Kidney Medicine

Center Volume and Kidney Transplant Outcomes in Pediatric Patients

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Rationale & Objectives: Recent data demonstrate that center volume is not a factor in the outcomes of adult kidney transplant recipients. This study assessed whether center volume affects graft survival in pediatric patients who received a kidney transplant.

Study Design: Case-cohort study.

Setting & Participants: Kidney transplantation centers, recipients younger than 18 years.

Results: Data were retrieved from the Scientific Registry of Transplant Recipients for transplantations performed July 1, 2010, to June 30, 2015, and the Organ Procurement and Transplantation Network for transplantations performed January 1, 2010, to December 30, 2015. Center volume was divided into 3 groups: low (<4 per year), intermediate (4-8 per year), and high (>8 per year). The primary outcome was 3-year graft survival rate. Outcomes were reviewed in 115 centers that performed 3,762 transplantations. There were no substantive differences in sex, age, ethnicity, diagnosis, and kidney donor profile index score in the 3 transplantation center volume categories. During the 5-year period (July 1, 2010, to June 30, 2015), 3-year graft survival in centers with low, intermediate, and high volumes were 88.4%, 90.3%, and 92.1%, respectively; $P = 0.02$. Although outcomes for deceased donor kidney recipients were similar in the 3 volume categories, outcomes in patients who received a living kidney donation were better in the high-volume centers. Low household income was associated with poorer outcomes. However, 3-year graft survival was similar in the 3 center volume categories in high and low mean household income states.

Limitations: Lack of information for complications and individual family household income of recipients.

Conclusions: Transplantation outcomes are worse in pediatric patients treated at lower-volume centers. The difference was more pronounced for patients receiving living versus deceased donor kidneys. The distribution of household income in pediatric transplant recipients may also be a factor that contributes to lower 3-year graft survival in low-volume centers.

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For many medical practices, favorable outcomes are directly related to the amount of practical experience of the practitioner.[1,2] This is especially the case for surgical procedures. There is extensive literature documenting that patients do better if they undergo interventions at centers with a higher volume of the procedure.[2-5] This is presumed to reflect increased workload, number of patients, and practical experience with the procedure by the specialists who perform the intervention and manage patients after transplantation. This finding has been noted for established operations such as coronary artery bypass surgery and innovative interventions such as transcatheter aortic valve replacement.[6,7]

There has been limited investigation into whether this observation applies to adult patients who undergo kidney transplantation. Although it is an established procedure, it involves extensive pre- and postoperative coordination of a wide range of services. It is unknown whether high transplantation volume translates into improved outcomes at individual centers, especially with greater organ sharing and the introduction of more effective immunosuppressive medications. A recent report demonstrated that outcomes for kidney transplantation in adults were comparable in centers with low, medium, medium-high, and high patient volumes. Although there were modest differences in patient characteristics in these 4 categories of centers, the small differences in outcome noted were not consistently related to center volume and were not clinically significant.[8]

Although kidney transplantation accounts for more than half the annual number of transplantations performed in the United States, kidney transplantation in children is much less common and accounts for ∼2% of the annual number of transplantations, according to Organ Procurement and Transplantation Network (OPTN) database as of January 1, 2019. The number of transplantations performed at even the highest volume pediatric center is only a fraction of the volume at the low end of the adult centers. Moreover, clinical characteristics of children with end-stage kidney disease who receive a kidney transplant are vastly different from their adult counterparts.[9] It is unclear whether the lack of impact of center volume on transplantation outcomes applies to children. It is conceivable that the downward shift to much lower volumes of kidney transplantations in pediatrics may reveal an impact of center volume on graft outcomes. Therefore, we conducted this retrospective study of graft survival in pediatric kidney transplant recipients during 2010 to 2015 in relationship to the annual volume of transplantations performed at the center.

METHODS

Data for pediatric (<18 years of age) kidney transplant recipients were retrieved from the Scientific Registry of Transplant Recipients (SRTR) for transplantations performed July 1, 2010, to June 30, 2015. This time frame was used to apply the most up-to-date information for 3-year outcomes at the time of this review, which was available in the January 2019 report. SRTR presents data in 2.5-year segments. Data were collected for 2 consecutive periods: period 1 (July 10, 2010, to December 31, 2012) and period 2 (January 1, 2013, to June 30, 2015). Information was collected for each period separately and then combined. Transplantation centers that performed zero transplantations in either period 1 or period 2 were excluded from the analysis. Due to lack of pediatric-specific data for the full range of covariates in SRTR, this information was retrieved from the OPTN for transplantations performed in the 6-year period of January 1, 2010, to December 30, 2015. This time frame was used because OPTN presents data annually, from January 1 to December 30 of that year. The 6-year OPTN period contained the 5-year SRTR interval.

