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Inferior allograft outcomes in adolescent recipients of renal transplants from ideal deceased donors

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Abstract

Objective—To measure the impact of the Share-35 policy on the allocation of ideal deceased donor kidneys, and to examine the impact of age on outcomes after kidney transplantation using ideal donor kidneys.

Summary Background Data—In the United States, through Share-35, transplant candidates <18 years of age receive priority for the highest-quality deceased donor kidneys. Adolescent (15 – 18 years) kidney transplant recipients (KTRs), however, may be more susceptible to allograft loss due to elevated rates of acute rejection and a possible increased risk of primary renal disease recurrence.

Methods—We used registry data to perform a retrospective cohort study of 39,136 KTRs from 1/1/1994 – 12/31/2008. Ideal donors were defined as 2 – 34 years old with creatinine <1.5mg/dL and absence of hypertension, diabetes and hepatitis C.

Results—After Share-35, the percentage of ideal donor kidneys allocated to pediatric recipients increased from 7 – 16%. In multivariable Cox regression, compared to adolescent KTRs, all age strata except recipients >70 years had a lower risk of allograft failure (p<0.01 for each comparison); results were similar after excluding KTRs with diseases at high risk of recurrence. Adolescent recipients had higher mortality rates than KTRs under 14 years, similar mortality compared to KTRs >18 and <40 years, and lower mortality than KTRs over 40 years.

Conclusions—The allocation of “ideal donors” to adolescent recipients may not maximize graft utility. Re-evaluation of pediatric allocation priority may offer opportunities to optimize ideal renal allograft survival.

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INTRODUCTION

According to the “Final Rule” governing organ allocation in the United States (US), the Organ Procurement and Transplantation Network (OPTN) must consider both equity and efficiency in offering kidneys for transplantation.¹ Since 2005, the “Share-35” policy has also directed the OPTN to give pediatric candidates a higher priority to receive the highest-quality deceased donor kidneys – those from donors under 35 years of age.² In one sense, the Share-35 policy may be viewed as consistent with the Final Rule’s directive to make the “best use of donated organs” by matching kidneys with the longest projected survival to the patients with the longest projected lifespan.¹ However, adolescent kidney transplant recipients (KTRs) have an elevated risk of acute rejection^{3–6} and may have increased risk of early primary renal disease recurrence after transplant.⁷ The Share-35 policy may therefore fail to optimize “ideal donor” allograft survival.

Share-35 provides a policy mechanism to recognize the unique benefits that children with end-stage renal disease (ESRD) derive from kidney transplantation. Compared to chronic dialysis, kidney transplantation lengthens survival and enables greater participation in school, athletics, and social activities.⁸ Transplantation also facilitates growth.^{9–11} These important benefits extend to adolescent patients, although perhaps not to the same degree as for younger patients. However, adolescents face significant barriers to allograft survival. Adolescents face substantial challenges to medication adherence.^{3, 12–15} Poor adherence may be driven by a number of issues including: difficulty with adaptation to the dual challenges of puberty and chronic illness; increasing independence from parents; and low self-awareness. During late adolescence, transplant outcomes may also suffer during transitions from pediatric health care centers to adult transplant centers, where more self-reliance is expected.¹⁶ Nonetheless, some centers have shown that some adolescent patients overcome all these barriers in settings of strong social support, careful adult supervision, and tailored education about the importance of medication adherence.^{12, 13}

The Share-35 policy seems to have accomplished the aim of lowering waiting times for ideal deceased donor kidneys in pediatric transplant recipients.² However, there have also been changes in donation patterns to pediatric renal transplantation since the implementation of Share-35 that may represent unintended consequences of this policy. While there is substantial evidence that living donor kidney grafts have superior long term survival in pediatric recipients than even ideal deceased donor grafts^{17–19}, rates of pediatric transplantation from living donors have decreased significantly since the implementation of Share-35 compared even to the overall decreased rate of living donation for all kidney recipients in the same time period.^{2, 20} This leads to concerns that the Share-35 policy, which elevates pediatric recipients to the top of the waiting list, may have de-incentivized living kidney donation to pediatric candidates and thus, created greater demands on the supply of deceased donor kidneys that are available to adults.²¹ Additionally, the degree of HLA matching between pediatric recipients and their allografts declined after the introduction of Share-35 and similar policies.^{20, 22–24} Many pediatric recipients, however, will need a second renal transplant later in life and thus, HLA matching may be an especially important consideration for this group.

