Experience With Laparoscopic Donor Nephrectomy Among More Than 1000 Cases

Low Complication Rates, Despite More Challenging Cases

Aaron J. Ahearn, MD, PhD; Andrew M. Posselt, MD, PhD; Sang-Mo Kang, MD; John P. Roberts, MD; Chris E. Freise, MD

Hypothesis: Despite the overall acceptance of laparoscopic donor nephrectomy (LDNX), concern remains about the application of this technique in certain complex situations, such as right-sided nephrectomies and in donors with complex kidney anatomy and obese donors. This study was designed to determine if complication rates have remained stable as we have offered LDNX to all medically acceptable donors and to analyze the results of cases in each of the complex categories. We hypothesized that complication rates in the 3 complex categories would be equivalent to those among more straightforward cases.

Design: Retrospective medical record review.

Setting: Academic medical center.


Main Outcomes Measures: Operative times, lengths of hospital stay, overall complications, major complications, conversions to open surgery, blood transfusions, readmissions, and reoperations.

Results: The outcomes of the first 250 patients (when LDNX was selectively offered) were compared with the outcomes of the last 795 patients (when LDNX was offered to all medically acceptable donors). Overall operative times significantly improved (212 vs 176 minutes), overall complication rates did not change (6.4% vs 5.5%), and major complication rates significantly declined (4.0% vs 1.4%). Among the last 795 patients, 1 conversion to open surgery and 1 blood transfusion occurred. There were no deaths in the series. Moreover, no differences in overall or major complication rates were seen when cases involving 200 right-sided nephrectomies, 204 donors with complex kidney anatomy, and 148 obese donors were analyzed independently.

Conclusions: Low complication rates persist for LDNX, even when applied to more technically challenging cases. This procedure is offered to all medically acceptable donors, with an excellent safety profile, and should be considered the standard of care for kidney donation.

The overall safety of laparoscopic donor nephrectomy (LDNX) has been documented in several large case series and was as safe as open donor nephrectomy in a large-scale multi-institutional database study and in a recent meta-analysis. Moreover, this technique has been shown to result in reduced postoperative pain, earlier return to work, and improved cosmetic results compared with open donor nephrectomy. These substantial benefits may have contributed to increased use of living donors for kidney transplantation. Therefore, LDNX has become the procedure of choice at most institutions in the United States.

However, concern remains about the application of this technique to several patient groups, including those with right-sided nephrectomies, donors with complex kidney anatomy, and obese donors (body mass index [BMI, calculated as weight in kilograms divided by height in meters squared] >30). The safety of LDNX in each of these complex categories has been evaluated in smaller case series. Specifically, right-sided nephrectomy was shown to result in shorter operating times, with an equivocal complication profile. A series among obese donors showed slightly increased rates of minor complications but no increase in major complications. Finally, series using donors with multiple arteries demonstrated longer operative times but no increase in rates of donor complications.

The University of California, San Francisco, has experienced excellent results with donors in all 3 of these complex categories. Since 2003, only 1 patient has...
undergone an elective open donor nephrectomy for kidney donation. This retrospective medical record review was designed to evaluate complication rates as we have offered LDNX to all medically acceptable donors. By comparing the complication rates of our first 250 patients (when LDNX was selectively offered) with those of our last 795 patients (when LDNX was offered to all medically acceptable donors), we sought to determine if rates changed as cases became progressively more challenging. Moreover, we independently analyzed the overall and major complication rates in 3 complex donor categories (right-sided nephrectomies, donors with complex kidney anatomy, and obese donors), hypothesizing that complication rates in the 3 complex categories would be equivalent to those among more straightforward cases. The overall objective of this study was to demonstrate that this LDNX could be offered to all medically acceptable donors with equal safety once the surgical team had achieved adequate experience.

### METHODS

One thousand forty-five LDNXs were performed at the University of California, San Francisco (a tertiary care teaching institution) between November 3, 1999, and August 28, 2009. A transplant surgeon (C.E.F.) performed the first 27 procedures alongside a laparoscopic general surgeon and a laparoscopic urologist. All subsequent procedures were performed by 1 of 3 transplant surgeons (A.M.P., S.-M.K. and C.E.F.) with the assistance of a transplant surgery fellow or a surgical resident (A.J.A. and colleagues).