Center volume was divided into 3 groups based on the average number of transplantations performed each year and to achieve groups with a comparable number of transplantation centers. A mean of 6.5 transplantations were performed each year across the total 115 centers included. Thus, 3 groups were defined: (1) low volume, fewer than 4 transplantations per year; (2) intermediate volume, 4 to 8 transplantations per year; and (3) high volume, more than 8 transplantations per year.

The main outcome was crude proportion of graft survival as a binary variable (yes/no) at the defined time points. Outcomes were assessed at 1 month, 1 year, and 3 years after kidney transplantation and the primary end point was 3-year allograft survival rate. The following covariates were assessed: sex, age, ethnicity, diagnosis, and kidney donor profile index (KDPI) score. Recipient age was divided into 0 to 5, 6 to 10, and 11 to 17 years. Ethnicity was divided into white, black, Hispanic, Asian, and other, which included American Indian, Pacific Islander, and multiracial. Diagnoses were divided into glomerular disease, nonglomerular disease, and other. Nonglomerular disease included congenital, rare, familial, and metabolic diagnoses; polycystic kidney disease; and tubular and interstitial diseases. Other disease included diabetes, hypertensive nephrosclerosis, neoplasms, renovascular, and other vascular disease; retransplantation/graft failure; and other. KDPI score was the only donor characteristic tabulated and is a numerical measure of the quality of deceased donor kidneys, with lower values associated with increased donor quality.[10] KDPI score was divided into the following categories: 0 to 20, 21 to 34, 35 to 85, and unknown.

Table 1. Number of Transplantations by Period

	Period 1	Period 2	Total
No. of total transplantations	1,824	1,938	3,762
No. of living donor transplantations	725	658	1,383
No. of deceased donor transplantations	1,099	1,280	2,379

Chi-squared tests were used to compare transplant outcomes and graft survival (yes/no) at the defined times in the indicated groups. Results were considered significant for $P < 0.05$.

This study was exempted from institutional review board review and the requirement for informed consent was waived because it used publicly available deidentified data.

RESULTS

Transplantation Centers

After exclusion of centers that performed 0 transplantation in either period 1 or period 2, included in this analysis were 115 centers. The total number of transplantations according to 1-month and 1-year graft survival data was 3,488. The total number of transplantations in the SRTR database according to 3-year graft survival data was 3,762 (Table 1). The consistently larger number of transplantations based on the 3-year milestone may reflect greater likelihood of entering the clinical data into the registries at later time points. We determined the number of transplantations at each center using the value entered for the 3-year survival based on the assumption that this time point represented the most accurate tally with more complete follow-up. The annualized rate (number of transplantations per year) for periods 1 and 2 was calculated for all centers. The average annualized rate for all centers was 6.5, while the median rate was 5.2 transplantations per year. The annualized number of transplantations performed at all centers is illustrated in Figure S1.

The general characteristics of transplantations performed (based on the SRTR database) categorized by center volume are summarized in Table 2. The living to deceased donor ratio decreased over the 2 periods, with relatively more deceased donor transplantations in period 2. It is possible that recent modifications to kidney allocation policies that facilitate deceased kidney donation in select patient subgroups may have affected this ratio; this requires further study.[11]

Recipients

Table 3 shows recipient characteristics—sex, age, ethnicity, and diagnosis—in the 3 center volume groups, derived from the OPTN database. Overall, there were no substantive differences in any of the features in the 3 transplantation center volume categories, although there

Table 2. Transplantation Center Characteristics by Center Volume

	Low (<4)	Intermediate (4-8)	High (>8)	Total
Total no. of transplantations	554	931	2,277	3,762
No. of living donor transplantations	166 (30%)	327 (35%)	890 (39%)	1,383
No. of deceased donor transplantations	388 (70%)	604 (65%)	1,387 (61%)	2,379
No. of centers	53	29	33	115

Table 3. Patient Characteristics by Center Volume: Recipient and KDPI

	Low (<4)	Intermediate (4-8)	High (>8)	*P*
Male sex	486 (58%)	870 (56%)	2,257 (57%)	0.4
Age				<0.001
0-5 y	105 (11%)	110 (14%)	411 (17%)	
6-10 y	258 (26%)	207 (25%)	612 (25%)	
11-17 y	640 (64%)	500 (61%)	1,465 (59%)	
Ethnicity				<0.001
White	326 (52%)	547 (51%)	1,267 (49%)	
Black	140 (22%)	219 (20%)	427 (16%)	
Hispanic	125 (20%)	261 (24%)	719 (28%)	
Asian	19 (3%)	26 (2%)	115 (4%)	
Other	16 (3%)	24 (2%)	76 (3%)	
Diagnosis				<0.001
Glomerular	186 (30%)	297 (28%)	592 (23%)	
Nonglomerular	213 (34%)	407 (38%)	1,067 (41%)	
Other	227 (36%)	361 (34%)	935 (36%)	
KDPI donor score				0.06
0-20	182 (29%)	249 (24%)	689 (26%)	
21-34	50 (8%)	87 (8%)	186 (7%)	
35-85	39 (6%)	74 (7%)	142 (5%)	
Unknown	349 (56%)	646 (61%)	1,601 (61%)	

Note: Values expressed as number (percent).
Abbreviation: KDPI, kidney donor profile index.

were more very young (aged 0-5 years) and fewer black recipients in the high-volume centers. KDPI score, the only donor characteristic that was tabulated, was also similar in the 3 classes of transplantation center volume.

