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REVIEW

Laparoscopy for living donor nephrectomy – particularities of the currently applied techniques

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Summary

Today, laparoscopic donor nephrectomy (LDN) in many centers features the standard approach for kidney retrieval in living donors. More than 60% of the centers in the USA currently perform LDN and numbers are rising in Europe as well. Today's variety of laparoscopic approaches reflects the evolution in the field of LDN. Multiple modifications have been made for the laparoscopic approach, with consequences for intraoperative handling of the kidney, operating and ischemic times and with impact on donor, organ, and recipient. We reviewed the literature from 1995 to 2004 and critically evaluated the different technical modifications, their specific advantages and disadvantages and their impact for the operation. The article aims to help the surgeon choose the technique he feels most safe with for performing laparoscopic kidney retrieval safely and with good results for donor and recipient.

Introduction

For most patients with end-stage renal disease, kidney transplantation offers the best cure but there is a growing disparity between the demand and supply of donor organs. With waiting time continuously increasing, 2–10% of the patients die while waiting for a kidney transplantation [1]. The persisting shortage of cadaveric kidneys has led to an increased utilization of living donor kidney transplantation (LDKT). From 2001 on the number of living kidney donors in the USA has outscored the number of cadaveric donors. In Europe Scandinavian countries have the highest share of LDKT but a general trend toward an increase in living kidney donation is seen in Europe as well [http://www.optn.org; 2,3].

Although potential kidney donors have strong altruistic motives, a proportion still refuses organ donation because they fear the invasiveness of the operation and its associated morbidity. Ten years ago, with knowledge of the advantages of urologic laparoscopy and fuelled by the idea to reduce donor obstacles to living kidney donation, Ratner *et al.* [4] performed the first laparoscopic live donor nephrectomy (LDN). Today, more than 200 centers worldwide offer LDN. The advantages for the donor over open nephrectomy are multiple and have been found in many studies. In many studies LDN bears the clinical benefits of reduced pain for the donor because of the minimal invasive technique, resulting in a shorter hospital stay, faster return to work and finally a better cosmetic result [5–7]. A LDN-technique immanent increased risk for the donor and the organ could not be detected by Matas *et al.* [8], who in a survey of all UNOS listed transplantation programs found a donor mortality of 0.03% for laparoscopic organ retrieval, a rate not different from the open approach. Also, a laparoscopically retrieved kidney does not seem to encounter disadvantages. In a survey of more than 680 publications Handschin *et al.* [7] found no difference for delayed graft function (DGF), rejection rates, creatinine at 1 year graft or graft and patient-survival between the open and the laparoscopic approach.

Far more than 10 000 kidneys have been procured laparoscopically during the last 3 years in the USA, covering almost 60% of all LDKT performed [based on organ procurement and transplantation network (OPTN) data as on April 2005]. Thus, LDN has become the standard approach for donor nephrectomy in most centers in the USA. Some authors reported that LDN, as intended by Ratner *et al.* [4], has even increased the number of willing donors [6,9,10], even though it remains a hard to prove issue and center effects must be taken into account.

The LDN was handled controversial in the beginning, as findings were inconclusive for graft function and recipient morbidity. Many surgeons are still reluctant toward this technique, because several specific complications were experienced in the beginning, like ureteral necrosis, ureteral leakage [11–13], DGF, and losses of right donor kidneys [14,15]. Nevertheless, overall graft- and patient-survival were not found to be different [8,11,16]. Therefore, numerous approaches to optimize the individual steps involved in LDN have been developed, like trans- and retro-peritoneal access, hand assistance (hand-assisted laparoscopic surgery, HALS) with different devices, different donor vessel handling, and organ harvesting techniques as well as robotic-assisted surgery. As a consequence of the learning curve in LDN, surgically more challenging donors are accepted for LDN today, like donors with an increased body mass index (BMI) [17,18] or multiple renal arteries [19,20].

To review the different techniques for each step of LDN and evaluate their impact on donor, graft, and laparoscopic surgeon we studied the literature on this topic from the initial LDN in 1995 until 2004.

