmonary complications, including atelectasis, pneumothorax, pulmonary congestion, hypoxia, thrombophlebitis, intramural thrombus, and deep vein thrombosis, were reported more often after open donor nephrectomy than after laparoscopic donor nephrectomy. Wound complications including wound infection or abscess, wound haematoma, or seroma and incisional hernia were reported both for laparoscopic donor nephrectomy and open donor nephrectomy patients. Vascular complications, in particular injury to renal arteries and veins, were reported more often for laparoscopic donor nephrectomy patients, whereas fever, pain, and nausea were reported more often for open donor nephrectomy patients. In 2006, Kocak *et al.* described a graded classification scheme for reporting complications of laparoscopic donor nephrectomy, which may be useful for maintaining registry information on donor outcomes and when informing potential donors about the risks and benefits of this procedure.⁶⁹ In their analysis of 600 laparoscopic donor nephrectomies a complication rate of 7.2% was reported. These complications were scored in four grades. Grade 1 was defined as all events that, if left untreated, would have a spontaneous resolution or needed a simple bedside procedure (39.5%). Grade 2 complications differ from grade 1 in that they are potentially life-threatening and usually require some form of intervention, but do not result in ongoing disability (55.8%). Grade 3 complications are events with residual or lasting disability (4.7%). Grade 4 events are those resulting in renal failure or death because of any complication (0%).

Long-term follow-up

Long-term follow-up data are crucial for potential donors. In the open (donor) nephrectomy group numerous studies have revealed no increased risk in morbidity or mortality.^{70,71} Forty-five year follow-up of World War II veterans who had undergone unilateral nephrectomy for trauma revealed no increased risk of hypertension or end-stage renal disease.⁷² A recent cohort study from a single centre published long-term follow-up after kidney donation.⁷³ In total 3698 kidney donors were followed from 1963 to 2007. End-stage

renal disease developed in 11 donors, a rate of 180 cases per million persons per year, as compared with a rate of 268 per million per year in the general population. Older age and higher body-mass index were associated with both a GFR <60 ml/min and hypertension. Survival appears to be similar to that in the general population.

In addition, the physical and mental quality of life of the donors was higher for the donors compared with a control group. Laparoscopic donor nephrectomy is a more recent technique and long-term follow-up data are not yet available.

Recipient graft function

One-year graft survival after laparoscopic donor nephrectomy ranges from 93 to 100% and after open donor nephrectomy from 91 to 100%.^{6,18} Five-year graft survival after laparoscopic donor nephrectomy is 91% and after open donor nephrectomy 86%.¹⁹

To date, no long-term graft survival data between laparoscopic donor nephrectomy and open donor nephrectomy are available.

We might conclude that laparoscopic procurement of living donor kidneys does not have a clinically measurable negative effect on the kidney transplant.

Quality of life

The benefits of living kidney transplantations are well documented and a recently published systematic review revealed that most donors have a quality of life that is similar or even better when compared with the general population.⁷⁴ Most studies in which the donor's quality of life is evaluated report equivalent or better results if compared with healthy controls.⁷⁵⁻⁷⁸ These results are linked to the intense medical evaluation of potential living kidney donors, resulting in the selection of only healthy and motivated individuals. Preoperatively, quality of life scores are higher than the age-matched healthy population. Postoperatively, the quality of life drops significantly; however, after three months it returns to the level at baseline.³⁴

Several studies as described earlier in this review have demonstrated a better quality of life of donors after laparoscopic donor nephrectomy than after open donor nephrectomy.^{14,79,80}

Costs

Laparoscopic donor nephrectomy has the potential to be more expensive due to the longer surgery and the use of disposable instruments. However, the shorter hospital stay and the donor's earlier return to work should negate the costs. Global hospital costs related to a living donor laparoscopic procedure depend on the balance between the length of the hospital stay and equipment costs.^{6,81} Several studies have demonstrated the better cost-effectiveness of laparoscopic donor nephrectomy as compared with open donor nephrectomy. This result of the laparoscopic

technique can only be achieved if the length of hospital stay is short and there is a low complication rate.

