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Recovery and Utilization of Deceased Donor Kidneys from Small Pediatric Donors

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The optimal use of kidneys from small pediatric deceased donors remains undetermined. Using data from the Scientific Registry of Transplant Recipients, 2886 small (<21 kg) pediatric donors between 1993 and 2002 were identified. Donor factors predictive of kidney recovery and transplantation (1343 en bloc; 1600 single) were identified by logistic regression. Multivariable Cox regression was used to assess the risk of graft loss. The rate of kidney recovery from small pediatric donors was significantly higher with increasing age, weight and height. The odds of transplant of recovered small donor kidneys were significantly higher with increasing age, weight, height and en bloc recovery (adjusted odds ratio = 65.8 vs. single; $p < 0.0001$), and significantly lower with increasing creatinine. Compared to en bloc, solitary transplants had a 78% higher risk of graft loss ($p < 0.0001$). En bloc transplants had a similar graft survival to ideal donors ($p = 0.45$) while solitary transplants had an increased risk of graft loss ($p < 0.0001$). En bloc recovery of kidneys from small pediatric donors may result in the highest probability of transplantation. Although limited by the retrospective nature of the study, kidneys transplanted en bloc had a similar graft survival to ideal donors but may not maximize the number of successfully transplanted recipients.

Key words: En bloc, kidney transplantation, organ recovery, pediatric transplantation, SRTR, utilization

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Introduction

The disparity between the number of patients with end-stage renal disease (ESRD) on the kidney transplant waiting list and the availability of deceased donor organs continues to grow. While the waiting list increased in number by more than 20% between 2000 and 2003, the number of deceased donors remained relatively stable (1). The prolonged waiting time for kidney transplantation and associated longer periods on dialysis have been associated with significant morbidity and mortality (2). While attempts have been made to maximize the donor pool, including the use of expanded criteria donors (3), donation following cardiac death and transplantation of both kidneys from an expanded criteria donor to one recipient (4–6), the optimal use of small pediatric donors has been less clear.

There has been reluctance to transplant small pediatric deceased donor kidneys into adults for several reasons, including associations with increased vascular (7,8) and urinary complications (8,9). There has also been concern about transplanting an insufficient nephron mass using this donor population (10). Others have also demonstrated an increased incidence of acute cellular rejection (11,12) and delayed graft function (11) when compared to transplants from adult deceased donors.

As first described in 1972, one possible solution to prevent the complications that may occur with the use of solitary small pediatric kidneys is to transplant them en bloc (13). Survival rates after transplantation of en bloc kidneys from donors less than 4 (14,15) or 5 years old (16) have been demonstrated to be similar to solitary transplants from older deceased donors. However, kidneys transplanted en bloc from donors less than 2 years old have been reported to have poor graft survival (8).

Because en bloc transplantation of pediatric kidneys halves the number of potential transplant recipients, some transplant centers have performed solitary kidney transplants from small pediatric donors. Mixed results have been reported. In one study where en bloc kidneys were separated if they measured more than 6 cm, 2-year graft survival was better for the solitary compared to the en bloc group (93% vs. 77%) (17). In contrast, both solitary and en bloc kidney transplants from donors less than 2 years old have been associated with poor results (8,11,18).

To date, direct comparison of solitary to en bloc kidney transplantation from pediatric donors to adult recipients has been performed in only a limited number of studies, most with small cohorts from individual centers (17,19). One recent study looked at outcomes in a national cohort and found that transplantation of single kidneys from donors less than 5 years old was associated with significantly worse graft survival than en bloc transplantation (20). In addition, there have been only a limited number of studies evaluating outcomes from donors less than 2 years old (11,17). To better understand and possibly improve the utilization of small pediatric kidney donors, the present study evaluated the effect of donor characteristics on the rates of recovery and utilization of kidneys from this population. In addition, we compared graft outcomes for recipients of either en bloc or single kidney transplants from small pediatric donors.

Materials and Methods

A retrospective cohort study of Scientific Registry of Transplant Recipients (SRTR) data as submitted by the members of the Organ Procurement and Transplantation Network, was performed. Mortality ascertainment was supplemented through the Social Security Death Master File (21). This study was approved by the Health Resources and Services Administration's (HRSA) SRTR project officer. HRSA has determined that this study satisfies the criteria for the Investigational Review Board (IRB) exemption described in the 'Public Benefit and Service Program' provisions of 45 CFR 46.101(b) (5) and HRSA Circular 03.