Material and methods

We performed a literature search for key words referring to LDN (laparoscopic donor nephrectomy, laparoscopy and kidney, living organ donation, living kidney donor, renal transplantation, operation technique, etc.) in several databases (PubMed, DIMDI, Medline). Showing the particularities of the consecutive steps during LDN and taking into account the established demands of this operation we aimed to evaluate the following topics with regard to the advantages, disadvantages, associated risks, and morbidity of different techniques.

1 Route of surgical access.
2 Hand assistance in LDN.
3 Handling of the ureter.
4 Handling of renal vessels and types of ligature.
5 LDN of right kidneys.
6 Length of warm ischemia time (WIT) depending on the different techniques.
7 Technique and site of donor organ delivery and impact on the donor.
8 Robotic-assisted LDN.

Results

Route and kind of surgical access

Independent of the surgical technique applied and the side of the kidney to be retrieved the donor is usually placed in a full flank (lateral decubitus) position with the kidney planned to be extracted facing upwards [2,5,21,22]. Tissues are typically dissected using bipolar forceps and a pair of Metzenbaum scissors [2,6,23], while some authors prefer an ultrasonic dissector [3]. Meticulous control of bleeding is essential to avoid loss of overview because of light absorption by blood [2,5,6,15,21,22,24–27]. Obesity is no contraindication to LDN. Kuo *et al.* [17] and Jacobs *et al.* [18] could show that laparoscopy is also safely feasible in markedly obese patients, but trocar sites and tool sizes must be adapted to the special needs.

The transperitoneal access is treasured by many authors as it provides large working space, irrespective of whether hand assistance is used or not. Not many articles give information about the patient position for inserting the Verres needle. For the hand-assisted approach Slakey *et al.* [28] prefer to insert the Verres neddle in the iliac region. In the pure laparoscopic approach we and other authors [29] prefer the patient to be rotated into the supine position for safe insertion of the Verres needle via an infraumbilical incision. This allows the intestine to retract from the anterior abdominal wall, minimizing the risk of intestinal injury. After inflation of the abdomen with carbon dioxide (12–15 cm water) the Verres needle is retracted and a camera trocar placed subumbilically. Following the inspection of the operative field for accidental injuries the table is tilted back again. Under vision another two to three trocars are inserted when using the purely laparoscopic, transperitoneal approach.

The colon is detached from the dorso-lateral wall prior to access of the retroperitoneum and exposure of the renal vessels and the ureter [2,5,21–23].

Critics object that manipulation of the colon in the transperitoneal approach is associated with an increased risk of injury to the intestine as well as a prolonged postoperative ileus [8]. Therefore, some authors favor the retroperitoneal access. So far only a few studies for the retroperitoneal access exist, with donor numbers between 3 and 29. As hoped for, the authors reported no postoperative bowel obstruction [30–35]. Today, the transperitoneal route is still the most often applied access in LDN. Results of the retroperitoneal access are promising but have to be proved in the future in larger series of donors.

Hand assistance versus pure endoscopy

Hand assistance for LDN was introduced by Wolf *et al.* [36] in 1998. Today about one-third of all donor kidneys in American centers are procured with this approach [8,26,37] and some centers in Europe apply this method as well [26,33]. Different hand assistance devices exist for which a comparative study proved an equal effectiveness with individual advantages and disadvantages [38]. Several arguments for HALS are apparent. First of all, hand assistance gives the operating surgeon his or her well developed tactile sense for dissection, retraction and kidney exposure and surgeons applying HALS report a better assessment and control of vascular structures [8,24–26,28,33,36]. As a consequence, intraoperative and postoperative bleeding were found to be reduced with HALS [8,12,26,28,33,39]. Also, with HALS a significant reduction of overall operating time compared with the pure endoscopic approach was reported. Comparative studies showed that with HALS overall operative time was about 45–60 min shorter [25,26,28,33,39]. Nevertheless, the times achieved within the comparative studies varied widely, expressing the importance of the surgeons experience in the field of LDN (Table 1).

Besides saving costs by reducing the operation time the donor kidney is also exposed shorter to the pneumoperitoneum. Hemodynamic effects of the pneumoperitoneum are thought to be responsible for a worse early graft function (increased creatinine, higher rate of DGF) in LDN [11,16,40]. As DGF was also found to be an independent risk factor for long-term graft-survival, reducing the exposure time of the donor kidney to the potentially negative effects of the pneumoperitoum may be a further argument for HALS [41,42]. Nevertheless, the influence of the pneumoperitoneum on graft function remains controversial. Others reported no difference when comparing the laparoscopic with the open approach [5,16] and it could be shown that the hemodynamic effect of the pneumoperitoneum may well be counterbalanced by optimizing the intraoperative donor management [40].