Outcomes

Patient survival was the same in low-, intermediate-, and high-volume centers at 1 month (99.8%) and nearly the same at 3 years: 99%, 98.3%, and 98.6%, respectively (Fig S2).

During period 1 (July 1, 2010, to December 31, 2012), 1-month and 1-year graft survival rates were similar in the 3 center volume categories. However, there was a significant difference in 3-year graft survival rates in the low-, intermediate-, and high-volume centers: 88.0%, 92.0%, and 93.4% respectively; P 0.01 (Fig 1A). During period 2 (January 1, 2013, to June 30, 2015), again 1-month and 1-year rates were similar in the 3 categories. The 3-year graft survival rates in the centers with low, intermediate, and high volume were 88.8%, 88.6%, and 90.7%, a trend that was similar to period 1 but not significant, $P = 0.4$ (Fig 1B). During the 5-year period (July 1, 2010, to June 30, 2015) created by combining periods 1 and 2, the 1-month and 1-year graft survival rates were similar among all 3 center volume groups. The 3-year survival outcomes in centers with low, intermediate, and high volume were 88.4%, 90.3%, and 92.1%, respectively; $P = 0.02$ (Fig 1C; Table S1). The number needed to harm, based on the difference in 3-year outcomes, is 27; that is, for every 27 patients receiving a transplant at a low- versus high-volume center, 1 additional graft loss would occur at a low-volume center.

To verify the impact of center volume, we compared centers with extremely low volume, defined as less than 1.5 transplantation per year, versus extremely high volume, defined as more than 14 transplantations per year. The difference in 3-year outcomes was magnified at these extremes of center volume, with the low and high extremes having 3-year graft survival rates of 85.66% and 93.52%, respectively; $P = 0.003$ (Fig 2).

Outcomes were compared in patients receiving transplants from living versus deceased donors. Outcomes from living donors significantly differed in centers with low, intermediate, and high volumes, with 3-year survival rates of 93.7%, 88.7%, and 95.3%, respectively; $P = 0.0002$. Because of the nonlinear trend in 3-year graft survival, we combined the low- and intermediate-volume centers and confirmed that the outcomes after living related donor transplantation were inferior to those achieved in high-volume centers: 91.7% versus 95.3%; $P = 0.005$ (Fig 3; Table S2). In contrast, outcomes from deceased donors were very similar in centers with low, intermediate, and high volumes, with 3-year survival rates of 88.8%, 89.1%, and 89.8%; $P = 0.8$ (Fig 3). It is important to note that living related transplantation procedures constituted a larger percentage of the workload at high-volume centers (Table 2).

Outcomes were also compared in centers that were in high versus low mean household income states to assess whether socioeconomic factors contributed to the differences in 3-year outcomes. Using information from the US Census Bureau, the 10 states with the highest median household incomes (District of Columbia, Maryland, New Jersey, Hawaii, Massachusetts, Connecticut, New Hampshire, Alaska, California, and Virginia) were compared

