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Minimally invasive living donor nephrectomy – introduction of hand-assistance

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Summary

Conventional open living donor nephrectomy (LDN) technique is perceived as a barrier for expanding living donor programmes. Thus, minimal invasive surgery techniques have been advocated to overcome this hurdle. The aim of this study was to evaluate our experience on minimally invasive LDN. During the last decade we have gradually expanded the use of minimally invasive LDN with various techniques; strictly laparoscopic versus hand-assisted, and laparoscopic versus retroperitoneoscopic. This study is based on 305 consecutive minimally invasive LDN's, from 1998 to 2009. By multiple regression analysis, minimally invasive hand-assisted technique was shown to be associated with a significantly lower risk of major complications and intraoperative incidents, as well as reduced warm ischemia and operative time. In our opinion, the introduction of hand-assisted technique is probably the most significant single factor for improved results, although accumulated experience and developments in equipment will contribute. Our experience indicates that learning curves are facilitated by the use of hand-assisted technique. Improvements in surgical outcomes following donor nephrectomy may enhance living donor programmes.

Introduction

Different methods of minimally invasive living donor nephrectomy (LDN) have gradually been introduced worldwide since the first report in 1995 [1]. Transplant centres differ on which method they prefer [2]. Some centres have chosen a modified procedure with hand-assistance to improve safety [3], others have chosen retroperitoneoscopic access to minimize the risk of injuring intraabdominal organs [4,5]. Refinements in surgical techniques have been paralleled by innovative improvements in equipment: 'High definition' imaging, less traumatic trocars, improved hand ports, and the development of excellent hemostatic devices.

The documented benefits of minimally invasive surgery, with faster recovery and less postoperative pain, have also been demonstrated for minimally invasive LDN [6,7]. A less invasive and safe surgical procedure may encourage more potential donors to come forward, and has led to an expansion of living donor programs in many centres. There have, however, been concerns related to the perioperative safety of donors [8,9].

At our transplant centre, we have since 1998 gradually expanded the use of minimally invasive techniques in LDN. Various approaches have been explored; strictly scopic versus hand-assisted, and laparoscopic versus retroperitoneoscopic technique. In a randomized study of laparoscopic versus open LDN [10], we experienced an unacceptably high rate of complications in the laparoscopic group (including two intestinal perforations), which urged us to explore alternative approaches.

In this study, we evaluate our overall experience with minimally invasive LDN. The study was approved by the regional ethics committee.

Materials and methods

Material

Oslo University Hospital, Rikshospitalet is the only transplant centre in Norway serving 4.6 million people.

Donor selection and work-up are performed by local nephrologists, before final evaluation for donation at the national centre. All Norwegian live kidney donors have since 1997 been registered in a Living Kidney Donor Registry [11]. Three hundred and five live donors were subjected to minimally invasive surgery from November 1998 to September 2009. Parts of our experience have previously been published [10,12,13].

Surgical technique

During the study period, three transplant surgeons were responsible for the minimally invasive donor nephrectomies. Four different types of minimally invasive technique have been utilized during these years: Strictly laparoscopic ($n = 53$), laparoscopic with hand-assistance at the final stages of the procedure without hand port ($n = 46$), hand-assisted laparoscopic with hand port ($n = 180$), and hand-assisted retroperitoneoscopic with hand port ($n = 26$). Hand-assisted laparoscopic or retroperitoneoscopic with hand port are currently the preferred techniques.

All minimally invasive LDN's were performed in flank position with minimal or no hip angulation. Pneumoperitoneum was created by open introduction of the first port, using a small transumbilical incision (strictly laparoscopic) or by the hand port incision (initially midline; later Pfannenstiel). The intraperitoneal pressure was maintained at a level of 10–12 mmHg. We have throughout the period used a 10 mm 30° optical device, and since 2007 a 'high definition' imaging system.

