ORIGINAL ARTICLE

Impact of cold ischemia time on the outcomes of kidneys with Kidney Donor Profile Index ≥85%: mate kidney analysis - a retrospective study

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SUMMARY

The new kidney allocation system recommends local and regional sharing of deceased donor kidneys (DDK) with 86–100% Kidney Donor Profile Index (KDPI) to minimize discard. Regional sharing can increase cold ischemia time (CIT) which may negatively impact transplant outcomes. Using a same donor mate kidney model, we aimed to define a CIT that should be targeted to optimize outcomes. Using Organ Procurement and Transplant Network/United Network for Organ Sharing database, we identified recipients of DDK from 2000 to 2013 with ≥85% KDPI. From this cohort, three groups of mate kidney recipients were identified based on CIT: group 1 (≥24 vs. ≥12 to <24 h), group 2 (≥24 vs. <12 h), and group 3 (≥12 to <24 vs. <12 h). Adjusted delayed graft function (DGF), and graft and patient survivals were compared for mate kidneys. DGF risk was significantly lower for patients with CIT <12 vs. ≥24 h in group 2 (adjusted OR: 0.25, 95% CI: 0.12–0.57, $P < 0.001$) while trending lower for CIT ≥12 to <24 vs. ≥24 h in group 1 (adjusted OR: 0.78, 95% CI: 0.59–1.03, $P = 0.08$) and CIT <12 vs. ≥12 to <24 h in group 3 (adjusted OR: 0.74, 95% CI: 0.55–1.0, $P = 0.05$). Adjusted graft and patient survivals were similar between mate kidneys in all groups. Minimizing CIT improves outcomes with regional sharing of marginal kidneys.

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Key words
Kidney Donor Profile Index, mate kidney analysis, regional sharing

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Introduction

Waiting list for kidney transplantation in the United States has been steadily growing with over 100,000 patients awaiting a transplant currently. Organ availability is the major limiting factor. With the aim to improve utilization of deceased donor kidneys (DDK), Organ Procurement and Transplant Network (OPTN) implemented the new kidney allocation system (KAS) on December 4, 2014. One of the aims of new KAS was to improve recovery and utilization of kidneys with high Kidney Donor Profile Index (KDPI) ranging from 86% to 100% [1,2]. KDPI score has a range from 0% to 100% and is derived by utilizing the donor-specific elements from the kidney donor risk index developed by Rao *et al.* [1]. Lower the KDPI score better is the quality of the kidney. The 10 factors influencing KDPI are donor age, height, weight, ethnicity, history of hypertension and diabetes, cause of death as cerebrovascular accident, serum creatinine level, hepatitis C status, and donation after circulatory death status. Kidneys with KDPI scores ranging from 86% to 100% are considered "marginal" and have a discard rate

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in excess of 40% [3]. However, these kidneys could be beneficial to some patients if transplanted [4]. In order to reduce the high discard rate of these kidneys, new KAS recommends offering them to a combined local and regional list of candidates. The intent of this recommendation was to incentivize organ procurement organizations to recover these kidneys even if their local centers do not utilize them and send them for acceptance in adjacent donor service areas where these organs can be transplanted into appropriate recipients [5].

Regional sharing could prolong associated cold ischemia time (CIT). It is unclear whether the increase in CIT that can come with regional sharing would adversely impact graft outcomes in kidneys with KDPI ≥85%. We aimed to compare the outcomes among recipients of "marginal" kidney transplants with KDPI ≥85% from the same deceased donor but with distinct CIT and define a CIT that should be targeted in order to optimize outcomes. We used the mate kidney model in our analysis to remove the confounding effects of donor organ quality on transplant outcomes.

Materials and methods

Study population

The study protocol was approved by the Institutional Review Board and performed in accordance with the ethical standards laid down in the 2000 Declaration of Helsinki as well as the Declaration of Istanbul 2008. Using the Organ Procurement and Transplantation Network/United Network for Organ Sharing (OPTN/UNOS) database as of 6/17/2016, we identified adult patients who underwent DDK transplantation between January 2000 and December 2013 utilizing allografts with KDPI ≥85% and were discharged on a calcineurin inhibitor (CNI)/mycophenolate mofetil (MMF)-based immunosuppression. KDPI was calculated retrospectively by OPTN/UNOS and is available in their database. The group was then narrowed to recipients of mate kidneys from same donor with information on CIT. From these patients, three groups were identified each consisting of recipients of mate kidneys but with differing CIT as follows: group 1 = CIT ≥24 h vs. CIT ≥12 h but <24 h; group 2 = CIT ≥24 h vs. CIT <12 h, and group 3 = CIT ≥12 h but <24 h vs. CIT <12 h.