Kidney recovery and discard rates were calculated overall and by donor weight. Small pediatric donors were defined as those <21 kg and from whom at least one organ was recovered for transplant during the study period of 1993–2002. The cutoff of 21 kg represents approximately the 90th percentile weight for 5-year-old boys and girls (22). The recovery rate was defined as the number of small pediatric donors with at least one kidney recovered divided by the total number of small pediatric donors. For calculation of discard rate, en bloc kidneys were considered as one transplantable unit, while solitary kidneys were considered separately. The discard rate was defined as the number of transplantable kidney units (single or en bloc) recovered but not transplanted, divided by the total number of transplantable units recovered.

Donor factors predictive of kidney recovery and of transplantation of recovered kidneys were identified using logistic regression models. Endpoints for the logistic regression models were at least one kidney recovered for transplant and transplantation of recovered kidneys. Logistic regression models were adjusted for the following donor covariates: age (years), weight (kg), height (cm), serum creatinine (mg/dL), sex, race, ethnicity, cause of death, ABO blood type, whether both dopamine and dobutamine were given to donor, whether kidneys were recovered en bloc (only for the transplantation of recovered kidneys model), year of recovery and donation service area (DSA). Missing values for donor height and serum creatinine were imputed using standard methods available with SAS 9.1 (SAS Institute; Cary, NC, USA) and IVEWARE 2.0 (University of Michigan, Ann Arbor, MI, USA) imputation software.

A Cox regression model was fitted to compute covariate-adjusted graft loss hazard ratios (HR), adjusted for the following potentially confounding covariates: donor weight, recipient race, cause of ESRD, recipient age, recipient weight, and method of transplant (solitary vs. en bloc). In addition, Cox non-proportional hazards models were fitted in order to compare solitary and en bloc covariate-adjusted graft loss by donor weight categories.

To compare the outcome of single or en bloc kidney transplantation using small pediatric donors to recipients of ideal donors during the same time period, an additional Cox model with the same adjustments as above was developed. 'Ideal' kidney donors were defined as those donating following brain death between the ages of 10 and 39 years old, without a history of hypertension, with cause of death other than a stroke and with serum creatinine less than 1.5 mg/dL (23).

All statistical analyses were performed using SAS 9.1 (SAS Institute). All univariate comparisons were unpaired and all tests of significance were 2-tailed. For univariate analysis, continuous variables were compared by Student's *t*-test. Categorical data were compared using the chi-square test. All values are expressed as the mean (continuous variables) or as a percentage of the group from which they were derived (categorical variables).

Results

Recovery of kidneys from small pediatric donors

Between 1993 and 2002, there were a total of 2886 small (<21 kg) pediatric donors. Of these, 2156 (74.7%) had at least one kidney recovered for transplant (Figure 1). There was considerable variation in the number of recoveries of kidneys from small donors depending on the transplant practices of the local centers. Between 1999 and 2002, kidneys were recovered from a range of 0–16 small donors in the 10 DSAs where no small donor kidney transplants were performed at that DSA's local transplant centers. In contrast, kidneys were recovered from 2 to 46 small pediatric donors in the 49 DSAs where local small donor transplants were performed.

The recovery rate of kidneys from small pediatric donors increased progressively with donor weight (Figure 2). While the recovery rate of donors <10 kg was only 42.9%, the recovery rate for donors weighing 10 to <21 kg was 90.8% ($p < 0.0001$). Predictors of recovery of kidneys from small pediatric donors are listed in Table 1. Significant predictors of organ recovery included increasing donor age (adjusted odds ratio [AOR] 1.15 per year, 95% confidence interval [CI] 1.04–1.28; $p = 0.007$) and donor weight (AOR 1.38 per kg, CI 1.32–1.45; $p < 0.0001$). Kidneys from small pediatric female donors were 30% more likely to be recovered than kidneys from male donors (AOR 1.30, CI 1.03–1.63; $p = 0.03$). As serum creatinine increased, kidney recovery was significantly less likely (AOR 0.52 per mg/dL serum creatinine, CI 0.44–0.63; $p < 0.0001$). Recovery of kidneys was also less likely from donors with central nervous system (CNS) tumors (AOR 0.16 compared to head trauma, CI 0.06–0.44; $p = 0.0004$) and a cause of death other than head trauma, CNS tumors, anoxia, stroke or meningitis (AOR 0.50, CI 0.33–0.78; $p = 0.002$).