The strictly laparoscopic technique required 4–5 ports (12/11/5 mm). Atraumatic, non-cutting trocars have been employed since 2006. During the hand-assisted era (2005–present) we initially used an infraumbilical midline incision (7–9 cm), but in 2006 changed to a transverse Pfannenstiel incision (Fig. 1a,f). Three different types of hand ports have been applied; inflatable balloon sleeve (2005–2006), iris principle type of sleeve (2006–2008) and lately the Gelport sleeve (2008–present) (Fig. 1b).

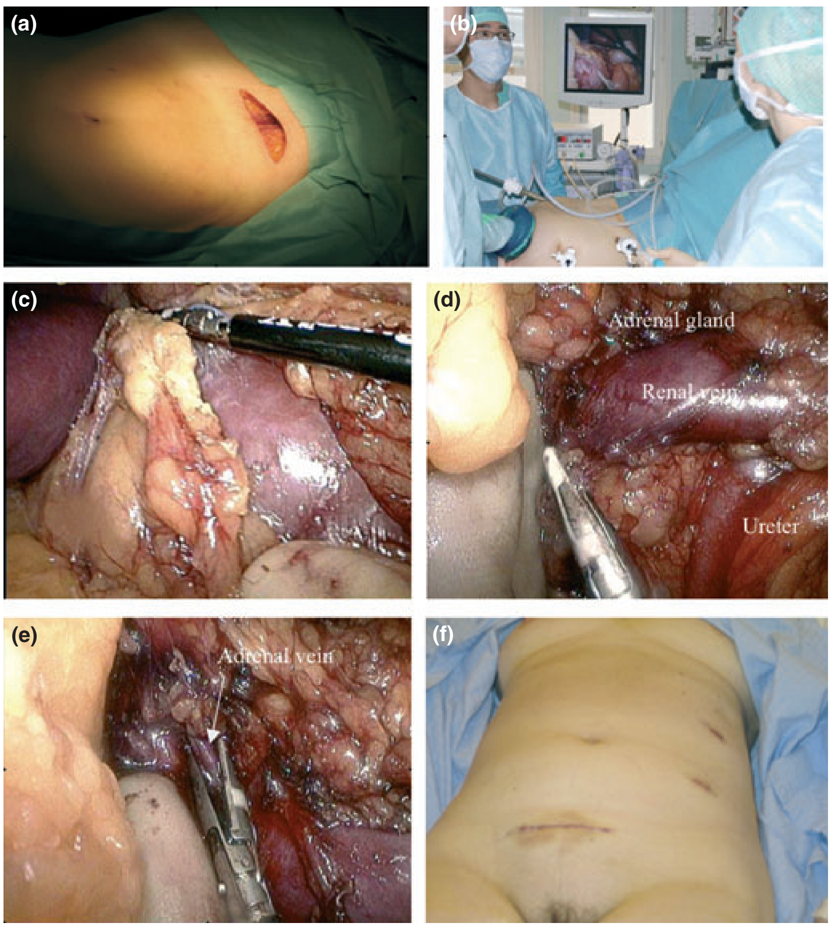

Figure 1 *Surgical technique.* (a) The Pfannenstiel incision (7–9 cm); transverse through skin, midline through fascia. (b) Hand port (Gelport) applied in right-sided living donor nephrectomy (LDN). (c) Efficient hand-assisted dissection by means of LigaSure (5 mm). (d) Liberating the left renal vein, by LigaSure sealing of all branches (no clips). (e) Dividing the left adrenal vein by LigaSure. (f) Exterior result of left-sided LDN.

From 2005 a retroperitoneoscopic, hand-assisted approach was applied. Initially we used an infraumbilical incision and created a hand-made retroperitoneal space/cavity by stripping off the peritoneal membrane from the caudal/lateral position. This technique was largely abandoned in favour of a laparoscopic route. However, some hand-assisted retroperitoneoscopic procedures are still performed due to personal surgical preferences.