Statistical analysis

Baseline recipient and transplant characteristics were compared using Wilcoxon signed-rank test for continuous variables and McNamar's test for categorical variables. The results were shown in absolute numbers and percent. Outcomes were compared between mate kidney recipients with different CIT under each group. These outcomes included delayed graft function (DGF, defined as the need for dialysis within the first post-transplant week), hospital length of stay (LOS) during the transplant admission, and acute rejection at hospital discharge as well as four-year overall graft and patient survivals. Transplant date was used as the index date. Overall kidney graft survival was determined from the time of kidney transplantation until re-transplantation, return to dialysis, death, or end of follow-up. Conditional logistic regression using the STATA "clogit" command was used to define odds ratio (OR) for the development of DGF. Kaplan–Meier product limit method was used to generate survival curves, and Cox regression using shared frailty model was used to define hazard ratio (HR) associated with graft failure and death in mate kidney transplant recipients with different CIT under each group. All results were adjusted for recipient and transplant characteristics, as reported in Table 1. Covariates with a *P*-value <0.1 were included in the final multivariate model. Results were expressed as OR and HR with their 95% confidence intervals (CI) along with associated *P*-values. All *P*-values were two-tailed and were considered significant if <0.05. STATA version 11 (StataCorp, College Station, TX, USA) was used as the statistical tool.

Results

Baseline characteristics

The process of study cohort formation is outlined in Fig. 1. During the study period, 7402 recipients of mate kidneys with ≥85% KDPI and documented CIT who were discharged on a CNI/MMF maintenance regimen were identified. From this pool of patients, three groups of mate kidneys that differed in CIT were identified as follows: group 1 with CIT ≥24 h ($n = 747$) vs. CIT ≥12 h but <24 h ($n = 747$); group 2 = CIT ≥24 h ($n = 127$) vs. CIT <12 h ($n = 127$); and group 3 = CIT ≥12 h but <24 h ($n = 701$) vs. CIT <12 h ($n = 701$). Table 1 demonstrates recipient and transplant characteristics of study groups. Recipient characteristics between the mate kidneys under each group were similar except for the following: A significantly higher proportion of patients with longer CIT under group 1 (64.7% vs. 54.5%, $P < 0.001$), group 2 (58.3% vs. 32.3%, $P < 0.001$), and group 3 (44.1% vs. 36.4%, $P < 0.001$)

Table 1. Recipients and transplants characteristics of study groups.