Discard of kidneys from small pediatric donors

The discard rate dropped sharply above a donor weight of 10 kg (Figure 2). Of the 2943 single kidneys and en bloc

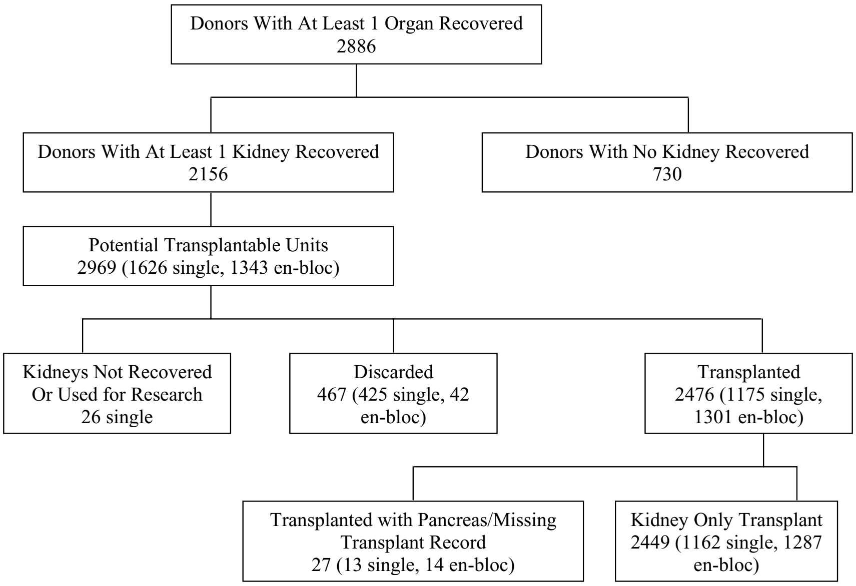

Figure 1: Disposition of kidneys procured from small pediatric donors, 1993–2002.

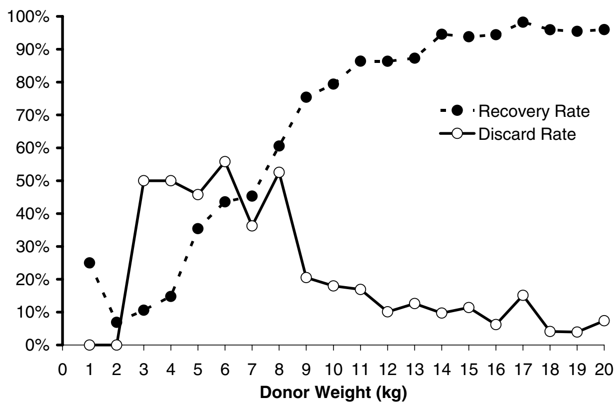

Figure 2: Kidney recovery and discard rates from small pediatric deceased donors.

pairs recovered, a total of 15.9% were discarded. Discard rates were significantly higher for donors <10 kg (40.3%) when compared to donors weighing 10–20 kg (10.5%, $p < 0.0001$). Common reasons for the discard of pediatric kidneys included vascular damage (11.6%), donor medical history (2.4%), organ trauma (2.8%), organ not as described (2.4%), biopsy findings (2.1%), poor organ function (3.2%) and anatomic abnormalities (9.9%). However, the most common reasons for discard were either missing (31.7%) or specified as 'other' (21.6%).

Independent predictors of transplantation of kidneys recovered from small pediatric donors

Over the study period, 1301 en bloc pairs and 1175 single kidneys were transplanted, representing 96.9% of 1343 recovered en bloc pairs and 73.4% of 1600 recovered single kidneys. Notably, compared to kidneys recovered individually, those recovered en bloc had an unadjusted odds ratio to be used for transplant of 1.32; however, after correcting for confounding factors using logistic regression, individually recovered kidneys were much more likely to be used for transplantation (AOR 65.8, CI 42.1–102.7; $p < 0.0001$). Other significant independent predictors of transplantation (as opposed to discard) of kidneys recovered from small pediatric donors included increasing donor age, weight and height (Table 2). As donor serum creatinine