CONCLUSION

Laparoscopic donor nephrectomy is a relatively new technique and has become a safe procedure. Various earlier contraindications to laparoscopic donor nephrectomy, such as right donor kidney, multiple vessels and anomalous vasculature, have been overcome with increasing experience. Compared with open donor nephrectomy, laparoscopic donor nephrectomy has shown superior results in terms of postoperative pain, cosmetics, convalescence, and return to normal daily activities. No significant differences exist between the two approaches in terms of complication rates, cost-effectiveness and graft function. Finally, the longer operating time and warm ischaemia time during laparoscopic donor nephrectomy showed no significant deleterious effect on graft survival. Laparoscopic donor nephrectomy has become the standard method for procuring kidney grafts of living donors in many centres.

REFERENCES

1. U.S. Department of Health and Human Services. 2005 Annual Report of the U.S. Organ Procurement and Transplantation Network and the Scientific Registry of Transplant Recipients: Transplant Data 1995–2004. Rockville, MD: Health Resources and Services Administration, Healthcare Systems Bureau, Division of Transplantation. 2005.
2. Simforoosh N, Basiri A, Tabibi A, Shakhssalim N, Hosseini Moghaddam SM. Comparison of laparoscopic and open donor nephrectomy: a randomized controlled trial. *BJU Int.* 2005;95(6):851-5.
3. Wolf JS, Jr., Marcovich R, Merion RM, Konnak JW. Prospective, case matched comparison of hand assisted laparoscopic and open surgical live donor nephrectomy. *J Urol.* 2000;163(6):1650-3.
4. Ratner LE, Ciseck LJ, Moore RG, Cigarroa FG, Kaufman HS, Kavoussi LR. Laparoscopic live donor nephrectomy. *Transplantation.* 1995;60(9):1047-9.
5. Shokeir AA. Open versus laparoscopic live donor nephrectomy: a focus on the safety of donors and the need for a donor registry. *J Urol.* 2007;178(5):1860-6.
6. Toher RL, Rao MM, Scott DF, Wall DR, Francis DM, Bridgewater FH, et al. A systematic review of laparoscopic live-donor nephrectomy. *Transplantation.* 2004;78(3):404-14.
7. Kok NF, Weimar W, Alwayn IP, IJzermans JN. The current practice of live donor nephrectomy in Europe. *Transplantation.* 2006;82(7):892-7.
8. Matas AJ, Bartlett ST, Leichtman AB, Delmonico FL. Morbidity and mortality after living kidney donation, 1999-2001: survey of United States transplant centers. *Am J Transplant.* 2003;3(7):830-4.
9. Srivastava A, Tripathi DM, Zaman W, Kumar A. Subcostal versus transcostal mini donor nephrectomy: is rib resection responsible for pain related donor morbidity. *J Urol.* 2003;170(3):738-40.
10. Kok NF, Alwayn IP, Schouten O, Tran KT, Weimar W, IJzermans JN. Mini-incision open donor nephrectomy as an alternative to classic lumbotomy: evolution of the open approach. *Transpl Int.* 2006;19(6):500-5.
11. Lewis GR, Brook NR, Waller JR, Bains JC, Veitch PS, Nicholson ML. A comparison of traditional open, minimal-incision donor nephrectomy and laparoscopic donor nephrectomy. *Transpl Int.* 2004;17(10):589-95.
12. Neipp M, Jackobs S, Becker T, et al. Living donor nephrectomy: flank incision versus anterior vertical mini-incision. *Transplantation.* 2004;78(9):1356-61.
13. Kok NF, Lind MY, Hansson BM, et al. Comparison of laparoscopic and mini incision open donor nephrectomy: single blind, randomised controlled clinical trial. *BMJ.* 2006;333(7561):221.