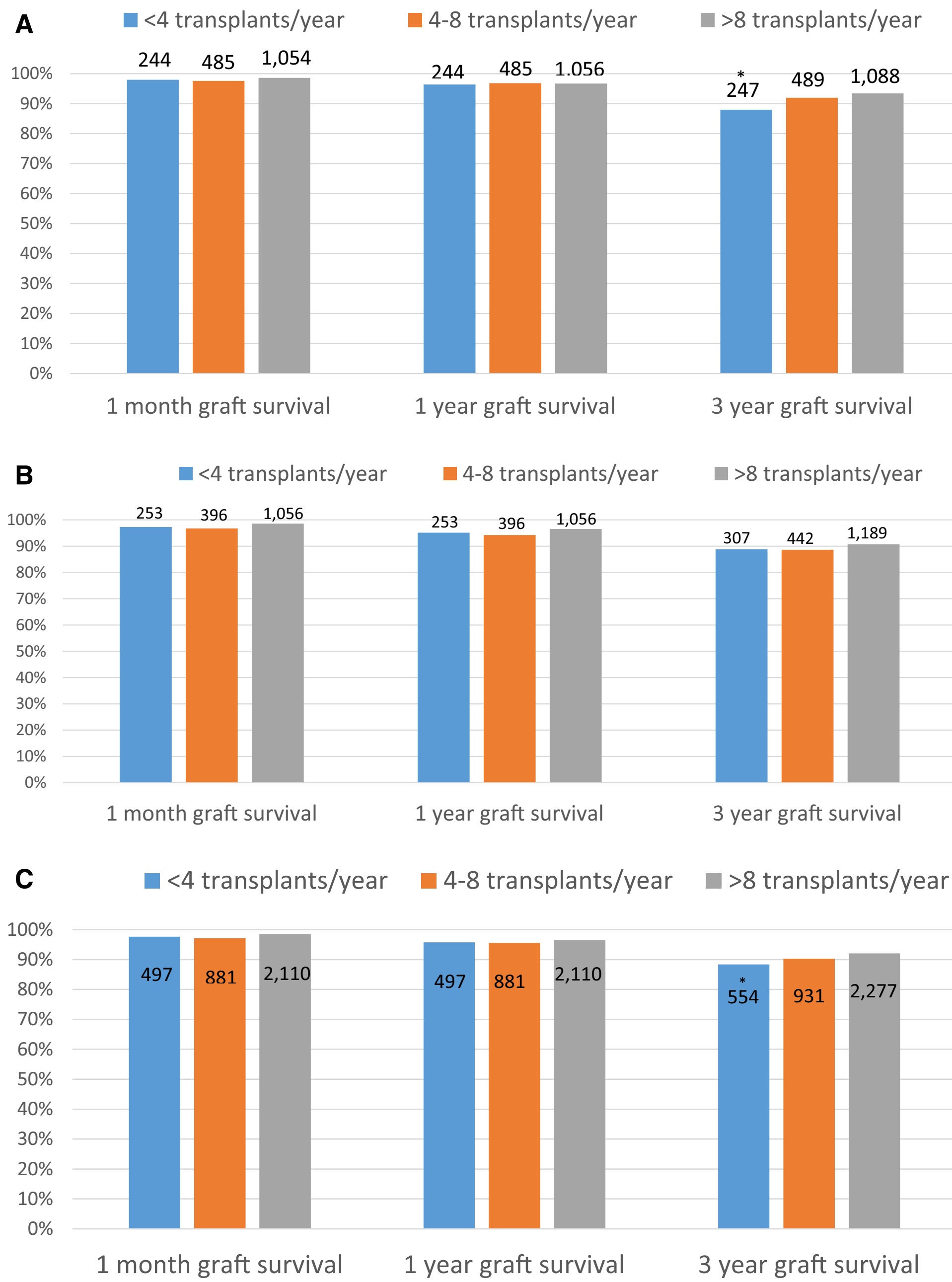

Figure 1. Graft survival for centers by volume for (A) period 1 (July 1, 2010, to December 31, 2012), (B) period 2 (January 1, 2013, to June 30, 2015), and (C) combined 5-year period (July 1, 2010, to June 30, 2015). Graphs illustrate graft survival at 1 month and 1 and 3 years after surgery in patients receiving a kidney transplant at low- (blue), intermediate- (orange), and high-volume (gray) centers. Numbers above columns indicate number of patients. (A) **P* = 0.01; (C) **P* = 0.02.

with the 10 states with the lowest median household incomes (Tennessee, South Carolina, Oklahoma, Kentucky, Alabama, New Mexico, Louisiana, Arkansas, Mississippi, and West Virginia). The 3-year graft survival rates differed markedly, with centers in high- and low-income states having 3-year graft survival rates of 94.0% and 83.6%, respectively; $P < 0.001$ (Fig 4). Interestingly, 1-year graft survival was also better in transplantation centers from high- versus low-income states: 97.0% versus 93.8%, respectively ($P = 0.008$; Fig 4).

However, when analyzing the interaction of household income and center volume, 3-year graft survival rates did not differ in centers from high-income states at low-, intermediate-, and high-volume centers: 93.9%, 94.9%, and 93.6%, respectively; $P = 0.7$ (Fig 5). Similarly, 3-year graft survival rates did not differ in centers from low-income states categorized by center volume: 82.4%, 84.7%, and 73.7% in low-, intermediate-, and high-volume centers, respectively; $P = 0.9$ (Fig 5). It is worth noting that the percentage of low-volume centers was similar in the high