	Group 1			Group 2			Group 3		
	CIT ≥24 h (*n* = 747)	CIT ≥12 & <24 (*n* = 747)	*P*	CIT ≥24 h (*n* = 127)	CIT <12 (*n* = 127)	*P*	CIT ≥12 & <24 (*n* = 701)	CIT <12 (*n* = 701)	*P*
Recipient characteristics									
Age(years)									
>60	367 (49.1)	402 (53.8)	0.005	64 (50.4)	72 (56.7)	0.14	392 (55.9)	406 (57.9)	0.24
Gender									
Male	450 (60.2)	452 (60.5)	0.88	87 (68.5)	86 (67.7)	0.92	448 (63.9)	449 (64.1)	0.97
Race									
Caucasian	323 (43.2)	346 (46.3)	0.92	49 (38.6)	56 (44.1)	0.81	319 (45.5)	302 (43.1)	0.10
BMI									
Nonobese	227 (30.4)	227 (30.4)	1.0	33 (26.0)	39 (30.7)	0.31	196 (28.0)	209 (30.0)	0.29
Obese	520 (69.6)	520 (69.6)		94 (74.0)	88 (69.3)		505 (72.0)	492 (70.0)	
Dialysis duration									
Days	1200 (713–1866)	1212 (719–1910)	0.71	1215 (680–1852)	1303 (683–1820)	0.98	1086 (521–1667)	1177 (639–1808)	<0.001
Diabetes mellitus									
Yes	336 (45.0)	323 (43.2)	0.13	47 (37.0)	57 (44.9)	0.68	324 (46.2)	311 (44.4)	0.33
PAD									
Yes	33 (4.4)	34 (4.5)	0.92	5 (3.9)	4 (3.1)	0.81	31 (4.42)	52 (7.42)	0.0008
Prior malignancy									
Yes	54 (7.2)	52 (6.9)	0.83	6 (4.7)	6 (4.7)	1.0	40 (5.71)	57 (8.1)	0.0093
CMV									
R−/D+	130 (17.5)	141 (19.0)	0.33	31 (24.6)	29 (22.8)	0.83	133 (19.1)	128 (18.4)	0.63
Hepatitis C									
Serum +ve	59 (7.9)	48 (6.4)	0.05	10 (7.9)	8 (6.3)	0.57	33 (4.71)	37 (5.28)	0.47
Hepatitis B									
Serum +ve	84 (11.2)	97 (12.9)	0.13	15 (11.8)	17 (13.4)	0.68	80 (11.4)	89 (12.7)	0.29
Transplant characteristics									
Induction									
T-cell depleting	406 (54.3)	407 (54.5)	1.0	66 (51.9)	62 (48.8)	0.45	409 (58.4)	407 (58.1)	0.86
PRA									
≥30	103 (13.8)	110 (14.7)	0.46	24 (18.9)	12 (9.5)	0.002	87 (12.4)	80 (11.4)	0.42
Re-transplant									
Yes	72 (9.6)	42 (5.6)	<0.001	10 (7.9)	7 (5.5)	0.36	37 (5.3)	42 (6.0)	0.46
Pump									
Yes	483 (64.7)	407 (54.5)	<0.001	74 (58.3)	41 (32.3)	<0.001	309 (44.1)	255 (36.4)	<0.001
Distance*									
Miles†	111 (14–425)	60 (7–196)	<0.001	222 (42–645)	21 (2–96)	<0.001	21 (4–94)	12 (3–68)	<0.001
CIT									
Hours†	27 (25–31)	19 (16–21)	<0.001	28 (26–35)	8 (5–10)	<0.001	15 (13.2–18)	9.1 (7.57–10.6)	<0.001

Table 1. Continued.

	Group 1			Group 2			Group 3		
	CIT ≥24 h (*n* = 747)	CIT ≥12 & <24 (*n* = 747)	*P*	CIT ≥24 h (*n* = 127)	CIT <12 (*n* = 127)	*P*	CIT ≥12 & <24 (*n* = 701)	CIT <12 (*n* = 701)	*P*
HLA MM	5 (4–5)	5 (3–5)	0.07	5 (4–5)	5 (4–5)	0.94	5 (4–5)	5 (4–5)	0.003
Primary insurance Private	187 (25.0)	166 (22.2)	0.06	37 (29.1)	29 (22.8)	0.11	163 (23.2)	174 (24.8)	0.32
Steroid, discharge Yes	713 (95.5)	720 (96.4)	0.17	119 (93.7)	121 (95.3)	0.54	668 (95.3)	701 (95.7)	0.44

PAD, peripheral artery disease; CMV, cytomegalovirus; PRA, panel reactive antibody; Pump, organ placed on mechanical perfusion; CIT, cold ischemia time; HLA MM, human leukocyte antigen mismatch.
*Distance from the transplant center.
†Median, Q25–Q75.