Table 1: Predictors of recovery of kidneys from small pediatric donors

	Mean or%	Adjusted odds ratio[1]	95% CI	p-Value
Donor age (years)	2.03	1.15	1.04–1.28	0.007
Donor weight (kg)	11.96	1.38	1.32–1.45	<0.0001
Donor height (cm)	80.95	1.01	1.00–1.02	0.08
Donor serum creatinine (mg/dL)	0.63	0.52	0.44–0.63	<0.0001
Donor sex				
Male	55.7%	1.00	Ref	Ref
Female	44.3%	1.30	1.03–1.63	0.03
Donor race				
White	78.1%	1.00	Ref	Ref
African American	19.0%	1.03	0.76–1.39	0.84
Asian	1.6%	0.78	0.32–1.90	0.58
Other or missing	1.4%	1.64	0.54–5.05	0.38
Cause of death				
Head trauma	46.5%	1.00	Ref	Ref
Anoxia	34.0%	0.85	0.66–1.10	0.22
Stroke	8.6%	0.85	0.55–1.30	0.45
CNS tumor	0.9%	0.16	0.06–0.44	0.0004
Meningitis	1.8%	0.64	0.30–1.39	0.25
Other	8.2%	0.50	0.33–0.78	0.002
Dopamine and dobutamine	12.6%	0.95	0.66–1.36	0.78

[1]Also adjusted for DSA.

Table 2: Independent predictors of transplantation of kidneys recovered from small pediatric donors

	Mean or%	Adjusted odds ratio[1]	95% CI	p-Value
Recovered en bloc	45.6%	65.78	42.12–102.73	<0.0001
Donor age (years)	2.76	1.61	1.42–1.83	<0.0001
Donor weight (kg)	13.88	1.18	1.11–1.25	<0.0001
Donor height (cm)	86.62	1.02	1.01–1.03	0.0012
Donor serum creatinine (mg/dL)	0.57	0.73	0.56–0.95	0.0174
Donor sex				
Male	55.8%	1.00	Ref	Ref
Female	44.2%	0.80	0.59–1.07	0.1316
Donor race				
White	78.9%	1.00	Ref	Ref
African American	18.0%	0.95	0.65–1.39	0.7935
Asian	1.6%	0.39	0.13–1.19	0.098
Other or missing	1.5%	0.70	0.18–2.64	0.5948
Donor cause of death				
Head trauma	49.5%	1.00	Ref	Ref
Anoxia	31.4%	1.09	0.78–1.52	0.6116
Stroke	9.0%	0.97	0.57–1.65	0.9133
CNS tumor	0.8%	1.08	0.22–5.31	0.9268
Meningitis	1.6%	0.65	0.23–1.81	0.4103
Other	7.6%	0.70	0.4–1.24	0.2253
Dopamine and dobutamine	13.0%	0.78	0.52–1.18	0.2379

[1] Also adjusted for DSA.

increased, the likelihood of kidneys being used for transplantation decreased. Kidneys recovered between 1995 and 2001 were less likely to be transplanted compared to those recovered in the year 2002 (data not shown). Compared to kidneys recovered from donors of blood type O, those from blood type AB donors were significantly less likely to be transplanted (data not shown).

Recipients of en bloc and single small pediatric kidney transplants

Characteristics of recipients of single kidney or en bloc small pediatric kidney transplants are presented in Table 3. Recipients of en bloc kidneys weighed slightly but significantly more than recipients of single small pediatric kidneys (66.0 vs. 63.8 kg, $p = 0.008$). A significantly higher proportion of en bloc kidney recipients were Asian race (9.5% vs. 5.9%, $p = 0.0008$). Significantly lower proportions of recipients of en bloc kidneys were of age 2–17 (1.2% vs. 3.7% for age 2–10 and 2.8% vs. 5.0% for age 11–17; both $p < 0.005$). The donor weight for kidneys transplanted singly was significantly higher than that for kidneys transplanted en bloc (16.3 vs. 12.8 kg, respectively, $p < 0.0001$).

Graft outcome after small pediatric donor kidney transplantation

Recipient and donor characteristics identified as significant independent predictors of graft failure are listed in Table 4. African American recipients (HR 1.42, CI 1.20–1.69; $p < 0.0001$), diabetics (HR 1.30, CI 1.05–1.61; $p = 0.02$) and

Table 3: Recipient characteristics for kidney transplants from small pediatric donors performed using either a single kidney or en bloc

	En bloc N = 1287	Single N = 1162	p-Value
Recipient race			
White	63.4%	66.0%	0.1784
African American	24.7%	26.3%	0.3825
Asian	9.5%	5.9%	0.0008
Other or missing	2.4%	1.9%	0.3814
Recipient sex			
Male	49.1%	47.4%	0.4038
Female	50.9%	52.6%	–
Recipient age			
<2 years	0.3%	0.6%	0.2812
2–10 years	1.2%	3.7%	<0.0001
11–17 years	2.8%	5.0%	0.0048
18–34 years	26.4%	24.0%	0.1710
35–49 years	36.1%	33.6%	0.1832
50–64 years	27.7%	27.7%	0.9781
65+ years	5.5%	5.4%	0.9178
Recipient weight (kg)[1]	66.00	63.76	0.0083
Etiology of ESRD			
Diabetes	13.6%	16.2%	0.0726
Hypertension	21.5%	21.3%	0.9507
Glomerulonephritis	30.2%	29.0%	0.5079
Other	33.5%	31.8%	0.3856