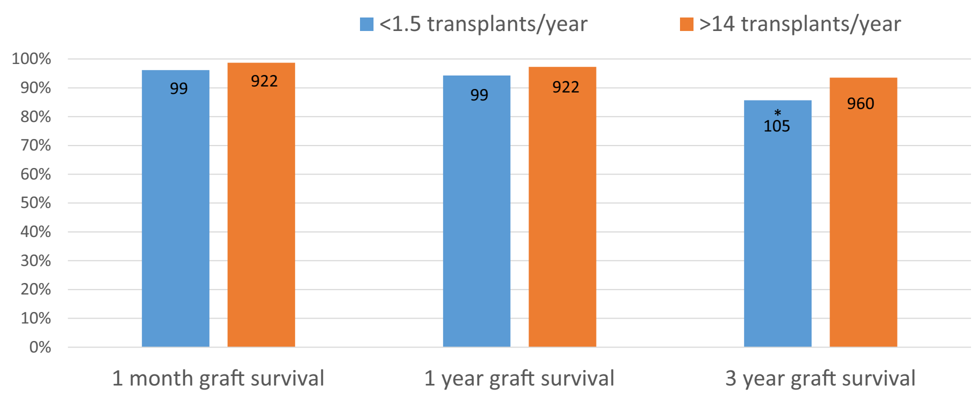

Figure 2. Graft survival for low- and high-volume center extremes. This graph illustrates graft survival at 1 month and 1 and 3 years after surgery in patients receiving a kidney transplant at extreme low- (blue) and high-volume (orange) centers. Numbers above columns indicate number of patients. *$P = 0.003$.

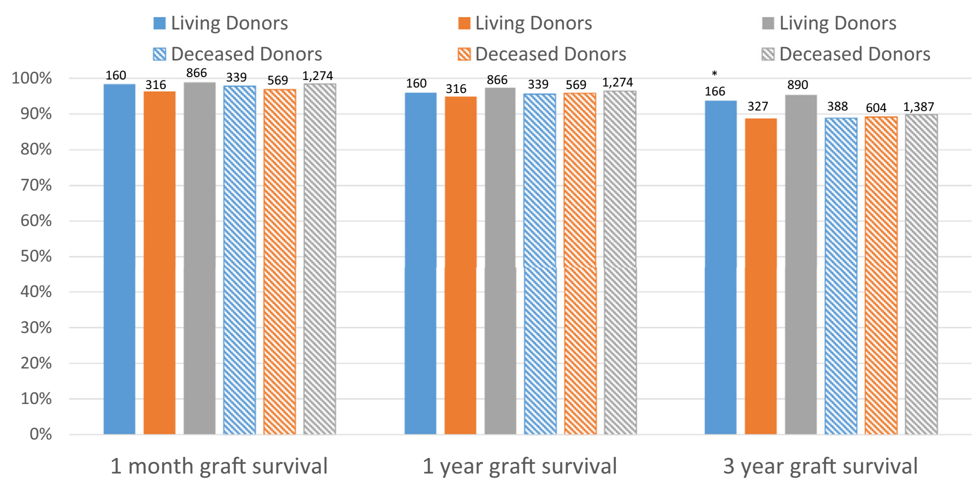

Figure 3. Living versus deceased donor graft survival. This graph illustrates graft survival at 1 month and 1 and 3 years after surgery in patients receiving a kidney transplant at low- (blue), intermediate- (orange), and high-volume (gray) centers. Solid bars represent graft survival from living donors, and striped bars represent graft survival from deceased donors. Numbers above columns indicate the number of patients. *$P = 0.0002$.

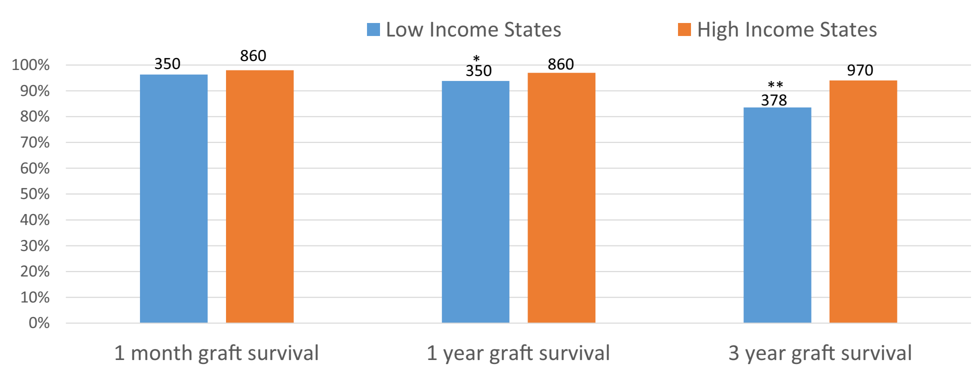

Figure 4. Graft survival in high- versus low-income states. This graph illustrates graft survival at 1 month and 1 and 3 years after surgery in patients receiving a kidney transplant at low- (blue) and high-income (orange) centers in states categorized by mean household income. Numbers above the columns indicate the number of patients. *$P = 0.008$; **$P < 0.00001$.