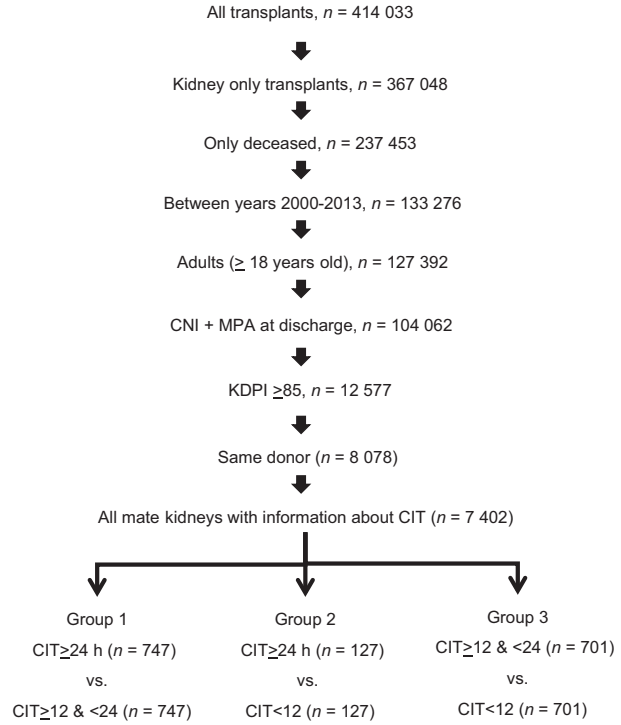

Figure 1 The process of study cohort formation.

had their kidneys perfused with mechanical pump prior to transplantation. Distance travelled to the transplant center was also longer in these patients. Under group 1, recipient age >60 years was higher for CIT ≥12 but <24 h and re-transplants were more in CIT ≥24 h category. Under group 2, patients with PRA ≥30% were more in CIT ≥24 h category. There were higher rates of peripheral arterial disease and prior malignancy along with longer pretransplant dialysis duration for CIT <12 h category under group 3. Majority of patients in every group were discharged on steroid.

Outcomes

Delayed graft function, length of stay, and rejection

Among the 7402 mate kidneys with KDPI ≥85%, the incidence of DGF steadily increased with increasing CIT as shown in Fig. 2. Incidence of DGF was significantly lower for patient with CIT <12 h vs. CT ≥24 h in group 2 (22.8% vs. 44.9%, $P < 0.001$) and for patient with CIT ≥12 & <24 h vs. ≥24 h in group 1 (35.6 vs. 32.3%, $P = 0.03$) but similar in group 3 (28.9 vs. 26.8, $P = 0.18$). Factors independently associated with the development of DGF among the three groups are shown in Table 2. A CIT of <12 h when compared to ≥24 h (group 2) protected against the development of DGF

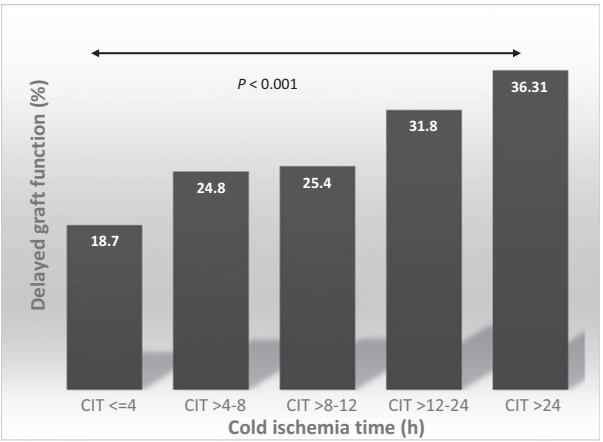

Figure 2 Incidence of delayed graft function among 7402 mate kidneys with Kidney Donor Profile Index ≥85%.

(adjusted OR: 0.25, 95% CI: 0.12–0.57, $P < 0.001$). Mechanical pump perfusion protected against the development of DGF in group 3 (adjusted OR: 0.29, 95% CI: 0.11–0.79, $P = 0.02$). Recipient obesity was a risk factor for DGF in all groups.

Acute rejection rates between mate kidney recipients at discharge from transplant admission were 3.1% vs. 3.2% with $P = 0.03$; 3.94% vs. 2.36% with $P < 0.001$; and 2.14% vs. 3.57% with $P = 0.18$ in groups 1, 2, and 3, respectively. Median LOS during the transplant admission was six days in all groups.