Preoperative donor evaluations included a history and physical examination by a nephrologist, standard kidney donor laboratory measurements (including urine collection for creatinine clearance), and health care maintenance studies (eg, colonoscopy and mammograms). Early in the series, renal anatomy was evaluated using renal angiograms and intravenous pyelograms. More recently, donors were evaluated using high-resolution computed tomographic angiography, generally at the transplant center. A selection committee (A.J.A., A.M.P., S.-M.K., J.P.R., C.E.F., and others) met to determine the final acceptance of all donors. Criteria for donor acceptance changed slightly over the course of the study, with a more liberal weight criterion (BMI, ≤36). The left kidney was generally preferred because of its longer vein unless arterial anatomy was more complicated on the left or some other feature distinguished the left kidney as the better kidney to leave in the donor (ie, a small stone in the right kidney, a large cyst in the right kidney, or a larger left kidney).

The surgical procedure has been described previously. The procedure for control and division of renal vasculature evolved during the study. For the first 5 cases, an endoscopic stapler (GIA; US Surgical, Norwalk, Connecticut) was used for vascular control and ligation. For the subsequent 1040 cases, venous control was obtained using a vascular stapler (TA; Tyco-Healthcare, Pleasanton, California). The renal artery was controlled by self-locking plastic clips (Heme-o-lok; Teleflex Medical, Research Triangle Park, North Carolina) and was further secured using a metal clip. After occlusion of the vessels, they were transected using laparoscopic shears. Following documented failure of the self-locking plastic clips, the renal artery was also controlled with a vascular stapler beginning with patient 654. Extraction of the kidney was generally through a 7- to 8-cm Pfannenstiel incision, without the use of an extraction bag. Port sites were closed at the skin level only, and the extraction incision was closed in layers.

Patient-controlled analgesia was used for the first 24 hours after surgery. Donors were allowed to drink and eat ad libitum within 8 hours after surgery and were encouraged to walk within 18 hours. Bladder catheters were removed within 24 to 48 hours. Discharge goals consisted of good pain control on oral analgesics, adequate oral intake, and resolution of any complications.

Demographic data were gathered from the patient medical records, and clinic visit records were analyzed retrospectively per a protocol approved by the Committee on Human Research at the University of California, San Francisco. Data collected included the following: age, sex, BMI, nephrectomy side, vessel management technique, operative time, need for blood transfusion, intraoperative complications, postoperative complications, length of hospital stay, and readmissions, as well as the number of arteries, veins, and ureters in the donor kidney. Comparisons between study groups were performed using a 2-tailed t test, assuming unequal variance.

### RESULTS

The donor characteristics of all cases, the first 250 cases, and the last 795 cases are summarized in Table 1. The mean age of donors was 41 years (age range, 18-77 years) and did not change over the course of the series. At our institution, most donors were female (61.1%), and this

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**Table 1. Donor Characteristics**

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Total Series (N = 1045)</th>
<th>First 250 Patients (n = 250)</th>
<th>Last 795 Patients (n = 795)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age, mean (range), y</td>
<td>41 (18-77)</td>
<td>41 (18-73)</td>
<td>41 (19-77)</td>
</tr>
<tr>
<td>Male sex, No. (%)</td>
<td>407 (38.9)</td>
<td>110 (44.0)</td>
<td>297 (37.4)</td>
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<tr>
<td>BMI</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Mean</td>
<td>26.5</td>
<td>25.5</td>
<td>26.9</td>
</tr>
<tr>
<td>&gt;30, %</td>
<td>14.3</td>
<td>8.9</td>
<td>23.2</td>
</tr>
<tr>
<td>Right-sided nephrectomies, No. (%)</td>
<td>200 (19.1)</td>
<td>31 (12.4)</td>
<td>169 (21.3)</td>
</tr>
<tr>
<td>Donors with complex kidney anatomy, No. (%)</td>
<td>204 (19.5)</td>
<td>41 (16.4)</td>
<td>163 (20.5)</td>
</tr>
</tbody>
</table>

Abbreviation: BMI, body mass index (calculated as weight in kilograms divided by height in meters squared).

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\(^{a}P < .05, 2\)-tailed t test (first 250 patients vs last 795 patients).
did not change over time. When comparing our first 250 patients with the last 795 patients, our policy of accepting all medically acceptable donors for LDNX led to more complex cases in the latter part of the series. The percentage of right-sided nephrectomies increased from 12.4% to 21.3% \( (P < .001) \). Although the mean donor BMI did not increase substantially (25.5 vs 26.9), the percentage of donors with BMI exceeding 30 significantly increased (8.9% vs 23.2%, \( P < .001 \)). In this study, complex kidney anatomy was defined as any case in which the recovered kidney had multiple arteries, multiple or retroaortic veins, or multiple ureters. The percentage of cases with complex kidney anatomy increased during the study period (16.4% among the first 250 patients vs 20.5% among the last 795 patients, \( P < .07 \)). Overall, we performed 200 right-sided nephrectomies, 204 cases with complex kidney anatomy, and 148 cases in obese donors.