Prior studies of adolescent outcomes have often been limited to comparisons between adolescent recipients versus other pediatric recipients, but did not make comparisons to adult recipient outcomes.^{2, 6, 7, 17, 20, 22, 25–29} Our goals in this work were to assess Share-35’s impact on access to ideal donor kidney allografts across all age groups, and to compare allograft survival for ideal kidney donor recipients between adolescents and recipients of other ages. We hypothesized that adolescent KTRs would have worse allograft survival compared to both younger recipients and adult recipients up to age 40 years.

METHODS

This is a retrospective cohort study of deceased donor KTRs performed in the US between January 1, 1994 and December 31, 2008, using registry data from the OPTN. The analysis was restricted to recipients of “ideal” deceased donor kidney allografts, which were defined as kidneys procured from donors aged 2 – 34 years with 1) terminal creatinine <1.5mg/dL, 2) absence of hypertension, 3) absence of diabetes, and 4) absence of hepatitis C. Exclusion criteria included any prior kidney transplant, multi-organ transplantation, or blood-group incompatible kidney transplantation.

Primary exposure of recipient age

We divided KTRs into age groups at transplant. We categorized adolescents as 15 – 18 years based on prior data showing adherence challenges in this group.^{13, 16, 30} The upper bound of 18 years was selected since this is the upper limit of eligibility for priority in receiving deceased donor kidneys through the Share-35 policy. The final age categories were: 0–14 years (n=2,128), 15–18 years (n=1,503), 19–25 years (n=1,799), 26–40 years (n=8,728), 41–55 years (n=14,061), 56–70 years (n=10,071), and >70 years (n=900). The primary outcome was allograft failure (non-death censored). The secondary outcome was mortality.

Statistical analyses

Analyses were performed using Stata 11.0 (Stata Corporation, College Station, TX, USA.) For univariate comparisons of means of continuous variables across age strata, ANOVA was used, and for univariate comparisons of categorical variables across age strata, chi-square was used. Univariate and multivariable comparisons of independent variables to survival were performed using Cox regression analysis.

Multivariable Cox regression analyses—Multivariable regression models were fit using variables that met nominal statistical significance ($p < 0.2$) in univariate analysis. We tested the following variables for inclusion in the multivariable models: **donor characteristics** of age, sex, race (African-American/other), waiting time, cause of death (cerebrovascular accident or stroke/other); **allograft characteristics** of cold ischemia (defined as <12/12–24 />24 hours), chronological era (the years 1994–1998/1999–2003/2004–2008), human leukocyte antigen mismatches (HLA mismatch, defined as 0/1/>1), donor kidney side (left/right); and **recipient characteristics** of age, sex, race, dialysis prior to transplant (yes/no), hepatitis C seropositivity, peak panel reactive antibody (PRA), and cause of ESRD. Causes of ESRD were categorized as follows: IgA, FSGS, other glomerulonephritis/autoimmune causes, uropathy/congenital, hypertension, diabetes, metabolic causes, calcineurin-inhibitor (CNI) toxicity, drug-related (non-CNI), Polycystic kidney disease, and other. Variables reaching significance in univariate analysis were included in the multivariable model for patient survival.

Secondary analyses—We performed multivariable analyses of non-death censored allograft survival and patient survival in which recipients at high risk of rejection or primary disease recurrence were not included. These high-risk recipients were defined as patients with PRA>0% and/or FSGS, systemic lupus erythematosus (SLE), or hemolytic-uremic syndrome (HUS).

We also performed a death-censored multivariable Cox analysis of allograft survival.

Missing data

Over 30% of cases were missing data on warm ischemic time, so we did not include warm ischemia as a variable in our analysis. A minority of recipients had no data on the

continuous variables of waiting time (N=5, 0.01%), peak PRA (N=1,628, 4.2%), and cold ischemia time (N=3,378, 8.6%). Likewise, for the following categorical variables, a small percentage of patients had either missing data or the variable was specified as being “unknown”, or “not done”: HLA mismatch (N=55, 0.1%), history of dialysis (N=359, 0.9%), and recipient hepatitis C (N= 4,287, 11.0%).