14. Kok NF, Alwayn IP, Tran KT, Hop WC, Weimar W, IJzermans JN. Psychosocial and physical impairment after mini-incision open and laparoscopic donor nephrectomy: A prospective study. *Transplantation.* 2006;82(10):1291-7.
15. Antcliffe D, Nanidis TG, Darzi AW, Tekkis PP, Papalois VE. A meta-analysis of mini-open versus standard open and laparoscopic living donor nephrectomy. *Transpl Int.* 2009;22(4):463-74.
16. Oyen O, Andersen M, Mathisen L, et al. Laparoscopic versus open living-donor nephrectomy: experiences from a prospective, randomized, single-center study focusing on donor safety. *Transplantation.* 2005;79(9):1236-40.
17. Leventhal JR, Kocak B, Salvalaggio PR, et al. Laparoscopic donor nephrectomy 1997 to 2003: lessons learned with 500 cases at a single institution. *Surgery.* 2004;136(4):881-90.
18. Nanidis TG, Antcliffe D, Kokkinos C, et al. Laparoscopic versus open live donor nephrectomy in renal transplantation: a meta-analysis. *Ann Surg.* 2008;247(1):58-70.
19. Nicholson ML, Kaushik M, Lewis GR, et al. Randomized clinical trial of laparoscopic versus open donor nephrectomy. *Br J Surg.* 2010;97(1):21-8.
20. Maartense S, Idu M, Bemelman FJ, Balm R, Surachno S, Bemelman WA. Hand-assisted laparoscopic live donor nephrectomy. *Br J Surg.* 2004;91(3):344-8.
21. Kokkinos C, Nanidis T, Antcliffe D, Darzi AW, Tekkis P, Papalois V. Comparison of laparoscopic versus hand-assisted live donor nephrectomy. *Transplantation.* 2007;83(1):41-7.
22. Bargman V, Sundaram CP, Bernie J, Goggins W. Randomized trial of laparoscopic donor nephrectomy with and without hand assistance. *J Endourol.* 2006;20(10):717-22.
23. El-Galley R, Hood N, Young CJ, Deierhoi M, Urban DA. Donor nephrectomy: A comparison of techniques and results of open, hand assisted and full laparoscopic nephrectomy. *J Urol.* 2004;171(1):40-3.
24. Wolf JS, Jr., Merion RM, Leichtman AB, et al. Randomized controlled trial of hand-assisted laparoscopic versus open surgical live donor nephrectomy. *Transplantation.* 2001;72(2):284-90.
25. Gjertsen H, Sandberg AK, Wadstrom J, Tyden G, Ericzon BG. Introduction of hand-assisted retroperitoneoscopic living donor nephrectomy at Karolinska University Hospital Huddinge. *Transplant Proc.* 2006;38(8):2644-5.
26. Sundqvist P, Feuk U, Haggman M, Persson AE, Stridsberg M, Wadstrom J. Hand-assisted retroperitoneoscopic live donor nephrectomy in comparison to open and laparoscopic procedures: a prospective study on donor morbidity and kidney function. *Transplantation.* 2004;78(1):147-53.
27. Wadstrom J, Lindstrom P, Engstrom BM. Hand-assisted retroperitoneoscopic living donor nephrectomy superior to laparoscopic nephrectomy. *Transplant Proc.* 2003;35(2):782-3.
28. Horgan S, Vanuno D, Sileri P, Cicalese L, Benedetti E. Robotic-assisted laparoscopic donor nephrectomy for kidney transplantation. *Transplantation.* 2002;73(9):1474-9.
29. Renoult E, Hubert J, Ladriere M, et al. Robot-assisted laparoscopic and open live-donor nephrectomy: a comparison of donor morbidity and early renal allograft outcomes. *Nephrol Dial Transplant.* 2006;21(2):472-7.
30. Lennerling A, Blohme I, Ostraat O, Lonroth H, Olausson M, Nyberg G. Laparoscopic or open surgery for living donor nephrectomy. *Nephrol Dial Transplant.* 2001;16(2):383-6.
31. Leventhal JR, Deeik RK, Joehl RJ, et al. Laparoscopic live donor nephrectomy--is it safe? *Transplantation.* 2000;70(4):602-6.
32. Sasaki TM, Finelli F, Bugarin E, et al. Is laparoscopic donor nephrectomy the new criterion standard? *Arch Surg.* 2000;135(8):943-7.

