Early and Late Recipient Graft Function and Donor Outcome After Laparoscopic vs Open Adult Live Donor Nephrectomy for Pediatric Renal Transplantation

Christoph Troppmann, MD; Jonathan L. Pierce, MD; Kevin M. Wiesmann, BS; Lavjay Butani, MD; Sudesh P. Makker, MD; John P. McVicar, MD; Bruce M. Wolfe, MD; Richard V. Perez, MD

**Background:** Laparoscopically procured live donor kidney grafts are increasingly transplanted into pediatric recipients. The safety and efficacy of this changed surgical practice are unknown.

**Hypothesis:** Outcomes of laparoscopic vs open donor grafts in recipients 18 years and younger are equivalent.

**Design and Setting:** Retrospective review at an academic tertiary care referral center.

**Patients:** Eleven consecutive pediatric recipients of laparoscopically procured kidneys between April 1, 1997, and December 31, 2001, were pair matched for age with 11 recipients of openly procured kidneys between December 1, 1991, and March 31, 1997; the 22 adult donors were also studied.

**Main Outcome Measures:** Recipients: surgical complications, graft function and survival. Donors: perioperative morbidity and length of hospital stay.

**Results:** Twenty (91%) of 22 kidneys were donated by a parent of the recipient. In recipients of laparoscopically procured grafts, we observed significantly lower creatinine clearances and higher creatinine levels on days 1, 4, and 6, but by 1 month, graft function was similar in both groups. No significant differences in surgical complications, delayed function, acute and chronic rejection, and graft survival rates were found. No laparoscopic or open donor required blood transfusion, reoperation, or hospital readmission. One laparoscopic donor (9%) was converted to open nephrectomy. For laparoscopic vs open donors, median operative time was longer (difference, 67 min; \(P = .08\)), but median postoperative length of stay was significantly shorter (3 vs 5 days; \(P = .02\)).

**Conclusions:** Laparoscopic live donor nephrectomy has no adverse impact on pediatric recipient outcomes. For donors, the laparoscopic operation is safe and the hospital stay is shortened. These results support the continued use of laparoscopically procured live donor kidneys in pediatric renal transplantation.

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**DURING THE PAST 4 DECADES, LIVE DONOR RENAL TRANSPLANTATION HAS EMERGED AS THE TREATMENT OF CHOICE FOR NEARLY ALL CHILDREN WITH END-STAGE RENAL DISEASE.**

Live donor transplants are associated with fewer technical graft failures, better short- and long-term function, and superior recipient growth and development than cadaver transplants. Moreover, a live donor may allow for preemptive transplantation, thus obviating dialysis access–related morbidity and the long waiting times for cadaver grafts. Hence, it is not surprising that in 1999, 52% of all kidney transplants in recipients less than 18 years of age in the United States were from live donors.

In contrast to the standardized pediatric recipient implantation technique, the surgical approach to live donors has recently undergone significant changes since the introduction of laparoscopic nephrectomy, first described in 1995. Currently, more than 60% of all live donor nephrectomies in the United States are performed laparoscopically. Studies have shown that compared with the conventional open technique, laparoscopic nephrectomy results in less postoperative pain, shorter length of hospital stay, faster return to work, and higher donation rates. However, operative-technical limitations inherent in minimally invasive surgery and in the pneumoperitoneum required for laparoscopy may have a detrimental impact on graft quality, in adult recipients of laparoscopic donor kidneys, some investigators have observed higher vascular and ureteral complication rates and slower early postoperative graft func-
PATIENTS, MATERIALS, AND METHODS

PATIENTS

Between December 1, 1991, and March 31, 1997, 15 consecutive live donor kidney grafts were procured by open nephrectomy for transplantation into pediatric (≤18 years old) recipients at the University of California, Davis, Medical Center. One of these 15 grafts was lost due to graft thrombosis during the first week after transplantation, leaving 14 open donor transplants with sufficient follow-up available for analysis of early and late graft function.

Between April 1, 1997, and December 31, 2001, 11 consecutive live donor kidney grafts were procured by laparoscopic nephrectomy for transplantation into pediatric recipients. All 11 laparoscopic donor graft recipients were matched as closely as possible by recipient age at transplantation with 11 of the 14 open donors. The overall patient population of this study thus includes 22 pediatric renal transplant recipients and their 22 adult donors. Recipients’ primary renal diseases are listed in Table 1.

PREOPERATIVE DONOR EVALUATION

During the preoperative donor evaluation, medical, surgical, and psychosocial suitability for live donation was assessed. Detailed informed consent was obtained. Imaging studies for delineation of renal and retroperitoneal anatomy included ultrasonography and conventional renal arteriography for open donors, and 3-dimensional computed tomography angiography combined with conventional renal arteriography or magnetic resonance angiography for laparoscopic donors. All donor-recipient pairs were T-cell crossmatch compatible and ABO blood-type compatible.