Graft and patient survival

Among the 64,970 deceased donor kidneys that included kidney pairs from same donor, overall graft survival was the lowest among the ≥85% KDPI group as shown in Fig. 3. Among the recipients of paired kidneys with ≥85% KDPI, overall graft survivals were similar between mate kidneys in group 1 (adjusted HR: 0.96, 95% CI: 0.79–1.17, log rank $P = 0.49$), group 2 (adjusted HR: 0.67, 95% CI: 0.41–1.11, log rank $P = 0.14$), and group 3 (adjusted HR: 0.97, 95% CI: 0.79–1.19, log rank $P = 0.82$) as shown in Figure 4a–c. Patient survivals were also similar between mate kidneys in group 1 (adjusted HR: 0.83, 95% CI: 0.65–1.05, log rank $P = 0.17$), group 2 (adjusted HR: 0.93, 95% CI: 0.49–1.79, log rank $P = 0.40$), and group 3 (adjusted HR: 1.12, 95% CI: 0.88–1.43, log rank $P = 0.20$) as shown in Figure 5a–c. We further performed a subgroup analysis for mate kidneys with CIT ≥24 h ($n = 63$) vs. CIT <8 h ($n = 63$) (a subgroup of group 2) as well as for mate kidneys with CIT ≥12 h but <24 h ($n = 193$) vs. CIT <8 h ($n = 193$) (a subgroup of group 3). We did not see any significant differences in graft and patient survivals in these mate kidney subgroups (data not shown).

Discussion

Utilizing a mate kidney model in DDK transplants with KDPI ≥85%, we found a significant reduction in the risk for developing DGF when the CIT was kept to <12 h compared to a CIT ≥24 h. In addition, there was a trend toward lower risk of DGF for kidneys with CIT ≥12 to <24 h vs. ≥24 h and with CIT <12 h vs. ≥12 to <24 h. Moreover, pump perfusion was protective when CIT was kept <24 h. While trying to improve the utilization of high KDPI kidneys by regional offers, every attempt should be made to keep CIT to <24 h and ideally to <12 h in order to reduce the risk of DGF in these marginal kidneys.

Delayed graft function has negative impact on long-term outcomes in DDK transplant recipients. A meta-analysis of 34 studies demonstrated a 41% increase in the risk for long-term graft loss and a 38% relative increase in acute rejection among patients who experienced DGF [6]. An increased risk for death with functioning graft was observed in patients who experienced DGF in another study [7]. Kidneys with very high KDPI are considered "marginal" and could especially be prone to the negative consequences of DGF. Mate kidneys with KDPI ≥85% and CIT >24 h experienced DGF more frequently in our analysis. Our follow-up was limited to four years, and there was a trend toward inferior graft survival in kidneys with CIT ≥24 h when compared to the mate kidneys that experienced CIT that was <12 h in group 2 with a median difference in CIT of 20 h. It is possible that with a larger number of patients in the cohort and longer follow-up, we might see significantly inferior graft survival associated with longer CIT. A subgroup analysis involving kidneys with CIT <8 h failed to show improvement in graft survival when compared to mate kidneys with longer CIT likely related to even smaller sample size and relatively short follow-up. A previous study utilizing paired kidney model by Kayler *et al.* [8] looked at the impact of CIT on graft outcomes among expanded criteria donor (ECD) kidney recipients. With a median difference in CIT of 5 h between the groups, DGF was significantly more likely with greater CIT, but overall graft survivals were similar.

Graft survival was the lowest for ≥85% KDPI group compared to kidneys with lower KDPI as shown in Fig. 3. One could argue whether these kidneys should

Table 2. Adjusted odds ratio (aOR) for delayed graft function in study cohorts.

	aOR (95% CI)	*P*-value
CIT ≥24 h (control) vs. CIT ≥12 & <24 (Group 1)	0.78 (0.59–1.03)	0.08
Dialysis duration		
Pre-emptive (control) versus ≤1 year	3.99 (1.30–12.22)	0.01
Pre-emptive (control) versus 1–3 years	6.29 (2.28–17.3)	<0.001
Pre-emptive (control) versus >3 years	11.8 (4.35–31.9)	<0.001
Gender: male(control) versus female	0.61 (0.41–0.90)	0.01
BMI		
Normal (control) versus underweight	0.74 (0.23–2.34)	0.61
Normal (control) versus overweight	1.09 (0.67–1.76)	0.71
Normal (control) versus obese	1.85 (1.06–3.21)	0.003
Normal (control) versus morbid obese	1.27 (0.58–2.77)	0.54
CIT ≥24 h (control) versus CIT<12 (Group 2)	0.25 (0.12–0.57)	0.001
BMI		
Normal (control) versus underweight	2.5 (0.06–113)	0.63
Normal (control) versus overweight	2.32 (0.60–8.96)	0.22
Normal (control) versus obese	19.2 (1.95–188)	0.01
Normal (control) versus morbid obese	2.7 (0.38–19.6)	0.32
Hepatitis B		
Negative (control) versus positive	8.5 (1.47–49.5)	0.02
CIT ≥12 & <24 (control) versus CIT <12 (Group 3)	0.74 (0.55–1.0)	0.05
BMI		
Normal (control) versus underweight	0.23 (0.03–1.78)	0.16
Normal (control) versus overweight	1.16 (0.69–1.95)	0.56
Normal (control) versus obese	1.69 (0.95–2.97)	0.07
Normal (control) versus morbid obese	3.53 (1.61–7.74)	0.002
Pump: no (control) versus yes	0.29 (0.11–0.79)	0.02
Dialysis duration		
Pre-emptive (control) versus ≤1 year	1.73 (0.47–6.34)	0.40
Pre-emptive (control) versus 1–3 years	7.26 (2.45–21.5)	<0.001
Pre-emptive (control) versus >3 years	9.66 (3.32–28.1)	<0.001