In the beginning of HALS intraoperative technical problems were the drawbacks of hand assistance. Today, technical modifications have made the application of adhesives to prevent desufflation unnecessary. Overall operation time could thus be reduced and the hand assistance devices was less prone to failure [22,28,38]. Also, additional costs as an argument against HALS do not apply anymore. The additional price of about $400–500 for the hand-port device can be compensated for by the lower costs resulting from shorter operating times and the money saved for other devices. In HALS neither a Verres needle is needed for insufflation nor an Endo-Bag for kidney procurement [22,24–26]. Thus, compared

Table 1. Operating times according to surgical access and method (open, hand assisted, pure endoscopy) with comparison of the different techniques.

			Operating time (min)			
Author	Trans/retro	*n*	Open	Hand assisted	Pure endoscopic	*P*-value
Jacobs *et al*. [21]	Trans	320			215	
Östraat *et al*. [3]	Trans	22			100–240	
Charité Berlin	Trans	70/77	159		203	NS
Brown *et al*. [5]	Trans	50/50	208		234	<0.05
Hazebrook *et al*. [40]	Trans	83/89	155		235	<0.05
Wolf *et al*. [36]	Trans	23/27	125	206		<0.05
Stifelman *et al*. [42]	Trans	31/60	265	240		NS
Lindström *et al*. [26]	Trans	11/11		197	270	<0.05
Stoffel *et al*. [33]	Trans	33/14		185	230	<0.05
Ruiz-Deja *et al*. [39]	Trans	23/11		165	215	<0.05
Slakey *et al*. [28]	Trans	12/10		121	187	<0.05
Velidedeoglu *et al*. [25]	Trans	50/60/40	175	260	255	Open versus laparoscopy: <0.05; hand assisted versus pure laparoscopy: NS
Hoznek *et al*. [30]	Retro	3			83	
Rassweiler *et al*. [31]	Retro	10		216		
Wadstrom and Lindstrom [32]	Retro	10		155		
Ng *et al*. [34]	Retro	29			190	
Bachmann *et al*. [35]	Retro	30/28		170	158	NS

with pure laparoscopy Lindström *et al.* [26] found that HALS saved up to 1100 US$.

Handling of the ureter

In the beginning of LDN an increased rate of ureteral necrosis and leakage after implantation was observed by some [11,13,21,27]. Different attempts to reduce manipulation of the ureter and secure its blood supply were made, like use of the harmonic scalpel for dissection and resection of the gonadal vessels together with the ureter [13,27]. Today it is mostly accepted that irrespective of the technique applied the learning curve of LDN seems to be the most important factor. With knowledge of the necessity to prepare the ureter most careful, avoid coagulation and secure its blood supply by dissecting it with as much as possible surrounding fatty tissue, complications resolved in the later series. In large series no higher rate of ureteral complications has been reported anymore [11,13,21,27].

Handling of renal vessels

Different aspects are important in donor vessel handling. To prevent spasms of the renal artery perivascular dissection rather than dissection of the renal artery itself is recommended as well as topical application of papaverine [11,22,43]. For secure lockage vessels are usually ligated by standard or locking clips (Fig. 1) or transfixing automatic stapler devices [endo-gastrointestinal anastomoses (GIA)/endo-TA] (Fig. 2).

Despite several variations, some principles in donor vessel handling should be kept in mind, concerning

1 secure lockage of the vessel stump remaining with the donor;

2 preservation of maximal arterial and venous length of the donor organ;

3 avoidance of vessel damage.

For this purpose the different authors propose multiple solutions.

1 The renal artery should be clipped prior to the vein and the portion of the graft vessel left unclipped [2,23,33].

2 When using titanium clips (Ethicon Endo-Surgery, Cincinnati, OH, USA), three clips should be placed on the proximal renal artery to secure lockage [44], as non-sufficient vessel lockage has been described [45]. Application of only one Hem-o-Lok clip (Tyco, Mansfield, MA, USA) on the renal artery was reported, bearing the advantage of only minimal loss of vessel length [43]. For safety reasons we and others rather rely on using two [46].