Our overall mean operative time was 184 minutes (Table 2). Among the entire series, we had 60 overall complications (5.7%) and 21 major complications (2.0%). All complications are listed in Table 3. There were no

<table>
<thead>
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<th>Table 2. Operative Outcomes</th>
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<tr>
<td>Outcome</td>
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<tr>
<td>Operative time, mean, min</td>
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<tr>
<td>Length of hospital stay, d</td>
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<tr>
<td>Overall complication, No. (%)</td>
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<tr>
<td>Major complication, No. (%)</td>
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<tr>
<td>Conversion to open surgery, No. (%)</td>
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<tr>
<td>Blood transfusion, No. (%)</td>
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<tr>
<td>Readmission, No. (%)</td>
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<tr>
<td>Reoperation, No. (%)</td>
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<tr>
<td>Operating room event, No. (%)</td>
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</tbody>
</table>

\( ^a P < .05, 2\)-tailed \( t \) test (first 250 patients vs last 795 patients).

<table>
<thead>
<tr>
<th>Table 3. Reported Complications</th>
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<tr>
<td>Variable</td>
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<tr>
<td>Major complication</td>
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<tr>
<td>Conversion to open surgery</td>
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<tr>
<td>Blood transfusion</td>
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<tr>
<td>Reoperation</td>
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<tr>
<td>Readmission</td>
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<tr>
<td>Renal insufficiency</td>
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<tr>
<td>Carbon dioxide embolism</td>
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<tr>
<td>Chylous ascites or lymph leak</td>
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<tr>
<td>Port site hernia</td>
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<tr>
<td>Rhabdomyolysis</td>
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<tr>
<td>Death</td>
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<tr>
<td>Minor complication</td>
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<tr>
<td>Wound infection</td>
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<tr>
<td>Urinary tract infection</td>
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<tr>
<td>Urinary retention</td>
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<tr>
<td>Ileus</td>
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<tr>
<td>Pneumonia</td>
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<tr>
<td>Respiratory depression</td>
</tr>
<tr>
<td>Pneumothorax, no intervention</td>
</tr>
<tr>
<td>Operating room event</td>
</tr>
<tr>
<td>Liver laceration</td>
</tr>
<tr>
<td>Spleen laceration</td>
</tr>
<tr>
<td>Adrenal injury</td>
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<tr>
<td>Venous injury</td>
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<tr>
<td>Small bowel injury</td>
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<tr>
<td>Bladder injury</td>
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<td>Ureter, donor side</td>
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</tbody>
</table>
Meta-analysis\(^6\) and review of a large multicenter donor database\(^5\) in combination with a body of case reports\(^1\text{-}^4\) have demonstrated that LDNX is as safe as open donor nephrectomy for procurement of live donor kidneys. With the improved donor experience associated with laparoscopic procurement,\(^7\text{-}^8\) these findings continue to favor LDNX as the procedure of choice for living renal graft procurement. To continue to expand the donor pool, it makes sense to offer the benefits of this procedure to the largest possible cohort of donors who would otherwise be considered acceptable to donate. However, given that LDNX is a major operative procedure with no physical benefit to the healthy donor, it is imperative that safety can continue to be demonstrated as the procedure is applied to more challenging cases.

This series reinforces and expands on earlier findings.\(^1\) Our rate of conversion to open surgery (0.3%) and blood transfusion rate (0.5%) continue to be lower than the rates reported in other large series.\(^2\text{-}^4\) This finding supports our belief that a purely laparoscopic procedure without the use of a hand-assistance device can provide adequate patient safety and vascular control. These results also demonstrate the importance of continued effort to improve our operative technique. We attribute our few vascular complications to progress in our methods of managing renal vessels. In our early operative experience, we
used an endoscopic stapler system for vascular ligation. However, a stapler misfire that fails to ligate but cuts the donor vessel can lead to a large-volume bleed and no alternative but to convert to an open operation. A previous study\(^1\) discussed a modification of our procedure in which self-locking plastic clips and metallic clips are used to ligate the renal artery before transecting the artery with laparoscopic scissors. We had no cases of significant bleeding using this technique, but documented donor deaths after failure of these locking clips led to warnings against the use of these clips for arterial control in living kidney donors.\(^18\) Therefore, we subsequently developed a third technique using a vascular stapler to ligate the renal artery and vein. Because the vascular stapler does not transect the vessel as the stapler mechanism fires, the staple line can be inspected before transection of the artery or vein. This technique provides the security of a staple line and conserves artery length, with reduced risk of bleeding. Our rates of major and minor complications have not changed significantly since we began using this technique, and there has been no need for conversion to open surgery because of failure of vascular control at the final stages of kidney removal.