aOR, adjusted odds ratio; BMI, body mass index; CIT, cold ischemia time; DGF, delayed graft function; HLA, human leukocyte antigen.

even be transplanted. However, survival benefits of high KDPI kidney transplantation were highlighted in the study by Massie *et al.* [4]. This study showed better cumulative survival at 5 years in patients >50 years at centers with median wait time ≥33 months who opted to receive kidneys with KDPI >70% when compared to those who stayed on waiting list longer in order to receive a lower KDPI kidney. Looking at the distance travelled by the organs to the transplant center in our study, longer CIT time appears to be associated with regional use of the organs for the most part. These marginal kidneys are likely offered to and rejected by local centers before being accepted by a center further away. This invariably could have added to prolonging the CIT. The current study involved patients transplanted before the implementation of KAS which promotes simultaneous local and regional offer for high KDPI kidneys. The aim of simultaneous local and regional sharing is improved utilization of high KDPI kidneys while minimizing CIT. Avoiding the delay resulting from organ offer to and rejection from individual transplant centers one at a time and identifying a center that would accept the organ upfront through simultaneous local and regional offers should help to achieve this goal.

Previous analyses have shown beneficial effects of mechanical pump perfusion of DDK in reducing DGF compared to cold storage [9,10]. A similar protective effect of pump perfusion against the development of DGF was observed in our study involving marginal kidneys among groups 3 but not group 1 and 2. Group 1 compared mate kidneys with CIT ≥24 h vs. CIT ≥12 to 24 h and group 2 compared mate kidneys with CIT ≥24 h vs. CIT <12 h. Lack of perceived beneficial effects of mechanical pumping on DGF in groups 1 and 2 could possibly be related to the dominant impact of

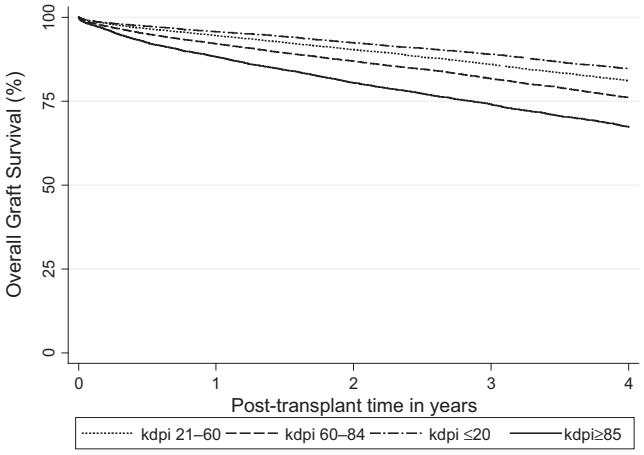

Figure 3 Overall graft survival stratified by Kidney Donor Profile Index among 64,970 mate kidneys.

higher CIT in these groups on DGF development. In other words, pump perfusion appears protective against the development of DGF when the CIT is kept <24 h. This finding supports efforts to lower CIT along with use of mechanical pumping in marginal kidneys in order to reduce risk for developing DGF.