3 For the renal vein, titanium clips are often too small and stapling devices are used (Table 2). The endo-GIA stapler causes a loss of renal vessel length of about 1.0 cm. Nevertheless, also clipping of the vein necessitates a vessel stump and thus leads to loss of venous length. Furthermore, WIT is (marginally) prolonged because the proportion of the renal vein with the row of staples has to be removed prior to perfusion. Avoiding the necessity of clip trimming by removing the lateral rows of the endo-GIA clips prior to stapling is not recommendable.

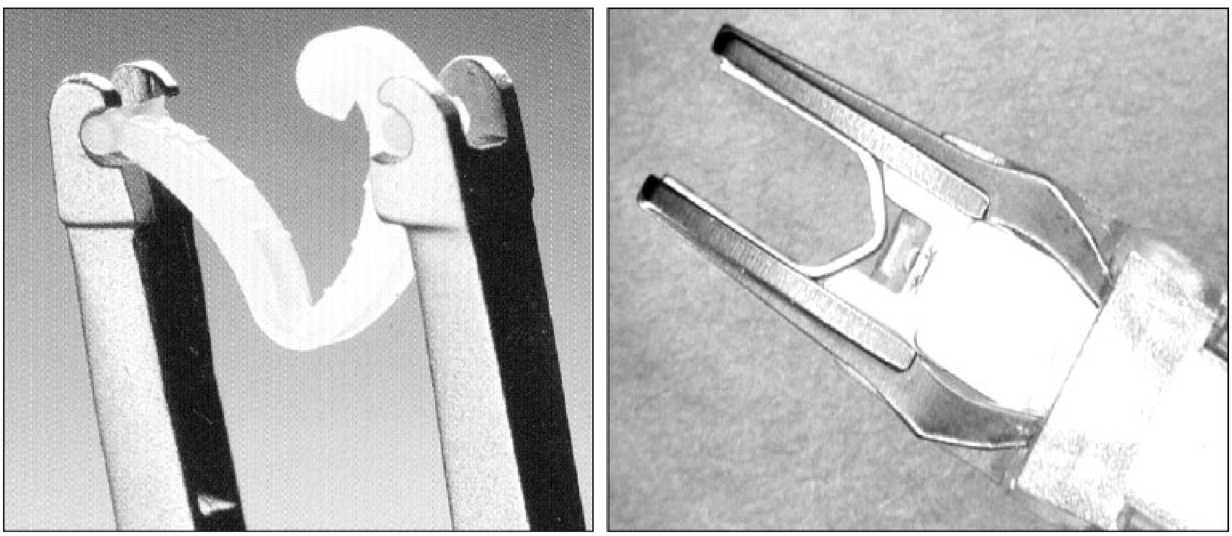

Figure 1 Clip devices for vessel control. Left picture: Hem-o-Lok clip (Tyco, Mansfield, MA, USA), right picture: titanium clip (Ethicon Endo-Surgery, Cincinnati, OH, USA).