During the first years, dissection was mainly carried out by means of a 5 mm ultrasonic knife (AutoSonix; US Surgical, Norwalk, CT, USA). The branches of the renal vein were exposed using a Kelly dissector and divided between titanium clips (AcuClip; US Surgical). From 2007, Ultracision (Ethicon, Somerville, NJ, USA) has been replaced by LigaSure (Covidien, Boulder, CO, USA), making division of all renal vein branches (and ureter) possible without clips (Fig. 1c–e). The renal artery has either been divided by an endo-GIA stapler/roticulator (Covidien; US Surgical) or by two titanium clips towards the aortic wall (mostly in cases of early arterial branching). Dividing of the renal vein has in all cases been handled by the endo-GIA roticulator.

At the start of the laparoscopic era, a basket (Endo-Catch; US Surgical) was used for kidney harvesting, which later was replaced with a modified, simple hand-assisted technique [10]. The left hand was introduced through a minimal, 'closely fitting' incision, without the use of hand port device – to facilitate the final handling and extraction of the kidney [13].

As detailed above, we have since 2005 employed full hand-assistance with hand-port, also in 26 retroperitoneoscopic procedures. After implementing full hand-assistance, we started performing right-sided nephrectomies in 2006. Periureteral dissection has been kept wide to avoid devascularization [14].

The open LDN's performed during the same era have been carried out by retroperitoneal access through flank incision (15–20 cm) at the level of the 11.0–12.0 rib without rib resection. Seven consultant transplant surgeons have been responsible for conventional open LDN's. Since March 2009, all LDN's have been performed by minimally invasive hand assisted technique.

Postoperative analgesia.

At the start of the donor operation, 8 mg dexamethason was administered intravenously (IV) as a single dose, while paracetamol and ketorolac were started at the end of anesthesia. At day 0, day 1 and day 2, the donors received paracetamol 1 g × 4 IV and ketorolac 30 mg × 3 IV, thereafter per oral medication; paracetamol 1 g × 4 and ketorolac 10 mg × 4. A patient-controlled analgesic device (PCA) offered pain relief during the first days, delivering ketobemidon in bolus doses of 0.1 mg/kg body weight. The PCA was discontinued at day 3–5, when oral opioid analgetics were offered and supplemental IV analgesics were used as needed.

Data collection/Definitions

Significant bleeding was defined as blood loss of more than 1000 ml or requiring transfusions. Warm ischemia time was defined as time from renal artery occlusion to the start of cold Eurocollins perfusion at the back table. Hospital stay was not included as an outcome variable, because donors due to long travel distances are allowed to stay in-hospital together with recipients at their will.

Postoperative complications were defined according to the Clavien classification [15]. This classification defines a postoperative complication as: 'deviation from the ideal postoperative course'. Complications are divided into five grades based on the level of treatment needed. Grade 1 requires no specific therapy, grade 2 requires medical therapy, grade 3 requires surgical or endoscopic treatment, grade 4 requires intensive care and grade 5 is death. Possible complications were reviewed and classified by two of the authors. More or equal to grade 3 was defined as a major complication. Grade 1 and 2 was defined as a minor complication.

Adverse events occuring intraoperatively, jeopardizing the donor or the donor kidney, but adequately handled and resulting in no deviation from the ideal postoperative course, were classified as intraoperative incidents.

Statistical analysis

Statistical analysis was conducted using SPSS version 16 (SPSS Inc., Chicago, IL, USA). Univariate tests and descriptive statistics were used where appropriate. Multiple linear regression analysis was used for examining effects of donor and operative risk factors on continuous outcomes, and multiple logistic regression was used for categorical outcomes.

Results

Characteristics of donors and donors' kidneys are described in Table 1. The right kidney was procured in 17% of donors, and 14.1% of removed kidneys had some kind of vascular variations. With increasing institutional experience, vascular variations on preoperative imaging were no longer considered a contraindication to laparoscopic surgery. Mean operative time was 176 min. Mean warm ischemia time was 3.6 min. Mean artery length in the procured kidney was 28 mm, mean vein length was 31 mm in left kidneys and 20 mm in right kidneys. Med-

Table 1. Preoperative donor characteristics.