In our primary multivariable analyses, for patients with missing data, we created categories for independent variables with missing data so that these patients were not dropped from the regressions. Subsequent sensitivity analyses, in which we imputed extreme values for missing data, revealed that our primary approach did not affect the main association of interest between recipient age and allograft failure, and are not shown.

RESULTS

Of the 114,773 primary deceased donor kidneys transplants performed in the 15 year period of study, 39,136 (34.1%) were from ideal deceased donors.

Subject characteristics

Compared to KTRs aged 0 – 14 years, adolescent (age 15 – 18 year) KTRs were more likely to have ESRD from a glomerulonephritis or auto-immune etiology (43.8% versus 28.7% for younger KTRs) and less likely to have an uropathy/congenital cause of ESRD (22.6% versus 37.4% for younger recipients) ($p<0.01$). Similar to KTRs aged 0 – 14 years, only a small proportion of adolescent KTRs had an elevated PRA (1.4% versus 1.0% for younger KTRs) and approximately half of adolescent KTRs had waited under 6 months for a transplant (46.9% versus 50.7% for younger KTRs).

Adolescent KTRs differed in multiple respects from older KTRs. Among KTRs in age groups over 25 years, >40% of ESRD was attributed to diabetes or hypertension, whereas these causes were responsible for only 4% of ESRD among adolescent KTRs ($p<0.01$). Compared to older KTRs, a lower proportion of adolescent KTRs were on dialysis (84% for adolescents versus 87 – 92% for older KTRs) ($p<0.01$). HLA mismatches were also more common among adolescent KTRs (97% for adolescents versus 76 – 86% for older KTRs) ($p<0.01$). These results are displayed in Table 1.

Changes in kidney allocation and donation since Share-35 implementation

As shown in Figure 1, the percentage of ideal kidneys allocated to individuals <19 years of age increased substantially after the implementation of Share-35 in 2005. From 1994 until the implementation of Share-35 in the year 2005, the percentage of ideal kidneys allocated to recipients <19 years was 7.2%. After Share-35 implementation until 2008, the percentage of ideal kidneys allocated to pediatric recipients more than doubled to 16.2% ($p<0.01$). Pre and post-Share-35, the percentage allocated to adolescent recipients 15 – 18 years increased from 2.8% in the period from 1994 – 2005 to 7.6% between 2005 and 2008 ($p<0.01$).

Figure 2 shows the percentage of kidney transplants from live donors pre- and post-implementation of the Share-35 policy. The percentage of transplants from live kidney donors decreased substantially among recipients in the 0 – 14 year old (from 56% to 40%) and 15 – 18 year old (from 50% to 33%) age groups ($p < 0.01$), whereas there were modest increases in the 19 – 25, 26 – 40 and 41 – 55 year old groups ($p < 0.01$), and little change among recipients over age 55 years.

Allograft outcomes

In univariate analysis, using adolescent KTRs as the reference, only recipients over age 70 years had worse allograft survival (HR 1.31; CI 1.15, 1.50; $p<0.01$), while all other age groups had better allograft survival. These data are displayed in Figure 3. Figure 4 shows rates of allograft survival at one and five years after kidney transplantation by recipient age at time of transplant. The curve at five years suggests a trend of decreased survival particularly among recipients aged 15 – 20 years and among recipients over age 70 years at transplantation.

In multivariable analysis, using adolescent KTRs as the reference, all other age groups had better allograft survival ($p<0.01$) except for recipients >70 years (HR 1.12; CI 0.98, 1.28; $p=0.11$). KTRs in the 26 – 40 years group (HR 0.52) and the 41 – 55 years group (HR 0.52) had the lowest hazard ratios compared to adolescent KTRs. These results are presented in Table 2.

Mortality

Observed survival by age group is displayed in Figure 3. In univariate analysis, adolescent KTRs had significantly lower mortality than all age groups ($p<0.01$) except recipients 0 – 14 years (HR 0.57; CI 0.45, 0.74; $p<0.01$) and recipients 19 – 25 years old (HR 0.97; CI 0.78, 1.22; $p=0.82$).