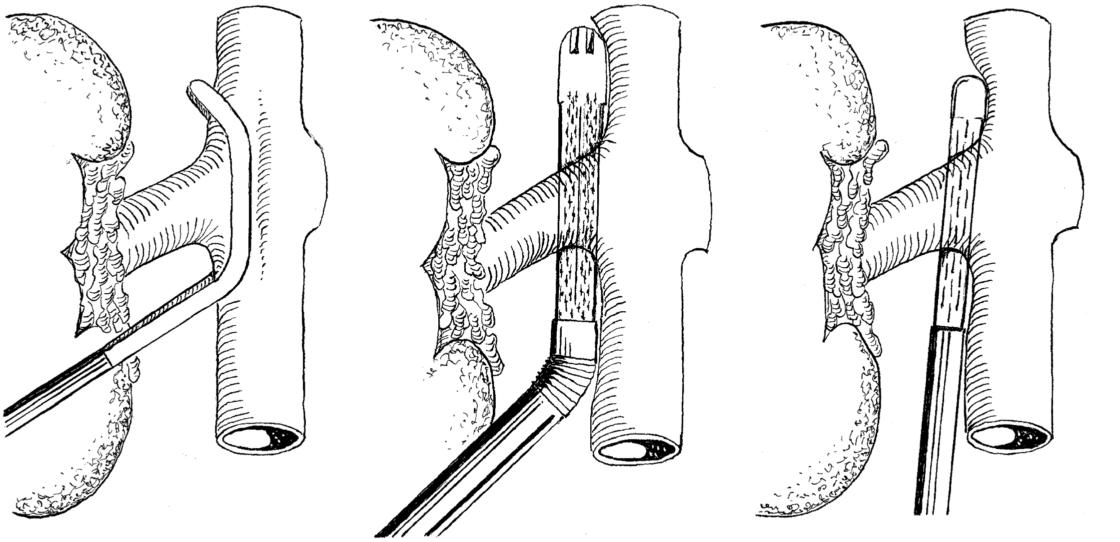

Figure 2 Different devices for vessel dissection. The modified endoscopic Satinsky clamp (left) allows for maximal preservation of vessel length as in the open approach. With the articulating endo-gastrointestinal anastomoses (GIA; ETS Flex Linear Cutter 45/2.5, Ethicon/Johnson & Johnson New Brunswick, NJ, USA) two triple rows of staples are placed followed by automatic cutting (middle). About 1.0–1.5 cm of vessel length are lost. The rigid endo-TA stapler (multifire Endo-TA 30/2.5, Auto suture/Tyco Healthcare) lays one triple row of suture lines, no automatic cutting is built in (right). With tension on the renal vessel while applying the endo-TA no loss of vessel length occurs.

Table 2. Warm ischemia times with different surgical accesses (trans = transperitoneal, retro = retroperitoneal), vessel handling and kidney delivery techniques.

			Warm ischemia time (min)							
Author	Trans/retro	*n*	Open	Hand assisted	Purely endoscopy	*P*-value	WIT def	Artery	Vein	Sequence vessel dissection/kidney delivery
Jacobs *et al.* [21]	Trans	320			2.4		1	S	S	Cut → laparoscopic sac
Östraat *et al.* [3]	Trans	22			3.5–7		3	C	GIA	Cut → laparoscopic sac
Brown *et al.* [5]	Trans	50			2.8		?	S	S	Cut → manual delivery
Stifelman *et al.* [42]	Trans	60		2.0			3	C/GIA	GIA	
Charité	Trans	70/77	2.0		2.4	NS	2	C	GIA (left); Satinsky (right)	Laparoscopic sac → cut
Hazebrook *et al.* [40]	Trans	83/89	4.8		7.8	<0.05	?	?	?	Pure laparoscopy = ?
Wolf *et al.* [36]	Trans	23/27	1.5	3.0		<0.05	2	?	?	
Lindström *et al.* [26]	Trans	11/11		3.6	4.9	<0.05	1	S	S	Cut → laparoscopic sac (pure laparoscopy)
Stoffel *et al.* [33]	Trans	33/14		2.4	7.5	<0.05	?	C	TA	Pure laparoscopy = ?
Ruiz-Deja *et al.* [39]	Trans	23/11		1.6	3.9	<0.05	2	?	?	Pure laparoscopy: cut → laparoscopic sac
Slakey *et al.* [28]	Trans	12/10		1.2	3.9	<0.05	2	GIA	GIA	Pure laparoscopy = ?
Hoznek *et al.* [30]	Retro	3			<5		1	C	GIA	
Rassweiler *et al.* [31]	Retro	10		4.0			3	C	GIA	*
Wadstrom and Lindstrom [32]	Retro	10		3.0			?	S	S	
Ng *et al.* [34]	Retro	29			5.03		?	C	S	Manual extraction
Bachmann *et al.* [35]	Retro	30/28	1.7		2.13	<0.05	2	TA 30	TA 30	*

Different definitions of WIT: WIT def, definition of warm ischemia time (from arterial clipping to: 1, positioning on ice; 2, influx of preservation solution; 3, efflux of clear preservation solution; ?, unknown).
Type of vessel dissection (artery/vein: C, clip; GIA/TA see Fig. 1; S, stapler not further specified; ?, not described).
In hand-assisted laparoscopy, the kidney was generally extracted using the hand-port device.
*Hand assistance only for vessels/extraction, no device.