[1] Includes nonmissing values only.

recipients 65 years and older (HR 1.75, 1.32–2.31; $p < 0.0001$) were at a significantly increased risk of graft loss (Figure 3). Recipients of a kidney or kidneys from larger donors exhibited a significantly decreased risk of graft loss (HR 0.96 per 1 kg increase in weight, CI 0.94–0.98; $p < 0.0001$). Even after adjustment for multiple donor and recipient characteristics, recipients of single kidneys from small pediatric donors had 78% higher risk of graft failure when compared to those who received en bloc transplants (Figure 3; $p < 0.0001$).

In order to evaluate the possible interactive effect of donor weight and en bloc or single transplant type, we grouped

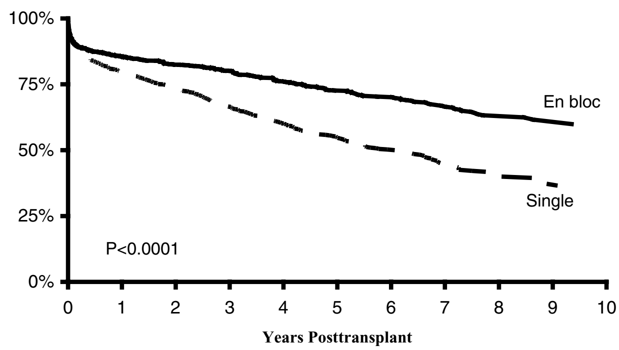

Figure 3: Adjusted graft survival after en bloc and single kidney transplants from small pediatric donors.

Table 4: Recipient and donor characteristics that independently predict graft failure following kidney transplantation from small pediatric donors

	Hazard ratio	95% CI	p-Value
Recipient age			
<2 years	1.04	0.37–2.91	0.94
2–10 years	0.89	0.52–1.51	0.66
11–17 years	1.10	0.76–1.62	0.61
18–34 years	1.16	0.97–1.4	0.10
35–49 years	1.00	Ref	Ref
50–64 years	0.94	0.79–1.13	0.53
65+ years	1.75	1.32–2.31	<0.0001
Recipient weight (per 10 kg greater)	1.00	0.95–1.06	0.91
Recipient race			
White	1.00	Ref	Ref
African American	1.42	1.20–1.69	<0.0001
Asian	0.65	0.47–0.91	0.01
Other or missing	0.61	0.33–1.15	0.13
Recipient male (vs. female)	1.08	0.94–1.25	0.30
Etiology of ESRD			
Diabetes	1.30	1.05–1.61	0.02
Hypertension	1.06	0.86–1.29	0.60
Glomerulonephritis	1.000	Ref	Ref
Other	0.97	0.81–1.17	0.78
Missing	0.96	0.51–1.82	0.91
Donor weight (per kg greater)	0.96	0.94–0.98	<0.0001
Single kidney (vs. en bloc)	1.78	1.52–2.09	<0.0001

donor weight into three categories. For donors weighing 10–21 kg, en bloc transplantation was associated with a significantly lower risk of graft failure at 5 years compared to transplantation of single kidneys (41% and 48% lower risk for en bloc transplants from donors 10 to 15 and 15 to 21 kg, respectively; both $p < 0.0001$). En bloc transplants from donors weighing less than 10 kg were also associated with a 24% lower risk of graft failure at 5 years compared to single transplants, although the number of cases was small and the difference was not statistically significant ($p = 0.31$). Further analyses compared various combinations of donor weight and en bloc or single transplant use compared to a reference group of single transplants from donors 15 to 21 kg (Table 5). As also demonstrated in Table 5, 750 transplants continued to function at 5 years from 813 solitary kidney donors (0.92 functioning grafts per donor) compared to 972 transplants from 1301 en bloc donors (0.75 functioning grafts per donor for en bloc).