33. Lind MY, Hazebroek EJ, Hop WC, Weimar W, Jaap BH, Ijzermans JN. Right-sided laparoscopic live-donor nephrectomy: is reluctance still justified? *Transplantation*. 2002;74(7):1045-8.
34. Minnee RC, Bemelman WA, Maartense S, Bemelman FJ, Gouma DJ, Idu MM. Left or right kidney in hand-assisted donor nephrectomy? A randomized controlled trial. *Transplantation*. 2008;85(2):203-8.
35. Belzer FO, Schweizer RT, Kountz SL. Management of multiple vessels in renal transplantation. *Transplant Proc*. 1972;4(4):639-44.
36. Roza AM, Perloff LJ, Naji A, Grossman RA, Barker CF. Living-related donors with bilateral multiple renal arteries. A twenty-year experience. *Transplantation*. 1989;47(2):397-9.
37. Guerra EE, Didone EC, Zanotelli ML, et al. Renal transplants with multiple arteries. *Transplant Proc*. 1992;24(5):1868.
38. Kok NF, Dols LF, Hunink MG, et al. Complex vascular anatomy in live kidney donation: imaging and consequences for clinical outcome. *Transplantation*. 2008;85(12):1760-5.
39. li-El-Dein B, Osman Y, Shokeir AA, Shehab El-Dein AB, Sheashaa H, Ghoneim MA. Multiple arteries in live donor renal transplantation: surgical aspects and outcomes. *J Urol*. 2003;169(6):2013-7.
40. Minnee RC, Surachno S, Bemelman F, et al. Impact of additional vascular reconstructions on survival of kidney transplants. *Int Surg*. 2008;93(2):111-5.
41. Simforoosh N, Basiri A, Shakhssalim N, Ziaee SA, Tabibi A, Moghaddam SM. Effect of warm ischemia on graft outcome in laparoscopic donor nephrectomy. *J Endourol*. 2006;20(11):895-8.
42. Demyttenaere S, Feldman LS, Fried GM. Effect of pneumoperitoneum on renal perfusion and function: a systematic review. *Surg Endosc*. 2007;21(2):152-60.
43. Barrientos A, Portoles J, Herrero JA, et al. Glomerular hyperfiltration as a nonimmunologic mechanism of progression of chronic renal rejection. *Transplantation*. 1994;57(5):753-6.
44. Sanchez-Fructuoso AI, Prats D, Marques M, et al. Does renal mass exert an independent effect on the determinants of antigen-dependent injury? *Transplantation*. 2001;71(3):381-6.
45. Epstein M. Aging and the kidney. *J Am Soc Nephrol*. 1996;7(8):1106-22.
46. Fauchald P, Sodal G, Albrechtsen D, Leivestad T, Berg KJ, Flatmark A. The use of elderly living donors in renal transplantation. *Transpl Int*. 1991;4(1):51-3.
47. Garg AX, Muirhead N, Knoll G, et al. Proteinuria and reduced kidney function in living kidney donors: A systematic review, meta-analysis, and meta-regression. *Kidney Int*. 2006;70(10):1801-10.
48. Boudville N, Prasad GV, Knoll G, et al. Meta-analysis: risk for hypertension in living kidney donors. *Ann Intern Med* 2006;145(3):185-96.
49. British Transplantation Society, The Renal Association. United Kingdom guidelines for living donor kidney transplantation (second edition). 1-4-2005. Internet.
50. Kerr SR, Gillingham KJ, Johnson EM, Matas AJ. Living donors >55 years: to use or not to use? *Transplantation*. 1999;67(7):999-1004.
51. Kumar A, Verma BS, Srivastava A, Bhandari M, Gupta A, Sharma RK. Long-term followup of elderly donors in a live related renal transplant program. *J Urol*. 2000;163(6):1654-8.
52. Tanaka K, Kinukawa T, Matsuura O, et al. The effect of donor age on living-related kidney transplantation. *Transplant Proc*. 2000;32(7):1583-4.
53. Remuzzi G, Cravedi P, Perna A, et al. Long-term outcome of renal transplantation from older donors. *N Engl J Med*. 2006;354(4):343-52.
54. Minnee RC, Bemelman WA, Polle SW, et al. Older living kidney donors: surgical outcome and quality of life. *Transplantation*. 2008;86(2):251-6.
55. Johnson SR, Khwaja K, Pavlakis M, Monaco AP, Hanto DW. Older living donors provide excellent quality kidneys: a single center experience (older living donors). *Clin Transplant*. 2005;19(5):600-6.
56. Tsuchiya N, Satoh S, Sato K, et al. Hand assisted retroperitoneoscopic living donor nephrectomy in elderly donors. *J Urol*. 2006;175(1):230-4.
57. Heimbach JK, Taler SJ, Prieto M, et al. Obesity in living kidney donors: clinical characteristics and outcomes in the era of laparoscopic donor nephrectomy. *Am J Transplant*. 2005;5(5):1057-64.