Linear staplers are very sensitive and we have experienced a misfiring after removal of one suturing row.
4 Working with linear stapling devices may be associated with multiple complications [6,21,45,47]. Deng *et al.* [47] reported 22 problems with linear staplers while performing a donor nephrectomy, necessitating a conversion in 16% and blood transfusions in 44% of the donors. Primary stapler malfunction was rare (0.3%), but accidental interposition of titanium clips may lead to insufficient vessel closure. Also, usage of linear staplers may injure the vessel or accidentally create more vessels in branching arteries/veins.

In a recent US-American study on vessel handling and hemorrhagic complications in living kidney donors Frieman *et al.* [48] found 68 arterial and 36 venous control problems, some resulting in the necessity of re-operation or blood transfusion, some resulting in renal failure or even death. Stapler malfunction was found to be the most often encountered intraoperative arterial and venous problem. Delayed arterial complications were associated with vascular clips in 61%. Because not only standard but also locking clips were involved, the authors recommend a transfixational technique for arterial control (multirow stapling device or ligature plus suture ligature transfixation) to assure a safe recovery from LDN.

The above-named principles also apply for atypical anatomy of the renal vasculature, which is found in about 25–30% of the donors. Johnston *et al.* [19], Hsu *et al.* [20] and others proved that with increased experience in LDN also donors with atypical renal vasculature, like multiple or early branching vessels, can be operated on safely.

Laparoscopic procurement of right donor kidneys

Tension on the anyways short right renal vein after implantation may increase the risk of thrombosis. Because application of an endo-GIA leads to further loss of vessel length significant problems have been encountered following right LDN [6,14,15]. Buell *et al.* [15], in a survey of seven centers, reported two graft losses of laparoscopically procured right kidneys. Mandal *et al.* [14] experienced a graft loss rate of 37.5% in their early experience with eight right donor kidneys because of vascular problems. In the subsequent preference of left donor kidneys in LDN critics saw the rule of 'leaving the better kidney with the donor' neglected. Endoscopic techniques have therefore been modified to render the same vein length as the open donor nephrectomy (see Fig. 2): the endoscopic Satinsky atraumatic vascular clamp, as described by Tuerk *et al.* [23], is placed during pure laparoscpy on the caval vein so the renal vein can be excised in full length. Alternatively, the endo-TA stapler, applied during retroperitoneoscopy while the kidney's vein is under tension, puts the stapling rows only on the lateral aspect of the vena cava, so that the right renal vein is maintained in full length [33,35]. Other authors recently published their promising experience with right side endoscopic nephrectomy, using a GIA stapler on the vein in a retro- or trans-peritoneal access [34,49]. They also proved the technical feasibility and the good outcome after endoscopic organ retrieval also for the right kidney. Overall, we believe that in the light of the above-named techniques, of which the surgeon can pick the one he is most comfortable and safe with, former disincentives to the minimal invasive right side donor nephrectomy are not further justified [14,15,23,33,50].

Warm ischemia time depending on the technique

A prolonged 'WIT' in LDN in comparison with open donor nephrectomy has often been criticized as a risk factor for initial renal malfunction, potentially triggering rejection and a worse long-term outcome. It has to be kept in mind that WIT is not defined uniformly (see Table 2). While the start of WIT is generally assumed to be the interruption of arterial renal blood flow there is disagreement about the end of the WIT period. While some authors define the end of WIT as placement of the donor kidney on ice [21,30], others take influx of preservation fluid [23,24,28,39] or efflux of clear perfusate [3,31,42]. These different definitions of WIT may account for differences of 1–2 min. Furthermore, WIT in the open approach was most often simply estimated (and not measured) at about 1 min. The few publications naming WIT in the open approach revealed times between 1.5 and 4.8 min, a range which can well be achieved with LDN [2,15,31,33].