Variable	N	Means (SD), frequencies (%)
Height (cm)	304	171.4 (9.6)
Weight (kg)	305	73.5 (12.7)
BMI (kg/m^2)	304	24.9 (3.1)
Age (years)	305	47.2 (11.3)
18–20		1 (0.3)
21–30		19 (6.2)
31–40		72 (23.6)
41–50		100 (32.8)
51–60		78 (25.6)
61–70		30 (9.8)
71–80		5 (1.6)
Male (%)	305	121 (39.7)
Smoking (%)	293	87 (28.5)
Renal vessel anomalies (%)	305	43 (14.1)
Multiple arteries		17 (5.6)
Pole artery		9 (3.0)
Early division		6 (2.0)
Multiple veins		11 (3.6)
Retroaortic renal vein		4 (1.3)
BMI >25 (%)	304	148 (48.5)
BMI > 30 (%)	304	17 (5.6)

N, number of donors; BMI, body mass index.

ian hospital stay was 7 days. The reduction in hemoglobin level from admission to discharge was significantly lower when performing hand-assisted surgery (1.0 g/dl vs. 1.7 g/dl, $P < 0.001$).

Surgical data are listed in Table 2. Eleven donors suffered a major complication, 30 donors experienced minor complications and 13 donors had an intraoperative incident (Table 3). Two of the intraoperative incidents were related to endo-GIA malfunction and one was related to slipped vascular clips. Among the intraoperative incidents there were three conversions to open surgery. These were caused by lesion of a renal artery branch, intimal tear in the aortic wall at the exit of the renal artery and malfunctioning/locked endo-GIA. There was no mortality.

The effects of donor and surgical factors on operative time and warm ischemia time are shown in Table 4. Hand-assisted surgery ($P < 0.001$), and right kidney ($P = 0.02$) were associated with shorter operative times. Hand-assisted surgery ($P < 0.001$) also resulted in shorter warm ischemia time. Male gender ($P < 0.001$) required longer operative time.

A combined outcome of major complications and intraoperative incidents was chosen to, study risk factors for adverse outcomes. Significantly decreased risk was associated with hand-assisted surgery ($P = 0.02$) (Table 5).

Discussion

Our experience indicates that hand-assisted technique should be the preferred surgical technique in living donor programmes. We have during the last decade observed improved safety and efficacy by using this technique. Hand-assistance was associated with a lower risk of major complications and intraoperative incidents. In our experience, this technique allows fast and efficient dissection,

Table 2. Surgical data.

Variable	N	All, *n* = 305	L-LDN, *n* = 102	HA-LDN, *n* = 177	HA-RP-LDN, *n* = 26
Time (min)	299	176 (42.5)	196 (51.3)	165 (34.2)	172 (31.0)
Warm ischemia (min)	296	3.6 (1.4)	4.4 (1.5)	3.2 (1.1)	3.1 (0.8)
Length of artery (mm)	241	28 (7)	28 (6)	29 (8)	28 (8)
Length of vein, left kidney (mm)	241	31 (7)	33 (6.4)	30 (7)	33 (7)
Length of vein, right kidney (mm)	52	20 (7)	NA	20 (7)	10 (NA*)
Ureter length (mm)	241	125 (21)	133 (18)	121 (20)	125 (24)
Patient controlled analgesia day 0 + 1 (mg morphine eq)	282	37.2 (21.6)	32.4 (18.3)	39.3 (22.4)	38.5 (24,1)
Hospital stay (days)	305	7 (3–50)	6 (3–50)	7 (4–11)	7 (4–9)
Right kidney	305	52 (17.0)	0 (0)	51 (28.8)	1 (3.8)
Hemoglobin preoperative (g/dl)	305	14.1 (1.1)	14.0 (1.2)	14.1 (1.1)	14.0 (1.0)
Hemoglobin discharge (g/dl)	305	12.9 (1.4)	12.3 (1.3)	13.2 (1.2)	12.3 (1.5)
Major complication	305	11 (3.6)	7 (6.9)	4 (2.0)	0 (0)
Minor complication	305	30 (9.8)	17 (16.7)	10 (5.6)	3 (11.5)
Intraoperative incident	305	13 (4.3)	6 (5.9)	7 (3.4)	0 (0)

Results are expressed as means (SD), median (range), and frequencies (%) where appropriate.
N, number of donors; L-LDN, laparoscopic living donor nephrectomy; HA-LDN, hand-assisted laparoscopic living donor nephrectomy; HA-RP-LDN, hand-assisted retroperitoneoscopic living donor nephrectomy.
*Only one case.