OPEN NEPHRECTOMY TECHNIQUE

All open nephrectomies were performed using a standardized (extraperitoneal) subcostal flank approach with or without rib resection as previously described.

Throughout the operation, fluids were liberally administered and furosemide and mannitol were given intravenously at the discretion of the surgeon before division of the renal artery. The kidneys were flushed with lactated Ringer solution or Euro-Collins solution at 4°C immediately after extraction and were preserved on ice until implantation. The backtable ex vivo kidney preparation was done in either the donor or recipient operating room. Arterial or venous extension grafts were not used. Donor operating time was calculated as the time from incision to skin closure.

LAPAROSCOPIC NEPHRECTOMY TECHNIQUE

The operation was performed as previously described. The hand-assisted laparoscopic technique was not used. For left-sided nephrectomy, a Foley catheter was inserted at the beginning of the operation, and the donor was placed in a right lateral decubitus position. Throughout the operation, fluids were administered to maintain the donor’s urine output at 2 mL/kg per hour. Furosemide and mannitol were administered intravenously at the discretion of the surgeon before division of the renal artery.

After appropriate abdominal insufflation with carbon dioxide to reach a maximal intra-abdominal pressure of 15 mm Hg, 3 laparoscopic ports were placed along the left paramedian line. The entire laparoscopic dissection was performed using an ultrasonic dissector. The left colon, including the splenic flexure, was mobilized, and the splenorenal ligament was divided, allowing the spleen to fall back into the upper abdomen. Next, we mobilized the upper kidney pole.

Before continuing the dissection, an additional port was placed subcostally in the left posterior axillary line, and a hook retractor was inserted, allowing retraction of the kidney laterally, gently stretching the renal artery and vein. The renal vein was identified, and the gonadal and adrenal vein were dissected, clipped, and divided. The renal artery was identified at its aortic takeoff and was freed from all periarterial ganglionic and lymphatic tissues.

Then, the ureter was dissected using a no-touch technique. The dissection was started in a plane medial to the gonadal vein. We did not insist on visualizing the ureter at this point; the periureteral fatty tissue in the infrapolar perirenal area was left intact to minimize the potential for ureteral devascularization. Dissection was carried further down to the point where the left ureter crosses the left common iliac artery. Here, the ureter was visualized, and its future distal transection point was identified.

A transverse Pfannenstiel incision centered on the midline was made supraumbically. A laparoscopic specimen retrieval bag device was inserted into the peritoneum through a purse-string suture. The abdomen was reinsufflated, and the patient was rotated back into the right lateral decubitus position. Intravenous heparin sodium was given (70 U/kg bolus), and the ureter was transected distally after clipping the distal portion.

Next, we transected the renal artery after applying a laparoscopic linear noncutting stapler (Multi fire ENDO

Continued on next page
examin...some component of the effect of laparoscopic procurement on the live kidney donors.

RESULTS

Graft Characteristics and Donor Outcomes

In all, 20 (91%) of the 22 kidneys were donated by a par...of unrelated stepmothers (Table 2). Demographics for open and laparoscopic donors were not significantly different (Table 2).

Of the 22 grafts, 17 (77%) were left kidneys and 5 (23%) were right kidneys (right-sided nephrectomies: open, n = 3; laparoscopic, n = 2; P > 0.05) (Table 3). We noted multiple renal arteries in 6 (27%) of the 22 grafts included in this analysis (Table 3). All 6 of the multiple-artery grafts had 2 arteries. Surgical management of the multiple arteries consisted of a side-to-side anastomosis (“pants” technique) in 3 patients (50%), end-to-side reimplantation of the smaller artery into the main renal artery in 1 (17%), separate anastomoses for both vessels to the recipient’s infrarenal aorta in 1 (17%), and ligation of a small upper polar artery in 1 (17%). None of
Table 1. Primary Renal Diseases in 22 Pediatric Renal Transplant Recipients

<table>
<thead>
<tr>
<th>Disease</th>
<th>Open Donor Recipients, No. (%) (n = 11)</th>
<th>Laparoscopic Donor Recipients, No. (%) (n = 11)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Congenital aplasia/dysplasia</td>
<td>3 (28)</td>
<td>3 (28)</td>
</tr>
<tr>
<td>Chronic glomerulonephritis</td>
<td>2 (18)</td>
<td>0</td>
</tr>
<tr>
<td>Obstructive uropathy</td>
<td>4 (36)</td>
<td>0</td>
</tr>
<tr>
<td>Focal segmental glomerulosclerosis</td>
<td>0</td>
<td>2 (18)</td>
</tr>
<tr>
<td>Chronic reflux/pyelonephritis</td>
<td>0</td>
<td>2 (18)</td>
</tr>
<tr>
<td>Unknown cause</td>
<td>1 (9)</td>
<td>2 (18)</td>
</tr>
<tr>
<td>Other causes</td>
<td>1 (9)</td>
<td>2 (18)</td>
</tr>
</tbody>
</table>