Variations in WIT during laparoscopic organ procurement may result from the technique of vessel handling and organ procurement. Clipping or stapling of the donor artery may prolong WIT, because clips/staple-lines have to be removed prior to perfusion, even though the time needed is in the range of seconds and therefore probably insignificant. For the pure endoscopic approach some authors describe a technique in which the renal vessels are cut prior to control the kidneys position safely in a retrieval bag. This means that the completely mobile donor kidney, no longer being attached to any tissue or vessel, has to be placed laparoscopically into the Endo-Bag prior to extraction, which may be very difficult. Therefore, it is not surprising that WIT is reported to be as long as 10 min with this method [3,21,39].

In comparative studies WIT was found to be significantly shorter with HALS than in traditional laparoscopic kidney retrieval, because the organ is procured through the access for the surgeons hand [8,22,26,30,33,39]. Nevertheless, some authors applying HALS still reported a WIT of up to 7 min (Table 2). Again, the reason was that vessel cutting was performed prior to securing the kidney in the surgeons hand and the kidney had to be found 'somewhere' in the operative field [5]. Therefore, independent of the surgical access, we and others [21] recommend to secure the position of the donor kidney prior to interruption of blood flow. With this method a WIT only about 30 s longer than with the open approach can be achieved [2].

Technique and site of donor organ delivery and impact on the donor

Surgeons preferring HALS (with or without hand-port device) procure the kidney through the incision site for their hand. The incision for HALS is generally longer than in the pure endoscopic approach (pure endoscopy: 5–6 cm vs. HALS: 10–12 cm), even though a size of 6–7 cm has been reported for hand assistance [2,22,23,28].

While for the pure endoscopic approach different sites are available for kidney extraction (upper flank, subumbilical midline, and Pfannenstiel incision), with the latter two being the most common [51], HALS is performed either through a midline (sub-, supra-, para-umbilical) or a Pfannenstiel incision. In hand assistance the transverse Pfannenstiel incision is too low for the operation and does not allow the surgeon's hand to reach into the upper abdomen [24,26,28,33,36,38,39]. The necessity to perform a midline incision may be a drawback for HALS. It is known from the general surgical literature that midline incisions are associated with increased postoperative pain and a higher incidence of postoperative hernias compared with transverse or flank incisions [52,53]. An increased number of hernias have been reported for HALS and several authors found this technique also associated with more postoperative ileus and bowel obstructions [8,25,39]. Surgeons should be aware that HALS might be more traumatic to the donor's intestine, which, in combination with a reflectoric reduction of intestinal motility because of increased pain from the larger incision, may account for an initially impaired bowel function.

Robotic-assisted LDN

Robotic actions are usually understood to be preprogrammed and independent. In surgical application robotics are rather understood to be computer-enhanced telemanipulator devices [54], helping the surgeon to perform fine manipulations in a restricted space. Experience with robotics in the field of LDN is rare. Today, two systems are mainly used (Zeus, da Vinci) and found to be both equally effective [55]. Fifteen hand-assisted donor nephrectomies have been reported so far with robotic assistance. No major complications occurred, operating and WITs were acceptable, graft function was good and a reduction of recovery time was reported [54,56]. Authors working with robotics in LDN think that this new technique bears great potential for improving accuracy of the operation and grafts quality, because tissue dissection is more meticulous than with pure endoscopy or HALS, but significant differences in favor of robotic-assisted procedures are still to be proved. Also, the high costs for a robotic will probably leave this technique to be practiced in a few hospitals only.

Conclusion

Today, 10 years after the first LDN has been performed, far more than 10 000 donor kidneys have been procured laparoscopically in more than 200 centers worldwide. With growing experience, technically more demanding donors can be operated on laparoscopically with the same good results as in the open approach. Multiple modifications reflect the evolution in LDN, like HALS, robotic-assisted LDN, different methods of renal vessel handling, meticulous ureteral dissection, right kidney retrieval and improved intraoperative donor management adapted to the specific demands of laparoscopy. Together with numerous variations of access sites and organ retrieval methods the surgeon performing LDN today is provided with a large armamentarium of technical options, optimizing the safety of LDN for donor, graft, and surgeon. Nevertheless, the surgeons position on the learning curve is the most important fact for performing LDN safely. For the steepness of the learning curve not only the absolute number of LDNs performed is important, but also the individual training of the surgeon in routine laparoscopic urologic operations. Therefore, while numbers ranged from initial 30 to initial 100 cases, some authors found no apparent learning curve effect in their series [7,21,57].

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