Multivariable Cox regression (shown in Table 2) revealed that kidney transplant recipients 0 – 14 years (HR 0.59; CI 0.46, 0.76; $p<0.01$) had lower mortality rates than adolescent recipients. Adolescent recipients experienced mortality rates that were not statistically different from mortality rates among recipients 19 – 25 years and 26 – 40 years, but were substantially lower than mortality rates for recipients over the age of 40 years.

The role of high-risk primary diseases and elevated panel reactive antibody in promoting poor outcomes among adolescents

We examined whether the worse outcomes among adolescent recipients were driven by a greater prevalence of primary causes of ESRD that commonly recur after transplantation, and/or a high prevalence of elevated PRA, in this age group versus others. We therefore repeated our analyses of allograft failure among 19,508 lower-risk KTRs (i.e., those without FSGS, HUS, or SLE causing ESRD, and with a PRA=0%). This analysis showed nearly identical results to our overall analysis of allograft failure; these results are therefore not shown.

Secondary analyses

In multivariable Cox regression for the outcome of death-censored allograft survival, adolescent KTRs had worse allograft survival than all other age groups ($p<0.01$ for every comparison).

We also examined the risk of acute rejection by one year after transplantation. Between 25 – 29% of KTRs had missing data for this variable. For our first multivariable logistic regression analysis of the outcome of acute rejection, we assumed that patients with missing data did not experience this outcome. This analysis, presented in Table 3, revealed that adolescent kidney transplant recipients had higher rates of acute rejection by one year after transplantation than every other age group. Other factors significantly associated with higher rejection rates were black race, dialysis dependence prior to transplant, >24 hours cold ischemia time, >1 HLA mismatch, and transplant year prior to 1998 (data not shown). When we repeated this analysis limited to patients without missing data, the results were unchanged.

DISCUSSION

The Share-35 policy decreased the waiting time and increased the volume of deceased donor kidney transplantation for pediatric candidates by giving this group the highest priority on the waiting list.² While prior investigators have shown that pediatric recipients make up a minority of waitlisted and transplanted patients, our study reveals that the Share-35 policy has directed an increasing percentage of the highest quality kidneys to adolescent recipients.^{2, 20, 23, 31} Unfortunately, adolescent KTRs of ideal donor kidneys had worse overall allograft survival than any other age group except recipients over 70 years of age, and this finding was not due to an elevated prevalence of high-risk primary diseases. Patient survival was not significantly different between adolescent KTRs versus adult recipients up to age 40 years. These findings highlight a troubling trade-off between the goals of maximizing access to transplantation for children with ESRD versus optimizing equity and efficiency for adult KTRs who also benefit greatly from ideal donor kidneys. These results emphasize the need for innovative strategies to improve allograft survival among adolescent patients, and could also point the way toward potential revisions of the Share-35 policy.

Early allograft loss is common among adolescent KTRs who receive the highest quality deceased donor kidneys. While previous studies have documented poorer graft survival among adolescents, these studies have generally compared pediatric groups to one another using data from the North American Pediatric Renal Transplant Cooperative Study and have rarely contrasted outcomes between adult and pediatric recipients.^{2, 6, 7, 17, 20, 22, 25–29} While comparisons of adolescent outcomes to other pediatric groups are valid, the result of Share-35 is to shift ideal kidneys from adult recipients (primarily 25–40 year olds from 2004–8 in our analysis) and thus comparisons of adult and pediatric outcomes are relevant here. The increased risk of graft loss among adolescent recipients is likely related to acute rejection, since the risk of early rejection was highest in this age group and since the results of our analysis of allograft survival were unchanged after exclusion of recipients with high PRA and/or primary renal diseases at high-risk of recurrence in pediatric patients. There is strong evidence that adolescent transplant recipients, as a group, have inferior adherence with immunosuppression medications compared to both younger pediatric recipients and adults.^{12–16, 32}