Table 2. Demographic Characteristics of 22 Renal Transplant Donors

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Open Donors* (n = 11)</th>
<th>Laparoscopic Donors* (n = 11)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sex, M/F, No. (%)</td>
<td>4 (36)/7 (64)</td>
<td>6 (55)/5 (45)</td>
</tr>
<tr>
<td>Donor-recipient relationship, No. (%)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mother</td>
<td>7 (64)</td>
<td>3 (28)</td>
</tr>
<tr>
<td>Father</td>
<td>4 (36)</td>
<td>4 (36)</td>
</tr>
<tr>
<td>Brother</td>
<td>0</td>
<td>1 (9)</td>
</tr>
<tr>
<td>Uncle</td>
<td>0</td>
<td>1 (9)</td>
</tr>
<tr>
<td>Stepmother</td>
<td>0</td>
<td>2 (18)</td>
</tr>
<tr>
<td>Related/unrelated, %</td>
<td>11 (100)</td>
<td>9 (82)/2 (18)</td>
</tr>
<tr>
<td>Age, median (range), y</td>
<td>34 (18-44)</td>
<td>37 (19-48)</td>
</tr>
</tbody>
</table>

Table 3. Kidney Graft Anatomy, Warm Ischemia Times, Donor Operative Time, and Donor Postoperative Length of Stay

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Open Donors (n = 11)</th>
<th>Laparoscopic Donors (n = 11)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Left/right nephrectomy, No. (%)</td>
<td>8 (73)/3 (27)</td>
<td>9 (82)/2 (18)</td>
</tr>
<tr>
<td>Single/multiple renal arteries, No. (%)</td>
<td>9 (82)/2 (18)</td>
<td>7 (64)/4 (36)</td>
</tr>
<tr>
<td>Warm ischemia time median (min)</td>
<td>0</td>
<td>2 (18)</td>
</tr>
<tr>
<td>Donor Operative Time, min</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Operative time median (range), min</td>
<td>38 (25-84)</td>
<td>38 (28-46)</td>
</tr>
<tr>
<td>Postoperative length of stay, min</td>
<td>288 (225-395)*</td>
<td>355 (203-515)*</td>
</tr>
</tbody>
</table>

*Open vs laparoscopic donors: *P = .08.
†Open vs laparoscopic donors: *P = .02.

Figure 1. Percentile plot showing longer donor operative times for laparoscopic vs open graft procurement (*P = .08*).

Table 4. Donor Operative Time, and Donor Postoperative Length of Stay

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*Open vs laparoscopic donors: *P = .08.
†Open vs laparoscopic donors: *P = .02.

RECIPIENT OUTCOMES

Recipient demographics did not differ significantly between groups (Table 4). Median follow-up was 2902 days for open vs 613 days for laparoscopic donor recipients (*P = .01*).

After transplantation, all open donor vs only 3 laparoscopic donor kidney recipients received cyclosporine (100% vs 27%; *P = .001*). Immunosuppression for the remaining 8 laparoscopic kidney recipients (73%) consisted of a tacrolimus-based regimen.

There was no incidence of vascular graft thrombosis in the laparoscopic group. In all, 4 ureteral complications (18%) occurred (3 in the laparoscopic donor group vs 1 in the open donor group; *P > .05*), including 1 late distal ureteral stenosis 3.7 years after transplantation caused by chronic rejection (Table 5). Recipient survival was 100%.

QUALITY OF GRAFT FUNCTION

There was no significant difference in immediate posttransplantation urine output between study groups (Table 6). Median posttransplantation urine output between study groups was 28 and 40 mL/min per 1.73 m² on day 1 of 22 Renal Transplant Donors

- **Sex, M/F, No. (%)**: 4 (36)/7 (64) vs 6 (55)/5 (45)
- **Donor-recipient relationship, No. (%)**
  - **Mother**: 7 (64) vs 3 (28)
  - **Father**: 4 (36) vs 4 (36)
  - **Brother**: 0 vs 1 (9)
  - **Uncle**: 0 vs 1 (9)
  - **Stepmother**: 0 vs 2 (18)
- **Related/unrelated, %**: 11 (100) vs 9 (82)/2 (18)
- **Age, median (range), y**: 34 (18-44) vs 37 (19-48)

The early relaparotomy rate was similar for both groups (*P > .05*) (Table 5). Recipient survival was 100%.