Table 3. Complications and incidents.

Complication/incident	Comment	No.
Major complication		
Jejunal perforation	Reoperation day 10	1
Incisional hernia	Reoperation after 1 year	2
Retained spomge	Reoperation day 2, pulmonary embolism	1
Port hernia, incarcerated bowel	Reoperation day 6, no resection necessary	1
Ileum perforation	Reoperation day 5	1
Wound infection		1
Port bleeding	Reoperation day 5	1
Subcutaneous seroma	Reoperation day 7	1
Lymphocele	Percutaneous drainage	1
Wound rupture	Reoperation day 0	1
Minor complication		
Deep venous thrombosis		2
Blood transfusion		2
Urinary tract infection		18
Other skin infection		1
Wound infection		1
Atrial fibrillation		1
Pneumonia		4
Pneumothorax		1
Intraoperative incident		
Renal artery laceration		4
Renal artery laceration	Open conversion	1
Ureter injury		1
Aortic tear	Endo-GIA failure, open conversion	1
Bleeding from renal artery	Slipped clip (1); endo-GIA failure (1)	2
Bleeding from renal vein		1
Bleeding from lumbar vein	Open conversion	2
Severed splenic artery		1

and enhanced security regarding vascular incidents and gastrointestinal complications. The multimodality of the hands/fingers offers superior technical abilities, by being used as graspers, retractors, tweezers, and not at least as sensory instruments. Allowing the operating surgeon to feel tissue consistency and pulse maintains the benefits of open surgery. These modalities are obtained simultaneously, without having to change instruments. Furthermore, bleeding events are more easily controlled by direct digital compression enhancing donor safety [3]. Since the introduction of hand-assistance with hand port, there has been no major organ injury in our series.

The observed improvements in surgical outcomes are also related to increased experience in minimally invasive surgery as well as refinements and innovations in technical devices and surgical instruments. Video imaging has been greatly improved by 'High definition' techniques. Less traumatic, non-cutting trocars have made port hernias and port bleeding less likely. In our opinion, the Gelport is the superior hand port, due to easy introduction and the easy interchange of operator hands with minimal gas leakage. Among the instrument innovations, the most significant has been the development of hemostatic devices, outranging the conventional diathermia used in open surgery. During the last years, the ultracision/harmonic scalpel' device has been replaced by LigaSure (Covidien), affording improved hemostasis. By LigaSure we now seal and divide all renal vein branches (and ureter) without the use of clips – which represents a major step forward.

We found a significant relationship between the use of hand-assistance and decreased warm ischemia time, as previously reported [16,17]. Operation time decreased throughout the series. Hand-assistance was significantly associated with shorter operative time [18,19]. A previous paper reported similar findings [20], whereas others have found the opposite [16].

Our data support that minimally invasive LDN is easier and faster in females, most likely due to the sex-dependent distribution and consistency of the abdominal fat tissue; in females mostly located subcutaneously, while in males located intra- and retroperitoneally, in many cases with a firm/adherent consistency [16,21,22].

Removal of the right kidney was significantly faster, in accordance with previous reports [16,23,24]. This is probably due to easier access (less colon dissection/ no spleen)

Table 4. Multiple linear regression.