Comparison of graft outcome after small pediatric donor to ideal donor kidney transplantation

Comparison of graft survival of the 2449 transplants using small pediatric donors to the graft survival of 24 530 single kidney transplants performed using ideal kidney donors (reference, HR 1.00) demonstrated that recipients of single kidneys from small pediatric donors were at a significantly increased risk for graft loss (HR 1.63, CI 1.44–1.84; $p < 0.0001$). In contrast, recipients of en bloc kidneys from small pediatric donors had a similar survival (HR 1.05, CI 0.92–1.21; $p = 0.45$) to ideal donors.

Discussion

While the number of candidates on the deceased donor kidney waiting list has steadily increased, the availability of deceased donors has increased very slowly by comparison (24,25). Ojo et al. demonstrated a survival advantage for recipients of kidney transplants from marginal deceased donors when compared to patients with renal failure being maintained on dialysis (26). Other efforts have been made to expand the donor pool using expanded criteria donors (26), donation following cardiac death, dual kidney transplants from a marginal donor to a single recipient and solitary or en bloc transplants from small pediatric donors (3–6,28). However, the best utilization of kidneys from small pediatric deceased donors is unknown and the pool of such donors may be underutilized. Issues relating to small pediatric donors are the subject of this report.

Table 5: Adjusted 5-year graft survival and risk of graft failure following en bloc or single kidney transplantation by pediatric donor weight

	Five-year graft survival				Risk of graft failure		
Donor weight	Transplants	Graft failures	Adjusted survival estimate[1] (%)	CI	HR	CI	p Value
En bloc							
Overall	1287	315	72.7	(69.2%, 76.3%)	–	–	–
1–<10 kg	271	97	60.0	(53.3%, 67.7%)	1.12	(0.89, 1.42)	0.33
10–<15 kg	601	138	71.1	(66.3%, 76.2%)	0.66	(0.54, 0.81)	<0.0001
15–<21 kg	415	80	77.8	(73.1%, 82.8%)	0.52	(0.41, 0.67)	<0.0001
Single							
Overall	1162	412	54.8	(50.1%, 60.0%)	–	–	–
1–<10 kg	37	17	41.9	(25.2%, 69.7%)	1.47	(0.90, 2.42)	0.13
10–<15 kg	323	115	56.6	(49.7%, 64.5%)	1.11	(0.89, 1.38)	0.35
15–<21 kg	802	280	58.7	(53.9%, 63.9%)	1.00	Reference	–

[1]Adjusted to the average recipient.

The present study used data from the SRTR to identify predictors for recovery, discard and transplantation of kidneys from donors <21 kg. As anticipated, kidneys from older and heavier donors were more likely to be recovered and transplanted from this pool of small pediatric donors. Remarkably, kidneys procured en bloc were much more likely to be transplanted, with an AOR of 65.8, than kidneys recovered as two separate single organs. Graft survival of en bloc kidney transplants was also demonstrated to be significantly better when compared to single kidney transplants. In fact, the graft survival of en bloc kidney transplants was found to be similar to ideal kidney donors while the graft survival for solitary kidney transplants from small pediatric donors was significantly decreased. However, offers for en bloc kidneys are often made prior to organ procurement and may possibly be used in selected candidates. This may lead to bias in recipient selection and is impossible to evaluate using the available registry data.

With respect to organ availability, the recovery rate was less than 50% for donors <10 kg, whereas the recovery rate for pediatric donors weighing 10–21 kg was 90%, similar to that seen in the adult population (25). During the 10-year study period, a total of 2886 potential donors were identified. However, this likely underrepresents the true number of potential small pediatric donors during this period. The present study identified potential donors as all those from whom at least one solid organ was recovered. There were almost surely additional potential donors whose other solid organs were not procured and whose kidneys were not recovered because small pediatric donors were not commonly used in that DSA. Therefore, the observed recovery percentage of kidneys from small pediatric deceased donors is likely artificially high because it does not include otherwise suitable donors where no organs were recovered at all. However, it is difficult to quantify the impact of a more aggressive approach to recovering kidneys from small donors from whom no other organs are being procured.

While lower donor weight independently predicted a higher risk of graft loss, there was no significant difference in long-term graft survival between kidneys from donors less than 10 kg transplanted en bloc compared to solitary kidney transplants from donors weighing 15–21 kg. In other words, the use of the en bloc technique appears to obviate the otherwise adverse effect of very small donor size on outcome. These data suggest that acceptable outcomes can be obtained from en bloc transplants using pediatric donors less than 10 kg and support a more aggressive approach for utilization of this donor population.