**Table 1. Primary Renal Diseases in 22 Pediatric Renal Transplant Recipients**

- **Congenital aplasia/dysplasia**: 3 (28) vs 3 (28)
- **Chronic glomerulonephritis**: 2 (18) vs 0
- **Obstructive uropathy**: 4 (36) vs 0
- **Focal segmental glomerulosclerosis**: 0 vs 2 (18)
- **Chronic reflux/pyelonephritis**: 0 vs 2 (18)
- **Unknown cause**: 1 (9) vs 2 (18)
- **Other causes**: 1 (9) vs 2 (18)

**Table 2. Demographic Characteristics of 22 Renal Transplant Donors**

- **Sex, M/F, No. (%)**
  - **Male/Female**: 4 (36)/7 (64) vs 6 (55)/5 (45)
- **Donor-recipient relationship, No. (%)**
  - **Mother**: 7 (64) vs 3 (28)
  - **Father**: 4 (36) vs 4 (36)
  - **Brother**: 0 vs 1 (9)
  - **Uncle**: 0 vs 1 (9)
  - **Stepmother**: 0 vs 2 (18)
- **Related/unrelated, %**: 11 (100) vs 9 (82)/2 (18)
- **Age, median (range), y**: 34 (18-44) vs 37 (19-48)

**Figure 1. Percentile plot showing longer donor operative times for laparoscopic vs open graft procurement (*P = .08*).**
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<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Open Donor Recipients* (n = 11)</th>
<th>Laparoscopic Donor Recipients* (n = 11)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sex, M/F, No. (%)</td>
<td>9 (82)/2 (18)</td>
<td>7 (64)/4 (36)</td>
</tr>
<tr>
<td>Ethnicity, No. (%)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>White</td>
<td>7 (64)</td>
<td>4 (36)</td>
</tr>
<tr>
<td>Hispanic</td>
<td>3 (27)</td>
<td>4 (36)</td>
</tr>
<tr>
<td>Black</td>
<td>1 (9)</td>
<td>2 (18)</td>
</tr>
<tr>
<td>Asian</td>
<td>0</td>
<td>1 (9)</td>
</tr>
<tr>
<td>Age, median (range), y</td>
<td>12.6 (1.2-17.3)</td>
<td>11.9 (1.6-17.7)</td>
</tr>
<tr>
<td>Weight at transplantation, median (range), kg</td>
<td>26 (8-59)</td>
<td>34 (7-74)</td>
</tr>
<tr>
<td>Height at transplantation, median (range), cm</td>
<td>135 (68-160)</td>
<td>138 (68-170)</td>
</tr>
<tr>
<td>Kidney retransplants, No. (%)</td>
<td>1 (9)</td>
<td>0</td>
</tr>
<tr>
<td>Dialysis status at transplantation, No. (%)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hemodialysis</td>
<td>3 (28)</td>
<td>4 (36)</td>
</tr>
<tr>
<td>Peritoneal dialysis</td>
<td>3 (28)</td>
<td>3 (28)</td>
</tr>
<tr>
<td>No dialysis</td>
<td>5 (44)</td>
<td>4 (36)</td>
</tr>
</tbody>
</table>

*All pairwise comparisons of open vs laparoscopic donor recipients: \( P = \) not significant.

Table 5. Surgical Complications in 22 Patients After Renal Transplantation

<table>
<thead>
<tr>
<th>Complication</th>
<th>Open Donor Recipients (n = 11)</th>
<th>Laparoscopic Donor Recipients (n = 11)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ureteral</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Early leak</td>
<td>0</td>
<td>1 (9)</td>
</tr>
<tr>
<td>Immediate postoperative mechanical obstruction (technical)</td>
<td>1 (9)</td>
<td>1 (9)</td>
</tr>
<tr>
<td>Late distal ureteral stenosis (chronic rejection)</td>
<td>0</td>
<td>1 (9)</td>
</tr>
<tr>
<td>Lymphocele</td>
<td>1 (9)</td>
<td>0</td>
</tr>
<tr>
<td>Early relaparotomy</td>
<td>1 (9)</td>
<td>2 (18)</td>
</tr>
</tbody>
</table>

*All pairwise comparisons of open vs laparoscopic recipients: \( P > .05 \).