58. Pesavento TE, Henry ML, Falkenhain ME, et al. Obese living kidney donors: short-term results and possible implications. *Transplantation*. 1999;68(10):1491-6.
59. Hsu CY, McCulloch CE, Iribarren C, Darbinian J, Go AS. Body mass index and risk for end-stage renal disease. *Ann Intern Med*. 2006;144(1):21-8.
60. Praga M, Hernandez E, Herrero JC, et al. Influence of obesity on the appearance of proteinuria and renal insufficiency after unilateral nephrectomy. *Kidney Int*. 2000;58(5):2111-8.
61. Reese PP, Feldman HI, Asch DA, Thomasson A, Shults J, Bloom RD. Short-term outcomes for obese live kidney donors and their recipients. *Transplantation*. 2009;88(5):662-71.
62. Aguiar WF, Passerotti CC, Claro JF, et al. Mini-incisions by lumbotomy or subcostal access in living kidney donors: a randomized trial comparing pain, safety, and quality of life. *Clin Transplant*. 2007;21(2):269-76.
63. Kok NF, Ijzermans JN, Schouten O, Tran KT, Weimar W, Alwayn IP. Laparoscopic donor nephrectomy in obese donors: easier to implement in overweight women? *Transpl Int*. 2007;20(11):956-61.
64. Najarian JS, Chavers BM, McHugh LE, Matas AJ. 20 years or more of follow-up of living kidney donors. *Lancet*. 1992;340(8823):807-10.
65. Clavien PA, Camargo CA, Jr., Croxford R, Langer B, Levy GA, Greig PD. Definition and classification of negative outcomes in solid organ transplantation. Application in liver transplantation. *Ann Surg*. 1994;220(2):109-20.
66. Mjoen G, Oyen O, Holdaas H, Midtvedt K, Line PD. Morbidity and mortality in 1022 consecutive living donor nephrectomies: benefits of a living donor registry. *Transplantation*. 2009;88(11):1273-9.
67. Patel S, Cassuto J, Orloff M, et al. Minimizing morbidity of organ donation: analysis of factors for perioperative complications after living-donor nephrectomy in the United States. *Transplantation*. 2008;85(4):561-5.
68. Permpongkosol S, Link RE, Su LM, et al. Complications of 2,775 urological laparoscopic procedures: 1993 to 2005. *J Urol*. 2007;177(2):580-5.
69. Kocak B, Koffron AJ, Baker TB, et al. Proposed classification of complications after live donor nephrectomy. *Urology*. 2006;67(5):927-31.
70. Baudoin P, Provoost AP, Molenaar JC. Renal function up to 50 years after unilateral nephrectomy in childhood. *Am J Kidney Dis*. 1993;21(6):603-11.
71. Fehrman-Ekholm I, Elinder CG, Stenbeck M, Tyden G, Groth CG. Kidney donors live longer. *Transplantation*. 1997;64(7):976-8.
72. Narkun-Burgess DM, Nolan CR, Norman JE, Page WF, Miller PL, Meyer TW. Forty-five year follow-up after uninephrectomy. *Kidney Int*. 1993;43(5):1110-5.
73. Ibrahim HN, Foley R, Tan L, et al. Long-term consequences of kidney donation. *N Engl J Med*. 2009;360(5):459-69.
74. Clemens KK, Thiessen-Philbrook H, Parikh CR, et al. Psychosocial health of living kidney donors: a systematic review. *Am J Transplant*. 2006;6(12):2965-77.
75. Fehrman-Ekholm I, Tyden G. Donors need support too. *Transplantation*. 2004;78(6):787.
76. Giessing M, Reuter S, Schonberger B, et al. Quality of life of living kidney donors in Germany: a survey with the Validated Short Form-36 and Giessen Subjective Complaints List-24 questionnaires. *Transplantation*. 2004;78(6):864-72.
77. Isotani S, Fujisawa M, Ichikawa Y, et al. Quality of life of living kidney donors: the short-form 36-item health questionnaire survey. *Urology*. 2002;60(4):588-92.
78. Johnson EM, Anderson JK, Jacobs C, et al. Long-term follow-up of living kidney donors: quality of life after donation. *Transplantation*. 1999;67(5):717-21.
79. Andersen MH, Mathisen L, Veenstra M, et al. Quality of life after randomization to laparoscopic versus open living donor nephrectomy: long-term follow-up. *Transplantation*. 2007;84(1):64-9.
80. Perry KT, Freedland SJ, Hu JC, et al. Quality of life, pain and return to normal activities following laparoscopic donor nephrectomy versus open mini-incision donor nephrectomy. *J Urol*. 2003;169(6):2018-21.
81. Kok NF, Adang EM, Hansson BM, et al. Cost effectiveness of laparoscopic versus mini-incision open donor nephrectomy: a randomized study. *Transplantation*. 2007;83(12):1582-7.