Risk factor	Operative time B (95% CI)	Operative time *P*-value	Warm ischemia time B (95% CI)	Warm ischemia time *P*-value
Age	0.06 (−0.34, 0.46)	0.78	−0.002 (−0.02, 0.01)	0.7
Hand-assisted surgery	−27.7 (−38.5, −16.9)	<0.001	−1.2 (−1.5, −0.8)	<0.001
Retroperitoneoscopic	2.9 (−13.3, 19.2)	0.72	−0.09 (−0.6, 0.42)	0.7
Male gender	18.3 (8.9, 27.7)	<0.001	0.27 (−0.03, 0.57)	0.07
Current smoking	2.7 (−7.3, 12.8)	0.60	−0.05 (−0.4, 0.3)	0.7
Renal vessel anomalies	3.7 (−9.6, 17.1)	0.58	0.08 (−0.3, 0.5)	0.7
BMI	1.0 (−0.6, −2.4)	0.22	0.04 (−0.01, 0.08)	0.1
Right kidney	−15.3 (−28.2, −2.3)	0.02	0.07 (−0.3, 0.5)	0.7

Table 5. Odds ratios for major complications and/or intraoperative incidents (n = 23/305).

Risk factor	Unadjusted Odds ratio	95% CI Lower	95% CI Upper	Adjusted Odds ratio	95% CI Lower	95% CI Upper	*P*-value
Hand-assisted surgery	0.43	0.18	1.01	0.26	0.09	0.77	0.02
Vascular anomaly	1.78	0.63	5.09	1.44	0.48	4.32	0.5
Right kidney	1.81	0.68	4.84	3.47	0.97	12.34	0.06

and fewer renal vein branches. However, the majority of right kidneys were removed late in our series.

Hand-assisted retroperitoneoscopic approach was abandoned in 2005 in favour of the hand-assisted laparoscopic LDN. This was due to technical preferences, and not because of inferior results. The laparoscopic approach exploits a natural working space, in contrast to creating a retroperitoneoscopic space by extensive stripping of the peritoneum, potentially giving rise to 'traumatic peritonitis'. Besides, peritoneal perforations are hard to avoid during the creation of the retroperitoneal cavity – and the obtainable working space is smaller than the pre-made peritoneal cavity. The argument that retroperitoneoscopic LDN reduces the hazard for injury to intraabdominal organs is compelling. However, since the introduction of hand-assistance, we have not experienced any organ injury. Hand-assisted approach may reduce the risk of organ injury by a more controlled introduction of ports and instruments.

In favour of the strictly laparoscopic approach, it might be argued that the incision is smaller. However, due to the elasticity of the skin, the hand port incision may be restricted to 6–8 cm, which is almost identical to the strictly laparoscopic approach. With the Pfannenstiel incision, no extra muscular tissue is cut with the hand-assisted approach, and only 1–3 cm extra incision in the midline is necessary (for large kidneys almost the same incision).

During the entire Norwegian experience from 1963 there has been no perioperative mortality. World-wide the mortality rate has been estimated at 0.03–0.04% [25–27].

Reported complication frequencies from the literature vary according to the definition and grading systems that have been used. In two studies utilizing the Clavien classification, major complication rates of 5.8% [28] and 4.2% [29] were found. These results are comparable to our major complication frequency of 3.6%.

Since the introduction of hand-assistance in 2005, we have not experienced any complications categorized as 'serious' (no organ injury/reoperations, only skin/subcutaneous tissue), though classified as 'major' according to the Clavien system.

Intraoperative incidents, mostly due to bleedings or vascular injuries, occurred in 4.3% of donors, similar to other studies [28]. These events are a common reason for conversion to an open procedure [14,30]. In our material the conversion rate was 1%, Previous studies report conversion rates in the range 1.2–3.3% [14,16,19,30–32], and that hand-assistance decreased the risk of conversion [31,33].

We have experienced serious equipment failure occurred in two cases with the Endo-GIA stapler [34,35]. Conventional open LDN is increasingly seen as a barrier for expanding living donor programmes. However, introduction of minimally invasive techniques should be done carefully, as the initial learning curve may be associated with an increased risk of complications. Our data support the use of the hand-assisted technique for minimally invasive LDN.

Authorship

GM: collected data, performed statistical analysis and participated in writing of the manuscript. HH, PP and P-DL: participated in writing of the manuscript. OØ: collected data and participated in writing of the manuscript.

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