(\( P = .02 \); 60 and 80 mL/min per 1.73 m\(^2\) on day 2 (\( P > .05 \)); 70 and 80 mL/min per 1.73 m\(^2\) on day 3 (\( P > .05 \)); 75 and 108 mL/min per 1.73 m\(^2\) on day 4 (\( P = .04 \)); 83 and 93 mL/min per 1.73 m\(^2\) on day 5 (\( P > .05 \)); 82 and 85 mL/min per 1.73 m\(^2\) on day 6 (\( P = .02 \)); and 82 and 93 mL/min per 1.73 m\(^2\) at 1 month (\( P > .05 \)) (Figure 3). Delayed function occurred in 1 laparoscopic graft recipient (Table 6). In that particular case, the delayed function had resulted from immediate postoperative transplant ureter obstruction (ureteroneocystostomy torsion) and resolved after surgical revision.

**REJECTION AND GRAFT SURVIVAL**

Rejection rates were not statistically significantly different between open and laparoscopic donor kidney recipients (Table 6). In all, we noted only one graft loss (in the laparoscopic donor group). The cause of graft loss 3.8 years after transplantation was chronic rejection. Graft survival at 1 and 3 years was 100% for both groups (\( P > .05 \)).

**COMMENT**

In pediatric renal transplantation, the currently available data support the preferential use of grafts from live donors.\(^1\)\(^-\)\(^3\) Facilitated by the introduction of laparoscopic nephrectomy, live kidney donation rates have been increasing recently.\(^4\)\(^,\)\(^1\)\(^4\) According to a survey, a significant proportion of transplantation centers performing live

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donor kidney transplantations have adopted the minimally invasive technique and believe that it will become the standard of care.7 For adult recipients, laparoscopic donor nephrectomy has been established as safe and efficacious.8–16 However, for pediatric recipients, laparoscopic donor kidney outcomes have not been reported in detail. We found only one published study20 (an abstract) investigating laparoscopic nephrectomy for pediatric renal transplantation; the authors noted similar posttransplant serum creatinine levels for recipients of laparoscopic vs open live donor kidney grafts. However, in children, creatinine levels may not be discriminatory enough to reveal subtle differences in posttransplantation graft function, and the potential adverse impact of laparoscopic nephrectomy on surgical complications in pediatric recipients also is unclear.

The lack of data supporting the shift of surgical practice toward laparoscopic nephrectomy prompted us to review our own experience by comparing our current laparoscopic graft outcomes with our historic open live donor pediatric renal transplantation outcomes. Because glomerular filtration rates are age dependent, and recipient age at transplantation has been noted by previous investigators1,2,22 to be a significant independent predictor of graft survival, we age matched all of the laparoscopic recipients with open donor recipients. We assessed early graft function by using the estimated standardized creatinine clearance to estimate glomerular filtration rate, which has been shown to be a valid outcome variable in pediatric kidney recipients.21 All donor kidneys were from adults and thus had comparable nephron masses, minimizing the potential impact of an important variable that may affect longterm outcome. Finally, the 2 study groups were demographically homogeneous, particularly with respect to dialysis mode at transplantation, race, and retransplantation status, all significant predictors of graft survival.1,2

As previously stated, we believe that extrapolation of laparoscopic live donor graft outcome results from adult recipients to pediatric recipients is not possible. Laparoscopic procurement may have detrimental nonimmunologic and immunologic consequences and could imperil the good outcomes that can now be achieved with live donor grafts in pediatric patients for the following 3 reasons.

First, the graft loss rate from vascular thrombosis is highest in pediatric recipients, for whom graft thrombosis remains the third most common cause of graft failure.1,3 Transplantation of a large adult kidney into a small child poses a significant hemodynamic challenge, and adequate recipient aortic blood flow during transplantation is crucial for optimal graft perfusion.21 The longer donor operative times and the associated longer exposure of the kidney to surgical manipulation during the laparoscopic dissection may lead to increased tissue injury and impaired postperfusion graft microcirculation and may result in renal parenchymal edema, all of which may increase graft thrombosis and infarction rates.10,11,16 Pneumoperitoneum during laparoscopy can affect renal blood flow and theoretically may cause a higher propensity for vascular thrombosis because of the temporary relative venous stasis in the donor’s renal vein during laparoscopy and the endothelial injury sustained from increased vein distention.17,18,20 Moreover, laboratory evidence of postoperative hypercoagulability after laparoscopic cholecystectomy was noted by Caprini et al.25 Consistent with this scenario, a case of native renal vein thrombosis after laparoscopic cholecystectomy was recently reported.26 Also, several investigators16,27 have described higher multiple renal artery rates in laparoscopically procured kidneys; these usually require additional surgical reconstruction. These higher multiple renal artery rates are due to the preference of laparoscopic surgeons for the left kidney (irrespective of its number of renal arteries) secondary to the longer left renal vein. In addition, a laparoscopic staple cannot be placed as close to the aorta and inferior vena cava as an openly applied clamp. A single renal artery with an early bifurcation, therefore, may become a double renal artery after the stapler has been fired. Because laparoscopic staplers are introduced from a distance and at an angle to the renal artery and renal vein, not all potentially available vascular length may be obtained. Moreover, the width of the vascular staple is generally greater than the width of an openly placed conventional vascular clamp, diminishing the amount of vessel length available at implantation. All these anatomical-technical factors can result in a higher incidence of grafts with multiple renal arteries and shorter vessel length.19 Vascular complications that have been described for grafts with multiple renal arteries include graft thrombosis and a higher incidence of early ureteral complications. In addition, particularly in smaller pediatric recipients, sufficient available donor vessel length is paramount to avoid torsion and kinking and to optimize alignment of the renal artery and vein in the face of restricted intra-abdominal spatial flexibility.3,35 Thus, in pediatric recipients, laparoscopically procured kidney grafts may be at higher risk for early graft failure from thrombosis and infarction. We did not observe a single technical graft loss in laparoscopic donor recipients, although the incidence of multiple renal arteries was twice as high as in the open donor group. Based on our analysis, we believe that application of the previously outlined intraoperative donor and recipient management principles in combination with standard surgical implantation and reconstruction techniques is safe for pediatric recipients. No technical modifications with respect to the recipient operation seem to be necessary when transplanting laparoscopically procured kidneys.