The results of the present study suggest additional strategies to improve utilization of kidneys recovered from small pediatric donors. First, a number of DSAs were found to have limited or no experience with transplantation of small pediatric kidneys, yet only one-half of the small donor kidneys from this group of DSAs were shared. Facilitated sharing to DSAs with more experience may help increase utilization. In addition, kidneys retrieved en bloc were found to be 32% (unadjusted odds ratio = 1.32) more likely to be transplanted than those procured as two separate, single organs. Kidneys procured en bloc may be more likely to have been accepted for a recipient before procurement, although the available data do not allow us to test this hypothesis. On the other hand, we speculate that kidneys from small pediatric donors that are recovered in a solitary fashion may reflect inexperience with the en bloc procurement technique or procurement by a team that does not utilize en bloc transplants for its recipients. Since organ procurement practices may vary from region to region, these data suggest that unless it is known *a priori* that the kidneys will be used for solitary transplantation, procurement as an en bloc pair should be performed.

In a prior study, Dharnidharka et al. compared the risk of graft failure between kidneys transplanted en bloc, as dual transplants, or singly (20). That study demonstrated a significantly higher risk of graft failure (adjusted HR = 1.18) for kidneys transplanted en bloc compared to single kidneys of all ages. However, among kidneys from donors less than 5 years old, those transplanted en bloc were found to have a significantly lower risk of graft loss when compared to those transplanted singly (adjusted HR = 0.71). Whether kidneys from all small pediatric donors should be transplanted en bloc or in a solitary fashion remains unclear. A study from the University of Maryland suggests that kidneys >6 cm can be used for solitary transplant with excellent outcomes. In that study, the average donor weight was 14 kg for solitary kidneys and 10 kg for those used en bloc (17).

Some authors have supported utilization of younger donors preferentially in pediatric recipients (29). However, not all recipient patient populations may benefit equally from en bloc kidney transplantation from small pediatric donors. An analysis from the North American Pediatric Renal Transplant Cooperative Study demonstrated a considerably increased rate of graft thrombosis for pediatric recipients receiving kidney transplants from donors under 5 years old (30). Further analysis is needed to evaluate if solitary or en bloc transplants from small pediatric donors leads to acceptable results in the pediatric recipient population.

Interestingly, the present study showed higher graft survival rates for en bloc versus single transplants for each donor weight category, with the difference at 5 years following transplantation ranging from 14.5% to 19.1%. Prior studies have demonstrated poor outcomes using small pediatric kidneys either singly or en bloc, (8,11,18) suggesting that small pediatric donors may be 'marginal' donors. However, these data suggest that the best results for an individual recipient of kidneys from a small pediatric donor are achieved with en bloc transplantation and, in fact, when transplanted en bloc, have the same graft survival as ideal kidney donors. However, twice as many candidates would be transplanted if all these kidneys were transplanted singly, albeit with poorer outcomes. While kidneys transplanted en bloc represent less than 10% of all renal transplants per year in the United States (20), procurement and utilization using an en bloc technique may improve utilization and outcomes. Ultimately, the goal should be to maximize the aggregate beneficial effects of transplanting these kidneys and further studies are needed to determine the optimal balance.