This study describes 200 right-sided donor nephrectomies and adds to the series reported in detail previously.\(^10\) As described in our methods, we preferentially perform left-sided nephrectomies but do not avoid right-sided nephrectomies if otherwise indicated. Our findings are consistent with previous studies\(^10,11\) that show shorter operating times in right-sided nephrectomies. This is because the right-sided procedure requires little or no colon mobilization to expose the kidney, and venous branches are rarely encountered. Despite the advantage of shorter operative time, many centers are reluctant to offer right-sided LDNX because of concern about vascular control and vessel length. In the present series, the overall complication rate among right-sided nephrectomies was not significantly different from that among the total series. However, a complication unique to right-sided nephrectomies is carbon dioxide embolism secondary to Veress needle puncture of the liver and subsequent insufflation. Two severe cases of carbon dioxide embolus led to abortion of the planned laparoscopic procedures. After the second occurrence, we changed our technique of establishing insufflation on the right from the Veress needle approach to the use of a special port system that allows entry into the abdomen under direct visualization. This is an important technical detail in performing right-sided nephrectomy but does not preclude safe procurement without this trocar.

Our low complication rate among obese donors is striking in that only 3 minor complications were noted among 148 patients. We believe that LDNX can be offered to patients with BMI exceeding 30 without additional risk to the patient compared with open donor nephrectomy. A more important question relates to long-term safety of kidney donation in obese donors, and we set a BMI limit of 36 for donors. This cutoff is somewhat arbitrary, and we have no long-term data to support the concept that donor nephrectomy in obese patients is safe over the life span of the patient or that a BMI of 36 is the correct cutoff. However, the operation seems to be safe in this cohort of patients. The question of long-term safety will need to be answered with more rigorous long-term follow-up studies, and the need for answers supports the concept of a donor registry.

We also report on more than 200 donors with complex kidney anatomy. There has been concern about using a laparoscopic technique to procure kidneys with multiple renal arteries, as these procedures are associated with longer warm ischemia times and more ureteral complications in the recipient population compared with cases involving kidneys having single arteries.\(^13\) However, there are similar risks for renal grafts with multiple arteries in the cadaveric setting.\(^14\) Although the risks are higher using a donor organ with multiple vessels, this risk is far outweighed by the benefit of avoiding time on hemodialysis if only a multiple-artery kidney is available for transplantation. This study shows that these complex kidney anatomy cases can be performed with no additional risk to the donor. However, because of concern about ureteral complications, we continue to prefer right-sided nephrectomies in preference to procuring left-sided kidneys with multiple arteries.\(^13\)

In conclusion, the operative times and major complication rates associated with LDNX improved in our last 795 patients compared with our first 250 patients. This division roughly approximates our institution’s decision to offer LDNX to all potential donors. Since 2003, we have performed only 1 scheduled open donor nephrectomy at the University of California, San Francisco, for a pelvic kidney with extremely complex vascular anatomy. It is clear from this experience that laparoscopic nephrectomy can be offered to all medically acceptable donors once adequate experience is obtained by a surgical team.

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**Author Contributions:** Dr Ahearn had full access to all the data in the study and takes responsibility for the integrity of the data and the accuracy of the data analysis. **Study concept and design:** Ahearn, Kang, Roberts, and Freise. **Acquisition of data:** Ahearn and Posselt. **Analysis and interpretation of data:** Ahearn and Freise. **Drafting of the manuscript:** Ahearn. **Critical revision of the manuscript for important intellectual content:** Ahearn, Posselt, Kang, Roberts, and Freise. **Statistical analysis:** Ahearn. **Obtained funding:** Kang. **Administrative, technical, and material support:** Ahearn. **Study supervision:** Posselt, Kang, and Freise.

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**Additional Contribution:** John T. Carter, MD, assisted with the database.
REFERENCES