The poor allograft outcomes and high risk of rejection among adolescent recipients show the importance for transplant professionals to recognize the unique psychosocial needs of adolescent patients.^{12, 13, 32} Adolescent KTRs require both careful supervision of medication adherence as well as acknowledgment of their developmental need for a sense of greater independence. From a pharmacological viewpoint, adolescent KTRs may benefit from medication delivery systems that do not require taking pills on a rigid schedule, such as via intramuscular or intravenous injection or transdermal application, or at wider intervals. Belatacept, which prevents acute rejection through selective blockade of a co-stimulatory pathway in T-cells and which is administered intravenously and less frequently, offers promise that maintenance immunosuppression will not always rely on the oral route. However, barriers exist in using these drugs in children, especially in light of concerns about use in Epstein-Barr virus (EBV) negative recipients.^{33, 34}

Other deserving areas of investigation include behavioral incentives for adolescents (such as providing money or prizes to KTRs that demonstrate medication adherence), the use of automated technologies that record and transmit the opening of pill-bottles, and programs that facilitate the smooth transition from pediatric to adult kidney transplant centers.^{32, 35} We believe that funding agencies such as the National Institutes of Health should devote greater resources to initiatives that improve adolescent outcomes. Such initiatives will also

require a high level of coordination between pediatric transplant centers, many of which have relatively small adolescent populations of KTRs.

Critical evaluation of the Share-35 policy requires examination of the sometimes conflicting principles that guide organ allocation in the U.S. To varying degrees, the current system for kidney allocation places high priority on equity (through waiting time) and on maximizing access to kidney transplantation for pediatric patients through Share-35.^{1, 36} Less emphasis is placed on maximizing allograft survival through HLA matching of donor and recipient. Although some studies have not supported a major impact of HLA matching on later sensitization, most acknowledge that poorer HLA matching in primary pediatric transplants may contribute to greater sensitization and more difficulty finding a compatible second transplant in this young group.^{24, 37–41} However, as the waiting list for adult kidney transplantation continues to rise, transplant leaders including the United Network for Organ Sharing Kidney Committee have emphasized the importance of achieving gains in efficiency in allocation.⁴²

Our findings related to poor adolescent outcomes should be considered alongside evidence that Share-35 implementation has been associated with lower rates of living kidney donation to pediatric recipients, and worse HLA-matching among pediatric recipients of deceased donor kidneys.^{2, 21} These trends are concerning because pediatric patients are more likely to require second transplants in their lifetimes. Moreover, our data indicate that the disturbing overall decrease in living donation in the period from 2004 – 2008 is largely attributable to decreases in living donation to children.

Our results and those of other groups might lead to a productive discussion of ways to revise the Share-35 policy in the future. For example, the highest priority allocation of ideal kidneys could be directed to the younger pediatric group with the highest risk of growth retardation, impaired cognitive development, and death on dialysis, while spreading a lower tier of priority covering adolescents and young adults who have equivalent patient survival after transplant. Notably, young adults (e.g. those up to age 40 years) are in the most productive part of their lives; many are young parents themselves and transplantation enables an opportunity to have professional opportunities as well.

Giving a lower priority for deceased donor kidneys to adolescents might lead to an increase in living kidney donation for this group, which could offset the loss of ideal deceased donor kidneys. Alternatively, a revised policy could allow pediatric recipients who undergo live kidney donor transplantation to receive enhanced priority on the deceased donor list for a second transplant even if outside of the pediatric age group at that time. This might incentivize families of adolescent patients with ESRD to move forward with live donation now instead of taking advantage of priority for a deceased donor kidney and “saving” a viable live donor for a possible re-transplant in the future. Notably, our mortality results suggest that allocating ideal donor kidneys to recipients up to age 40 would improve allograft survival and would not lead to worse patient survival. Lastly, sharing ideal deceased donor kidneys over a larger distribution area with some priority placed on degree of HLA matching might allow greater HLA matching in pediatric organ allocation under Share 35 without changing the overall priority of allocation to children. These ideal kidneys would likely not be significantly impacted by a reasonable increase in cold ischemic time that might be necessary to enact such a policy.