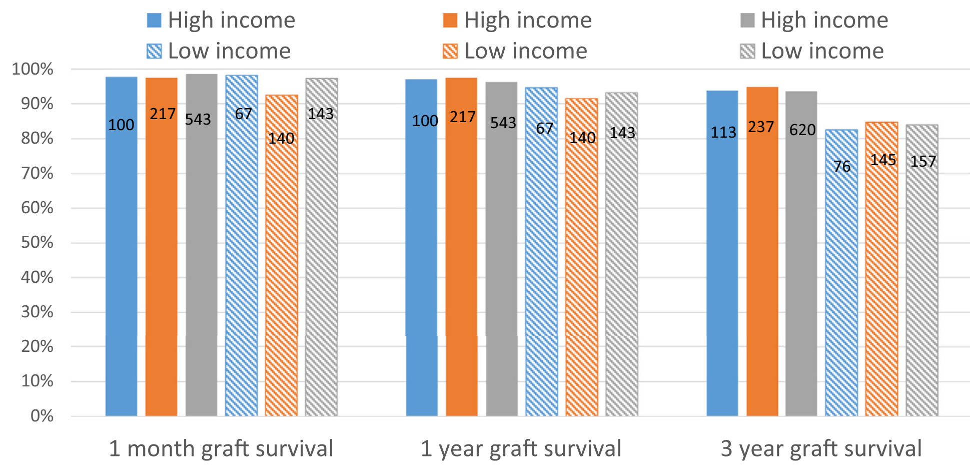

Figure 5. Graft survival in high- versus low-income states by center volume. This graph illustrates graft survival at 1 month and 1 and 3 years after surgery in patients receiving a kidney transplant at low- (blue), intermediate- (orange), and high-volume (grey) centers in states categorized by mean household income. Solid bars represent graft survival from high-income states, and striped bars represent graft survival from low-income states. Numbers above columns indicate number of patients.

and low mean household income states: 46% (12/26) and 50% (7/14), respectively.

Sensitivity analysis was performed on high- and low-income states but controlling for state size as a surrogate of travel distance. States were ranked by income and states were then matched with other states of equal area at the extremes of income (Table S3). Figure 6 illustrates 1-month, 1-year, and 3-year outcomes for high- and low-income states controlled for geographic area. There is a reduced but persistent difference in 3-year graft survival rates, with centers from high- and low-income states having 3-year graft survival rates of 90.7% and 86.2% respectively; $P = 0.004$ (Fig 6).

However, when comparing outcomes by center volume, 3-year graft survival rates did not differ in centers from high-income states matched for area: 88.8%, 90.1%, and 92.2% in low-, intermediate-, and high-volume centers, respectively; $P = 0.3$ (Fig 7). The 3-year graft survival rates were different in centers from low-income states, with graft survival rates of 93.5%, 83.1%, and 92.5% in low-, intermediate-, and high-volume centers, respectively; $P = 0.003$ (Fig 7). In combination with the data from Figure 4, these findings suggest that income is another factor that contributes to lower 3-year graft survival in low-volume centers, even after accounting for distance from the transplantation center.

DISCUSSION

This retrospective study of graft survival in pediatric kidney transplant recipients showed that 3-year graft survival outcomes were slightly but significantly higher in high- versus low-volume centers. The difference was concentrated in recipients of living kidney donation, which constituted a larger percentage of transplantations performed at high-volume centers. Median household income is also a significant factor in determining 3-year graft outcomes in pediatric patients. However, when median household income is accounted for at the state level (high vs low), 3-year graft outcomes do not vary by center volume. Distance from the center could contribute in part to the effect of low household income.

Prior studies suggest that a number of factors related to transplantation programs and patient volume may affect 3-year graft survival in children and adolescents. For example, the low-volume pediatric centers performed much fewer procedures than even the smallest adult centers. This low volume may translate into large time gaps between procedures. This may interfere with physicians' abilities to "learn by doing" and improving their skills through practice.[12] Even though establishing a transplantation program requires training and coordination among a wide range of members of the relevant health care team,[8] long intervals between procedures may blunt the skills and expertise that are prerequisites for successful outcomes.[1]

Another explanation could be the "selective referral" hypothesis, namely that centers with better outcomes attract more patients, causing them to be higher-volume centers.[1] Although this hypothesis did not appear to be a factor in adult transplant recipients,[8] it may apply to the small number of procedures in children. Another possible explanation to account for why high-volume and high-income centers perform better is that they may have access to more specialized equipment.[1]

Finally, although children are thought to have greater resilience in recovering from medical illnesses, this may not apply posttransplantation. Children are at risk for developing psychosocial problems posttransplantation,[13] and improved psychosocial adjustment postintervention results in better outcomes.[14,15] Large-volume centers may