Finally, we expect the higher incidence of multiple renal arteries in the laparoscopic era to diminish because we10 recently successfully started to implement right-sided laparoscopic nephrectomy (as in 2 donors in this series). Second, pediatric recipients have a higher rate of congenitally diseased urinary outflow tracts with or without the need for operative revision before transplantation. For laparoscopically procured grafts, some authors have described higher posttransplantation ureteral complication rates in adult recipients, which may be related to surgical trauma (e.g., ureteral devascularization) at the time of procurement.7,9,35 Any impairment of the transplant ureter as a result of the donor operation may therefore be particularly disadvantageous to pediatric recipients. We noted a 27% ureteral complication rate in laparoscopic recipients vs a 9% rate in open donor recipients. However, closer analysis of our experience in—
dictates that of all 3 ureteral complications in the laparoscopic group, only 1 (an early leak) was potentially attributable to laparoscopic procurement. The second ureteral complication was related to a technical error occurring during the recipient operation (ureteroneocystostomy torsion). The third ureteral complication (a late distal ureteral stenosis >3 years after transplantation) was related to chronic rejection; the kidney graft also failed from chronic rejection within 1 month after the distal ureter stenosis was diagnosed. Thus, we did not find any substantial evidence that laparoscopic nephrectomy increases ureteral complication rates. We believe that careful periureteral dissection in the donor, leaving a large amount of periureteral tissue intact and avoiding stripping the ureter, is paramount for achieving low ureteral complication rates for pediatric and adult recipients.

Third, with respect to graft function, several studies have shown slower early posttransplantation function for laparoscopic (vs open) grafts when analyzing recipients' serum creatinine levels. However, this difference was not observed on all posttransplantation days, did not persist beyond the first month, and did not achieve statistical significance at all times in all studies. In our pediatric analysis, there was also a trend toward slower initial posttransplantation recovery of renal function (measured by estimated glomerular filtration rates and serum creatinine levels) for laparoscopic grafts. However, by 1 month after transplantation, and at all later follow-up times, graft function was similar in both groups. Most laparoscopic graft recipients received tacrolimus (vs cyclosporine for all open donor graft recipients). Given the study design, it was not possible to determine whether the observed initial functional differences can be attributed solely to the laparoscopic procurement (eg, to the adverse effects of pneumoperitoneum on renal cortical blood flow) or to the sequential immunosuppressive protocol with delayed calcineurin inhibitor administration that was exclusively used for the open donor group or if potential differential nephrotoxic adverse effects of tacrolimus vs cyclosporine may have contributed to our findings. Because the stringent hemodynamic goals required for good immediate function in children cannot always be met, any potential additional impairment of posttransplantation graft function as a result of the laparoscopic procurement may be particularly disadvantageous to them. Early graft function is the most sensitive noninvasive clinical variable available to assess the degree of early graft injury. Increased immunologic graft losses after nonimmunologic, nonspecific graft injury as evidenced by slower initial graft function may result from the injury-inflammation-immune recognition triangle proposed by Halloran et al.