Our study has methodological limitations. OPTN registry data lack detailed information on recipient co-morbidities, leading to the possibility of unmeasured confounding. On the other hand, because single-center studies from pediatric centers typically report small numbers of KTRs, the OPTN database offers the opportunity to achieve sufficient power to compare

outcomes across all age groups. Also, since older patients have more comorbidities than the young, if comorbidities were fully reported, this would only widen the difference between the poor adolescent outcomes versus those of adult KTRs. A second potential limitation of our analysis is that episodes of acute rejection, especially those beyond the immediate post-transplant period, are not well captured by the OPTN database and thus, we did not adjust for rejection in our survival models. On the other hand, acute rejection is likely in the causal pathway between young age and worse outcomes; therefore, it would not be appropriate to adjust for rejection.

An additional consideration is differential ascertainment of allograft outcomes across age groups (i.e., bias). It is possible that differential reporting of graft loss between pediatric and adult centers could confound the analysis.⁴³ We have no evidence that such differential reporting bias exists and if anything, the usual transition of pediatric patients to adult centers would likely favor underreporting of graft loss in the pediatric group, making the adverse effect of adolescent age stronger than we report here.

In conclusion, pediatric KTRs receive priority for kidneys from ideal deceased donors under the Share-35 policy in the US. This study reveals, however, that adolescent recipients of ideal deceased donor kidneys have substantially worse allograft survival than recipients in all age groups up to age 70 years, and no difference in mortality compared to adult recipients up to age 40 years. New strategies – both medical and behavioral – to improve kidney transplant outcomes among adolescent KTRs are urgently needed. Poor transplant outcomes among adolescent KTRs may also lead to review of the Share-35 policy and discussion of the best methods to optimize the outcomes of ideal kidney transplant allocation policy in the US.

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Figure 1.
Ideal Kidney Distribution by Recipient Age, Pre and Post Share 35 Implementation

Figure 2.
Percentage of Live Donor Transplants by Recipient Age Category, Pre and Post Share 35

Figure 3. Allograft survival after kidney transplant using ideal deceased donor kidneys, by recipient age (left panel); Patient survival after kidney transplant using ideal deceased donor kidneys, by recipient age (right panel)

Figure 4. Observed One and Five Year Allograft Survival among Recipients of Kidney Transplants from Ideal Donors*

*Five year transplant survival was calculated only among kidney transplant recipients transplanted from 1994–2004

Table 1

Characteristics of kidney transplant recipients, by age*

RECIPIENT CHARACTERISTICS	15–18 years n = 1503	0–14 years n = 2128	19–25 years n = 1799	26–40 years n = 8728	41–55 years n = 14061	56–70 years n = 10017	>70 years n = 900	p
CAUSE OF ESRD (%)								<0.01
GN other	199 (13.2)	171 (8.0)	311 (17.3)	1319 (15.1)	1583 (11.3)	992 (9.9)	83 (9.2)	
IgA	55 (3.7)	35 (1.6)	96 (5.3)	463 (5.3)	458 (3.3)	183 (1.8)	13 (1.4)	
FSGS	279 (18.6)	298 (14.0)	238 (13.2)	729 (8.4)	710 (5.0)	400 (4.0)	29 (3.2)	
Uropathy/Congenital	340 (22.6)	795 (37.4)	226 (12.6)	469 (5.4)	351 (2.5)	204 (2.0)	23 (2.6)	
PCKD	34 (0.9)	101 (2.7)	36 (2.0)	370 (4.2)	1974 (14.0)	1097 (11.0)	84 (9.3)	
HTN	54 (3.6)	24 (1.1)	280 (15.6)	2165 (24.8)	3484 (24.8)	2414 (24.1)	301 (33.4)	
DM	3 (0.2)	4 (0.2)	45 (2.5)	1336 (15.3)	3466 (24.7)	3428 (34.2)	206 (22.9)	
Metabolic	101 (6.7)	71 (3.3)	78 (4.3)	193 (2.2)	145 (1.0)	73 (0.7)	9 (1.0)	
ReTx	13 (0.9)	8 (0.4)	20 (1.1)	69 (0.8)	85 (0.6)	28 (0.3)	1 (0.1)	
Drug	3 (0.2)	4 (0.2)	7 (0.4)	42 (0.5)	92 (0.6)	73 (0.7)	9 (1.0)	
CNI	9 (0.6)	13 (0.6)	5 (0.3)	19 (0.2)	74 (0.5)	114 (1.1)	16 (1.8)	
Autoimmune	125 (8.3)	108 (5.1)	212 (11.8)	699 (8.0)	605 (4.3)	237 (2.4)	17 (1.9)	
Other	288 (19.2)	496 (23.3)	245 (13.6)	855 (9.8)	1034 (7.4)	774 (7.7)	109 (12.1)	
DIABETES (%)								<0.01
No	1489 (99.1)	2120 (99.6)	1743 (96.9)	7308 (83.7)	10068 (71.6)	5946 (59.4)	624 (69.3)	
Yes	14 (0.9)	8 (0.4)	56 (3.1)	1420 (16.3)	3993 (28.4)	4071 (40.6)	276 (30.7)	
DIALYSIS BEFORE TRANSPLANT (%)								<0.01
No	236 (15.7)	397 (18.7)	130 (7.2)	652 (7.5)	1272 (9.1)	952 (9.5)	98 (10.9)	
Yes	1256 (83.6)	1710 (80.4)	1656 (92.0)	8009 (91.8)	12660 (90.0)	8962 (89.5)	787 (87.4)	
Unknown	11 (0.7)	21 (1.0)	13 (0.7)	67 (0.8)	129 (0.9)	103 (1.0)	15 (1.7)	
PEAK PRA % (%)								<0.01
≤ 80	1379 (91.8)	1945 (91.4)	1618 (89.9)	7772 (89.0)	12604 (89.6)	8985 (89.7)	810 (90.0)	
> 80	21 (1.4)	22 (1.0)	90 (5.0)	601 (6.9)	910 (6.5)	697 (7.0)	54 (6.0)	
Unknown	103 (6.8)	161 (7.6)	91 (5.1)	355 (4.1)	547 (3.9)	335 (3.3)	36 (4.0)	
RACE (%)								<0.01