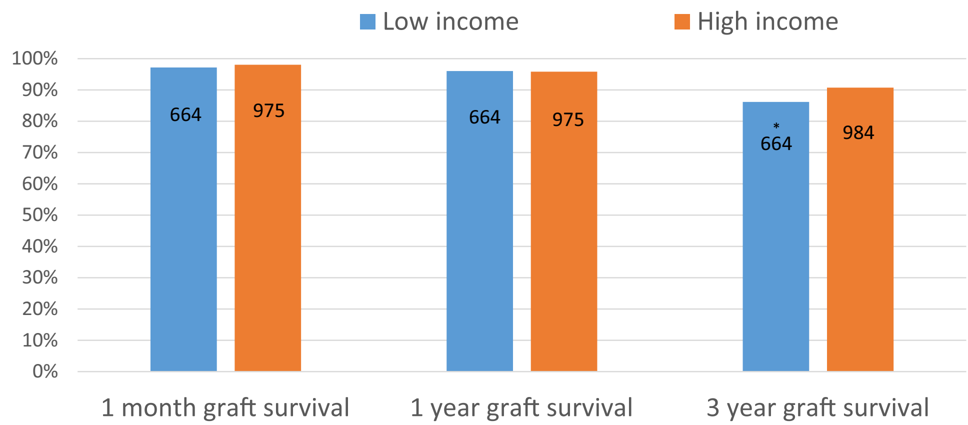

Figure 6. Graft survival in high- and low-income states matched for state size. This graph illustrates graft survival at 1 month and 1 and 3 years after surgery in patients receiving a kidney transplant at low- (blue) and high-income (orange) centers in states categorized by mean household income but matched for area. Numbers above columns indicate number of patients. *P = 0.0035.

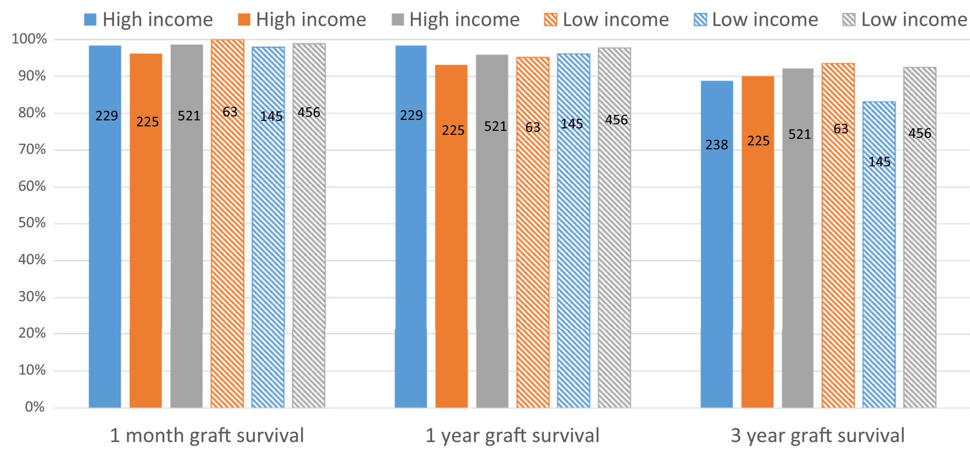

Figure 7. Graft survival in high- and low-income states matched for state size, by center volume. This graph illustrates graft survival at 1 month and 1 and 3 years after surgery in patients receiving a kidney transplant at low- (blue), intermediate- (orange), and high-volume (grey) centers in states categorized by mean household income but matched for area. Solid bars represent graft survival from high-income states, and striped bars represent graft survival from low-income states. Numbers above columns indicate number of patients.

be more adept at handling the psychosocial adjustment during the postoperative period, which may explain the better outcomes noted in this study. Although these are possible explanations for the findings that we report on graft outcomes in pediatric kidney transplant recipients based on center volume, we believe that the differences are not due to factors intrinsic to the centers. Instead, they reflect differences in patient characteristics, namely the percentage of living kidney donation procedures and possibly family household income. This suggests that our results are similar to the recent report showing that center volume itself does not affect outcomes in adult kidney transplant recipients.[8]

The rationale for this study was that high-volume centers have better outcomes due to a higher volume of procedures and therefore better surgical expertise. Long-term graft outcomes are less related to the technical aspects of the surgery and more linked to medical management. The comparable 1-month graft survival across the center volume spectrum argues against surgical factors being a key factor and suggests that limited experience may compromise the optimal handling of immunosuppression and prevention of infection accounting for the differences in 3-year graft survival.

It is worth noting that transplantation centers need to meet a benchmark based on graft survival to maintain certification and funding, which may spur institutional efforts to achieve better outcomes or prompt other sites to discontinue the procedure.[16,17] Pediatric programs are attached to adult programs for the purposes of Centers for Medicare & Medicaid Services flagging. This is based in the assumption that a single episode of graft loss could trigger regulatory action in smaller low-volume centers that perform kidney transplantations in children. However, this may allow pediatric programs to be out of compliance without being decertified as long as the adult program is in good standing. This progress of "natural selection" may explain why adult programs are more homogenous in terms of outcomes irrespective of volume while pediatric programs can have wider outcome disparities that are tolerated.