In line with this postulated cycle, it is now well established that early graft injury, as manifested by delayed function, is associated with increased acute rejection rates also in pediatric recipients and constitutes a significant risk factor for chronic rejection and poor long-term graft survival. Because pediatric recipients have higher acute rejection rates than adults, any potential long-term consequences related to the magnitude of early graft injury may become particularly apparent. In our analysis, delayed function rates were not significantly different between the 2 study groups, and we were not able to document any significant differences in immunologic outcomes (incidence of acute rejection and immunologic graft loss). However, our study was limited by sample size and by the fact that rejection episodes were not consistently biopsy proven. Moreover, with 100% graft survival 3 years after transplantation in both groups, any differences in immunologic outcomes for laparoscopic vs open donor grafts may be difficult to demonstrate and must await further analysis in larger study populations with longer follow-up. In summary, we believe that the subtle differences in early posttransplantation graft function underscore the importance of strict adherence to management principles that have been shown to be renoprotective in previous studies, including aggressive intravenous volume replacement during donor nephrectomy and targeting specific intraoperative recipient hemodynamic goals.

What are the implications of laparoscopic nephrectomy for donors? First and most important, laparoscopic donors had a significantly shortened postoperative length of hospital stay. It is likely that this shortened length of stay is associated with faster convalescence, faster return to usual activities of daily life, and faster return to work, as previously reported. In this context, it is particularly important to note that, as in many other live donor pediatric renal transplantation studies, more than 90% of our donors were parents of the recipients. Shorter postdonation hospital stay and likely shortened postsurgical convalescence allow the donors to return faster to their ongoing family obligations with respect to child and recipient care. Laparoscopic nephrectomy, therefore, also is likely to further enhance the previously reported high postdonation satisfaction scores after open nephrectomy and the improved relationship between live kidney donors and their pediatric recipients. Because of the retrospective nature of this study, we did not assess the 2 donor populations for differences in postoperative analgesic requirements and postsurgical pain.

Second, we noted longer donor operative times for laparoscopic nephrectomies. Renal transplants from laparoscopic live donors may thus slightly postpone the break-even point (time required before the transplantation cost is recovered by saving the cost of dialysis). However, because we used historic controls, we could not perform a comparative economic analysis. Such an analysis would need to establish whether the added costs for the higher operating room and anesthesia charges, as well as the disposable laparoscopic instruments used for laparoscopic nephrectomy, outweigh the benefit of the shorter postdonation hospitalization.

This study has several limitations. From an immunologic outcome perspective, it encompasses 2 different immunosuppressive eras with different recipient immunosuppressive protocols. Furthermore, rejection episodes were not systematically biopsy proven. Given the study design, follow-up observation times in the 2 groups were significantly different, and there was a relatively small proportion of laparoscopic donor grafts with more than 2 years of follow-up. For these reasons, we caution against overinterpreting the results with respect to long-term immunologic outcomes. Last, our sample size was small owing to the recent introduction...
of the laparoscopic technique, but this study represents the most comprehensive published analysis and the largest single-center experience available on the subject, to our knowledge.

In conclusion, we observed no detrimental impact of laparoscopic live donor nephrectomy on pediatric recipient outcome. Laparoscopic nephrectomy was also safe for our live kidney donors, and it shortened their postoperative length of stay significantly. We believe that these findings justify the continued application of laparoscopic live donor nephrectomy in pediatric renal transplantation for now. However, further research on larger patient populations with longer follow-up times is necessary for definitive confirmation of these findings.

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Linda L. Wong, MD, Honolulu, Hawaii: When laparoscopic donor nephrectomies were first introduced in 1993, there was much skepticism. We were suddenly taking a well-established, safe procedure and replacing it with a procedure that now required increased operative time, specialized equipment, and 2 attending surgeons in the room. Only the left kidney was used initially, organs were a little more bruised, and ureteral problems were reported. In the meantime, recipient surgeons waited patiently in another room to finally receive a kidney with short and frequently multiple vessels.

Now that we have gone past the learning curve, laparoscopic donor nephrectomies have been done safely and suc-
cessfully in over 100 centers in over 5 different countries. Graft function has been comparable and complications are no different from the open procedure. Multiple studies have reported less blood loss, less pain, and decreased hospital length of stay. Donors have smaller incisions and decreased recuperation time. Most importantly, the advent of this minimally invasive procedure has increased live donor transplants up to 200% in certain East Coast programs.

Little, however, has been published on the use of this procedure in the pediatric population. Dr. Troppmann and his group in this series have studied 11 consecutive laparoscopic donor nephrectomies for pediatric recipients and have compared this to 11 age-matched historical controls. They noted no difference in patient survival or serum creatinine; however, as they have mentioned, it is very difficult to look at rejection and long-term graft function as the historical controls were done with a cyclosporine-based immunosuppression while those receiving kidneys from the laparoscopic procedure primarily received tacrolimus.