RECIPIENT CHARACTERISTICS	15-18 years n = 1503	0-14 years n = 2128	19-25 years n = 1799	26-40 years n = 8728	41-55 years n = 14061	56-70 years n = 10017	>70 years n = 900	p
White	588 (39.1)	906 (42.6)	725 (40.3)	3810 (43.6)	7319 (52.0)	5894 (58.8)	679 (75.4)	
Black	444 (29.5)	519 (24.4)	579 (32.2)	2938 (33.7)	4017 (28.6)	2348 (23.4)	116 (12.9)	
Hispanic	356 (23.7)	564 (26.5)	349 (19.4)	1340 (15.4)	1725 (12.3)	1140 (11.4)	64 (7.1)	
Asian	75 (5.0)	69 (3.2)	88 (4.9)	435 (5.0)	669 (4.8)	412 (4.1)	32 (3.6)	
Other	40 (2.7)	70 (3.3)	58 (3.2)	205 (2.3)	331 (2.3)	223 (2.2)	9 (1.0)	
MONTHS ON WAITING LIST (%)								<0.01
0 to 6	705 (46.9)	1079 (50.7)	443 (24.6)	2000 (22.9)	3319 (23.6)	2345 (23.4)	232 (25.8)	
7 to 12	287 (19.1)	437 (20.5)	325 (18.1)	1355 (15.5)	2292 (16.3)	1663 (16.6)	152 (16.9)	
13 to 24	373 (24.8)	462 (21.7)	509 (28.3)	2199 (25.2)	3411 (24.3)	2527 (25.2)	199 (22.1)	
>24	137 (9.1)	149 (7.0)	522 (29.0)	3173 (36.4)	5037 (35.8)	3482 (34.8)	317 (35.2)	
Unknown	1 (0.1)	1 (0.0)	0 (0.0)	1 (0.0)	2 (0.0)	0 (0.0)	0 (0.0)	
ALLOGRAFT CHARACTERISTICS								
HOURS OF COLD ISCHEMIA (%)								<0.01
<12	424 (28.2)	641 (30.1)	357 (19.8)	1487 (17.0)	2339 (16.6)	1607 (16.0)	155 (17.2)	
12 to 24	707 (47.0)	931 (43.8)	883 (49.1)	4244 (48.6)	6894 (49.0)	5031 (50.2)	424 (47.1)	
>24	229 (15.2)	296 (13.9)	417 (23.2)	2306 (26.4)	3705 (26.4)	2448 (24.4)	233 (25.9)	
Unknown	143 (9.5)	260 (12.2)	142 (7.9)	691 (7.9)	1123 (8.0)	931 (9.3)	88 (9.8)	
HLA MISMATCHES (%)								<0.01
0	50 (3.3)	57 (2.7)	239 (13.3)	1195 (13.7)	2393 (17.0)	2016 (20.1)	215 (23.9)	
1	16 (1.1)	16 (0.8)	55 (3.1)	225 (2.6)	406 (2.9)	295 (3.0)	18 (2.0)	
> 1	1435 (95.6)	2053 (96.6)	1501 (83.6)	7295 (83.7)	11241 (80.1)	7695 (76.9)	665 (74.1)	
TRANSPLANT YEAR (%)								<0.01
1994 - 1998	325 (21.6)	506 (23.8)	685 (38.1)	3273 (37.5)	4930 (35.1)	2808 (28.0)	165 (18.3)	
1999 - 2003	351 (23.4)	567 (26.6)	571 (31.7)	2841 (32.5)	4632 (32.9)	3354 (33.5)	279 (31.0)	
2004 - 2008	827 (55.0)	1055 (49.6)	543 (30.2)	2614 (30.0)	4499 (32.0)	3855 (38.5)	456 (50.7)	
DONOR CHARACTERISTICS								
AGE IN YEARS (%)								<0.01
2 to 16	465 (30.9)	748 (35.1)	632 (35.1)	2715 (31.1)	4197 (29.8)	2828 (28.2)	250 (27.8)	
17 to 20	380 (25.3)	558 (26.2)	404 (24.5)	1994 (22.9)	3241 (23.1)	2208 (22.0)	196 (21.8)	