On closer inspection, when comparing graft survival in period 1 versus period 2, the outcomes were not significantly different in high- versus low-volume centers in the later period, suggesting possible improvement in outcomes over time in smaller-volume centers. This could be the result of improved physician training and increased standardization of procedures in all patient subgroups.[8]

The question arises whether the modest differences in 3-year outcomes that we have documented are clinically meaningful. The overall number needed to harm is 27, which is greater than the annual volume of patients who undergo transplantation at most pediatric centers and suggests that the difference would not be manifested over short periods. The difference in outcomes based on center volume may become more pronounced with extended follow-up. It is worth noting that if more pediatric programs were forced to decertify due to outcome differences, this could lead to significant geographic disparities in access for children to transplantation, particularly for lower-income families that lack resources to travel extensively.

The difference between deceased and living donation is striking and suggests that greater attention should be given to center volume in the latter circumstance. The number needed to harm may be smaller if the analysis is limited to living kidney donation. We cannot explain why low-volume centers should perform poorly compared with high-volume centers when dealing with a living donor, which is almost uniformly associated with better outcomes for adult kidney transplant recipients. One possible explanation is that the outcomes of living donor transplantations are dependent on the success of 2 operations with separate competencies. Additionally, the recipient operation with a live donor in the pediatric population is technically more challenging due to shorter vessels without donor vascular patches, which may be more significant when the recipient vessels are smaller. Further work is required to determine the factors that influence outcomes after living kidney donation in centers with different transplantation volumes.

The impact of household income on transplantation outcomes has been documented in select subpopulations such as African American adults with lupus nephritis.[18] It may be the consequence of having limited financial wherewithal to pay for immunosuppressive medications.[19] There is little information for the effect of household income on transplantation outcomes in children. The impact of household income and the distribution of families with different financial means among transplantation centers requires further investigation.

To our knowledge, this is the first report that examines transplantation outcomes in children in relation to center volume. It is worth noting that Rana et al[20] have documented that children who are listed at low-volume centers undergo transplantation less frequently and have a significantly higher risk for dying while on the wait list. These findings underscore the clinical relevance of center volume on overall health outcomes in children who require a kidney transplant.

There are several limitations of this study. First, by the nature of the data collected in the SRTR and OPTN, we did not have access to individual patient-level data and had only aggregate data by center at each time point. There was no information for timing of events. These features limited the statistical analyses that we could perform.

Second, the primary outcome was graft survival. SRTR and OPTN do not capture data for complications that patients experienced. Additional data for other outcomes, such as infections, could provide a clearer conclusion as to whether patients from high-volume centers are experiencing improved outcomes overall. The 5-year SRTR period was embedded in a 6-year OPTN period. However, we do not think that this small difference, equally divided on both ends of the SRTR period, would influence our analysis of patient- and center-related factors. There are no data for patient adherence to treatment, health literacy, and other social factors that might influence transplantation outcomes. There is also no patient-level or zip code information to determine whether more patients with low household income undergo transplantation at low-volume centers, which could account for the slightly poorer outcomes at the low-volume centers. Access to individual family income data is needed to address this question. The time was fairly narrow but was chosen to allow at least 3 years of follow-up in each case and at the same time avoid meaningful changes in clinical practice. Although the rules for organ allocation were changed in 2014, the impact should be limited to transplantations performed in the last year.

Finally, we focused solely on pediatric kidney transplantation outcomes and did not evaluate the relationship between outcomes in the 2 age groups based on center volume. The effect of center volume on graft survival in adults who receive a kidney transplant has already been analyzed by Sonnenberg et al.[8] In addition, the adult transplantation center volume could influence the outcomes in pediatric transplant recipients because of a number of factors for which we did not have information, such as surgical staffing with a dedicated pediatric surgeon and cross coverage, site of postoperative care, and composition of the transplantation team.

In conclusion, our analysis suggests that parents who are considering where to have a kidney transplantation performed for their child should not solely base their decision on center volume, even if they are pursuing a living related donation. The difference in graft survival under these circumstances and overall is not large enough to preclude selection of a center closer to home to take advantage of established medical relationships and available social support networks. We recommend that this information be shared with families confronting this problem with their child so that they can make an educated choice that balances medical and social exigencies. More research is needed to address the impact of financial resources on center selection and transplantation outcomes in children. We suggest that center volume not be included as a factor in the standardized assessment of post-transplantation outcomes.

SUPPLEMENTARY MATERIAL

Supplementary File (PDF)

Figure S1: Histogram illustrates the number of centers with defined annualized rates of kidney transplantation procedures

Figure S2: Patient survival for centers by volume for the combined 5-year period (07/01/2010 – 6/30/2015)

Table S1: The 3-year graft survival based on transplantation center volume with confidence intervals

Table S2: The 3-year graft survival in living kidney transplantation procedures based on center volume with confidence intervals

Table S3: High- and low-income states, controlled for state size as a surrogate of travel distance.

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