The laparoscopic procedure appeared to take longer, but the hospital stay was significantly reduced by 2 days. Laparoscopic donor patients stayed a mean of 3 days in the hospital. The University of Maryland has reported performing this procedure as a 23-hour stay postoperatively. My questions to the group are: What are your thoughts on the 23-hour postoperative stay? Do you think that in reality some of your donors could have been discharged sooner but because their child and often their spouse are in the hospital anyway, you were inclined to keep them longer? I realize that cost data are often hard to obtain retrospectively, but do you think that the decrease in hospital length of stay overcomes the increased operative cost in the laparoscopic procedure?

My second set of questions: Your laparoscopic donor nephrectomies appear to have 3 times as many ureteral complications; yet, only one of these 3 complications appears to be directly related to the laparoscopic procedure. This is compared to the open procedure in which only 1 ureteral complication occurred and was not related to the donor procedure. Do you think that the ureteral problem related to the laparoscopic procedure was related to the learning curve? What is your overall ureteral complication in the adult population with this laparoscopic approach?

My final comments and questions are centered around organ donation. Has the use of laparoscopic donor nephrectomy in the pediatric population had any effect on the waiting time for pediatric patients on the list? What percentage of your patients now currently receive living vs cadaveric donors? This procedure is the ideal one for the parents donating their kidneys to their child. Kidney transplantation is clearly the most effective way of dealing with end-stage renal disease in the pediatric population. The laparoscopic donor procedure allows parents to recuperate quickly since most need to return home to serve as the caregiver or to return to work quickly to support the family.

S. Eric Wilson, MD, Irvine, Calif: One could reasonably postulate that the slight decrease in early renal function (manifested by the decreased creatinine clearance) seen in the laparoscopically harvested kidney indicates an absolute loss of nephrons from ischemia. Could this shorten the ultimate life expectancy of the transplanted kidney?

Whitney M. L. Limm, MD, Honolulu: Two questions about the donor nephrectomies. At UC Davis currently, which donor is not a candidate for the laparoscopic approach? The second question is about the patient who required a conversion. What was your preoperative imaging study?

Dr. Wolfe: Concerns regarding the kidney function in these transplantation patients arise from 2 basic issues. The first, is laparoscopy bad for the kidney? In a recently concluded randomized trial in obesity patients, urine output was diminished in the laparoscopic group. The second, as was noted, is that there is an ischemic interval that is longer in the laparoscopic patients. We assume that those 2 factors together account for the transient diminished creatinine clearance that is seen in the recipients. Whether this has a long-term effect on the kidneys’ outcomes or not is not clear. We have not seen any impact on graft function beyond postoperative day 30 in this study, in which the controls are historic. The follow-up is longer on the open patients.

Dr. Wong asked about the 23-hour postoperative stay. This issue we discussed yesterday regarding the colectomy patients. Surgeon attitudes and willingness to move people out of the hospital, and patients’ desire to leave the hospital, are all issues that influence how long they stay. In these donors, we pretty much give them as much space as they want. Pain control is an issue. If the patients really want to go home, we do not hold them up. But the 3-day hospital stay seems to be popular with the patients, and we haven’t really tried to push for earlier discharge. It should also be noted in the 23-hour hospital stay report, the protocol failure rate (inability to discharge at 23 hours as readmission) was as high as 15%, which is problematic in the context of living donation.

The issue of ureteral complications: it is correct that there was 1 in the open and 3 in the laparoscopic groups. Earlier in the experience reported by other centers there were some ureteral complications that may have related to imprecise preservation of blood supply to the donor ureters in the laparoscopic dissection. By the time we were doing these children, we were pretty well aware of this problem such that we really can’t draw any conclusions. The numbers are too small for statistical significance.

An important issue as Dr. Wong noted is that the donor pool has expanded in the era of laparoscopic donor nephrectomy. This is felt to be at least partially due to the availability of the minimally invasive procurement technique. We haven’t analyzed the specific waiting time, which is influenced by other demographic factors, such as expansion of the population in Sacramento. Approximately 60% of our pediatric kidney transplantsations are done with living donors, and 40% with cadaveric donors. The exclusions for laparoscopic donor nephrectomy are basically the same as we use for exclusions in other laparoscopic procedures. In general, the presence of adhesions would be the most common exclusion. If the patient is known to have severe adhesions, then we would stay away from such a patient. We had 1 patient as was noted who had a small accessory renal vein that was not appreciated by magnetic resonance imaging preoperatively. In the laparoscopic dissection technique, it is possible to enter a vein if you don’t know its location from preoperative imaging. Perhaps dissection of the vessels is a little more difficult in laparoscopy than it is in open surgery, and that did lead to the necessity for conversion to open. Our approach is immediately to convert any laparoscopic operation to an open if control of bleeding is an issue since all of the patients are advised that we would prefer to open rather than to have ongoing hemorrhage, which is difficult to control in a laparoscopic operation, and to have to transfuse blood.