RECIPIENT CHARACTERISTICS	15–18 years n = 1503	0–14 years n = 2128	19–25 years n = 1799	26–40 years n = 8728	41–55 years n = 14061	56–70 years n = 10017	>70 years n = 900	p
21 to 26	333 (22.2)	457 (21.5)	388 (21.6)	1992 (22.8)	3233 (23.0)	2386 (23.8)	221 (24.6)	
27 to 34	325 (21.6)	365 (17.2)	375 (20.8)	2027 (23.2)	3390 (24.1)	2595 (25.9)	233 (25.9)	

PCKD – polycystic kidney disease, IgA – IgA nephropathy, GN – glomerulonephritis, FSGS – focal segmental glomerulosclerosis, HTN – hypertension, DM – diabetes mellitus, CNI – calcineurin inhibitor toxicity, PRA% – panel reactive antibody percentage, HLA – human leukocyte antigen

* Percentages are calculated from the entire groups, rather than from the number of patients with complete data on each variable

Table 2

Multivariable analyses of patient and allograft survival

RECIPIENT CHARACTERISTICS	ALLOGRAFT SURVIVAL	p	PATIENT SURVIVAL	p
	HR (CI)		HR (CI)	
AGE				
15–18	REFERENCE		REFERENCE	
0–14	0.72 (0.64–0.81)	<0.01	0.59 (0.46–0.76)	<0.01
19–25	0.77 (0.69–0.86)	<0.01	0.85 (0.67–1.06)	0.15
26–40	0.52 (0.47–0.57)	<0.01	0.94 (0.78–1.13)	0.50
41–55	0.52 (0.47–0.57)	<0.01	1.47 (1.22–1.77)	<0.01
56–70	0.73 (0.67–0.81)	<0.01	2.58 (2.14–3.10)	<0.01
>70	1.12 (0.98–1.28)	0.11	4.25 (3.45–5.24)	<0.01

Table 3

Results of multivariable logistic regression model for the outcome of acute rejection within one year of kidney transplantation

RECIPIENT CHARACTERISTICS	ACUTE REJECTION Odds Ratio (CI)	p
AGE		
15–18	REFERENCE	
0–14	0.80 (0.66–0.97)	0.02
19–25	0.76 (0.62–0.92)	<0.01
26–40	0.59 (0.50–0.69)	<0.01
41–55	0.49 (0.41–0.58)	<0.01
56–70	0.39 (0.33–0.46)	<0.01
>70	0.36 (0.26–0.49)	<0.01