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References

1. *2004 OPTN/SRTR Annual Report*, http://www.ustransplant.org/annual_reports/2004/home.aspx?f = /default.htm1.
2. Wolfe RA, Ashby VB, Milford EL et al. Comparison of mortality in all patients on dialysis, patients on dialysis awaiting transplantation, and recipients of a first cadaveric transplant. N Engl J Med 1999; 341: 1725–1730.
3. Remuzzi G, Grinyo J, Ruggenenti P et al. Early experience with dual kidney transplantation in adults using expanded donor criteria. Double Kidney Transplant Group (DKG). J Am Soc Nephrol 1999; 10: 2591–2598.
4. Johnson LB, Kuo PC, Schweitzer EJ et al. Double renal allografts successfully increase utilization of kidneys from older donors within a single organ procurement organization. Transplantation 1996; 62: 1581–1583.
5. Dietl KH, Wolters H, Marschall B, Senninger N, Heidenreich S. Cadaveric 'two-in-one' kidney transplantation from marginal donors: Experience of 26 cases after 3 years. Transplantation 2000; 70: 790–794.
6. Lu AD, Carter JT, Weinstein RJ et al. Outcome in recipients of dual kidney transplants: An analysis of the dual registry patients. Transplantation 2000; 69: 281–285.
7. Lledo Garcia E, Diez Cordero JM, Subira Rios D et al. Pediatric renal transplantation from young children donors (aged $<$ or $=$ 6 years). Complications and functional clinical course. Actas Urol Esp 2004; 28: 40–48.
8. Satterthwaite R, Aswad S, Sunga V et al. Outcome of en bloc and single kidney transplantation from very young cadaveric donors. Transplantation 1997; 63: 1405–1410.
9. Hayes JM, Novick AC, Streem SB et al. The use of single pediatric cadaver kidneys for transplantation. Transplantation 1988; 45: 106–110.
10. Terasaki PI, Gjertson DW, Cecka JM, Takemoto S, Cho YW. Significance of the donor age effect on kidney transplants. Clin Transplant 1997; 11(5 Pt 1): 366–372.
11. Modlin C, Novick AC, Goormastic M, Hodge E, Mastrioanni B, Myles J. Long-term results with single pediatric donor kidney transplants in adult recipients. J Urol 1996; 156: 890–895.
12. Smith AY, Van Buren CT, Lewis RM, Kerman RH, Kahan BD. Short-term and long-term function of cadaveric kidneys from pediatric donors in recipients treated with cyclosporine. Transplantation 1988; 45: 360–367.
13. Meakins JL, Smith EJ, Alexander JW. En bloc transplantation of both kidneys from pediatric donors into adult patients. Surgery 1972; 71: 72–75.
14. Lackner JE, Wright FH, Banowsky LH. Long-term function of single pediatric kidneys less than 48 months of age transplanted into adult recipients compared with adult cadaveric and living-related transplants. Transplant Proc 1997; 29: 3283–3287.
15. Banowsky LH, Lackner J, Kothmann R, Wright FH. Results of single kidneys from donors aged 9 to 60 months: Results in 144 adult recipients. Transplant Proc 1997; 29: 3271–3273.
16. Merkel FK. Five and 10 year follow-up of en bloc small pediatric kidneys in adult recipients. Transplant Proc 2001; 33: 1168–1169.
17. Borboroglu PG, Foster CE, 3rd, Philosophe B et al. Solitary renal allografts from pediatric cadaver donors less than 2 years of age transplanted into adult recipients. Transplantation 2004; 77: 698–702.
18. Abouna GM, Kumar MS, Chvala R, McSorley M, Samhan M. Transplantation of single pediatric kidneys into adult recipients—a 12-year experience. Transplant Proc 1995; 27: 2564–2566.
19. Ratner LE, Cigarroa FG, Bender JS, Magnuson T, Kraus ES. Transplantation of single and paired pediatric kidneys into adult recipients. J Am Coll Surg 1997; 185: 437–445.
20. Dharnidharka VR, Stevens G, Howard RJ. En-bloc kidney transplantation in the United States: An analysis of United Network of Organ Sharing (UNOS) data from 1987 to 2003. Am J Transplant 2005; 5: 1513–1517.
21. Social Security Administration Death Master File. Federal Computer Products Center, National Technical Information Service, U.S. Department of Commerce, Springfield, VA.
22. 2000 CDC Growth Charts: United States. (Accessed June 10, 2005 at http://www.cdc.gov/growthcharts).
23. Port FK, Bragg-Gresham JL, Metzger RA et al. Donor characteristics associated with reduced graft survival: An approach to expanding the pool of kidney donors. Transplantation 2002; 74: 1281–1286.
24. Port FK, Dykstra DM, Merion RM, Wolfe RA. Organ donation and transplantation trends in the USA, 2003. Am J Transplant 2004; 4(Suppl 9): 7–12.
25. Sheehy E, Conrad SL, Brigham LE et al. Estimating the number of potential organ donors in the United States. N Engl J Med 2003; 349: 667–674.
26. Ojo AO, Hanson JA, Meier-Kriesche H et al. Survival in recipients of marginal cadaveric donor kidneys compared with other recipients and wait-listed transplant candidates. J Am Soc Nephrol 2001; 12: 589–597.
27. Sung RS, Guidinger MK, Lake CD et al. Impact of the expanded criteria donor allocation system on the use of expanded criteria donor kidneys. Transplantation 2005; 79: 1257–1261.
28. Cho YW. Expanded criteria donors. Clin Transpl 1998; 421–436.
29. Pape L, Offner G, Ehrich JH, de Boer J, Persijn GG. Renal allograft function in matched pediatric and adult recipient pairs of the same donor. Transplantation 2004; 77: 1191–1194.
30. Singh A, Stablein D, Tejani A. Risk factors for vascular thrombosis in pediatric renal transplantation: A special report of the North American Pediatric Renal Transplant Cooperative Study. Transplantation 1997; 63: 1263–1267.