Organ quality significantly impacts early allograft function and long-term transplant survival [11–13]. Adjustment for donor characteristics and analyses by organ types such as standard and extended criteria donor kidneys are generally utilized by studies to minimize the impact of donor variables on transplant outcomes. However, specific factors such as allograft histology [14,15], and events around the time of organ procurement and perioperative periods such as hemodynamic instability and vasoactive drug use are not easily adjustable in multivariate analysis. The ideal way to correct for donor factors and organ quality on transplant outcomes is to compare between transplants performed from the same donors in a mate kidney analysis. We utilized a mate kidney model for the current analysis in an attempt to exclude bias related to donor organ quality when evaluating the impact of CIT on transplant outcomes. Mate kidney, also termed paired kidney analysis, is a well-recognized method that has been used previously to evaluate the impact of induction agents on transplant outcomes [16], influence of CIT on ECD kidneys, and outcomes related to viral infections [17] in KTRs.

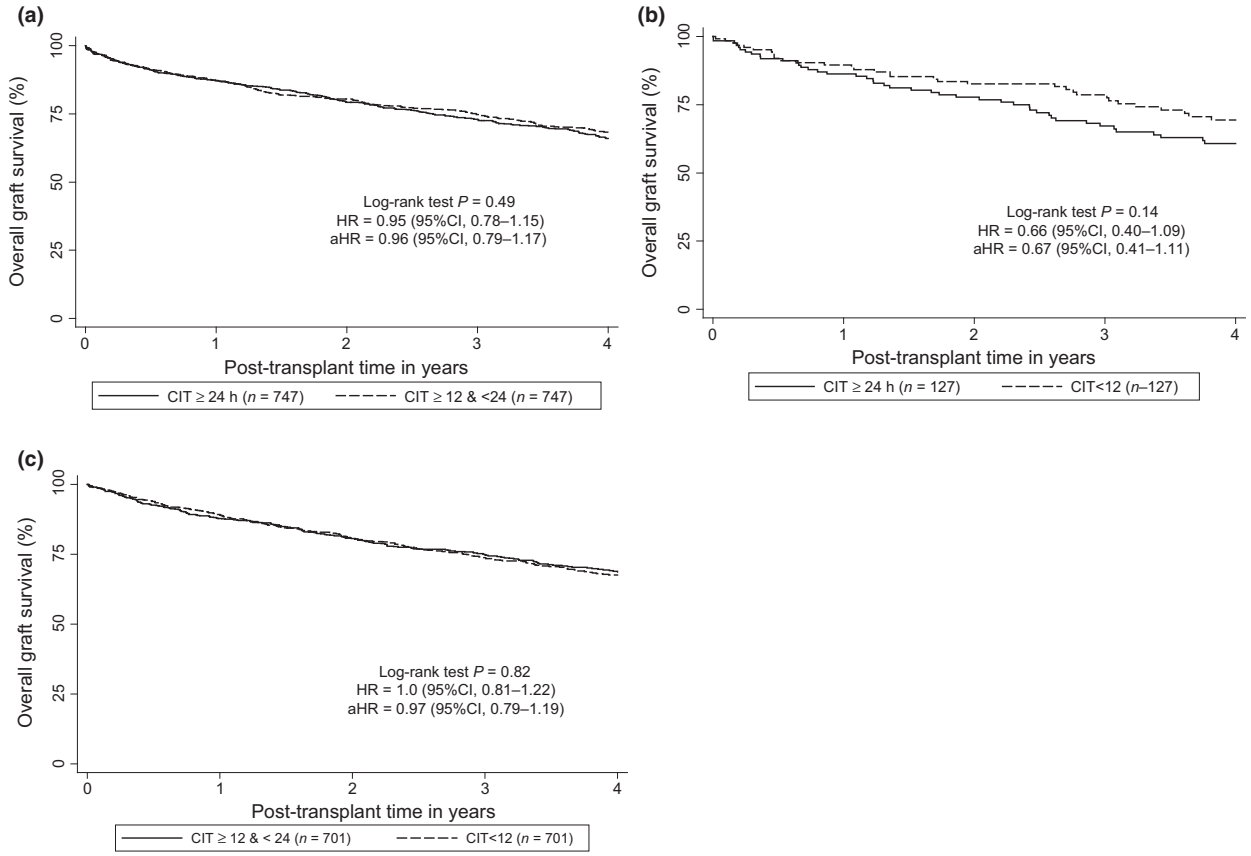

Figure 4 Kaplan–Meier analysis of graft survival between mate kidneys for groups 1 (a), 2 (b), and 3 (c).

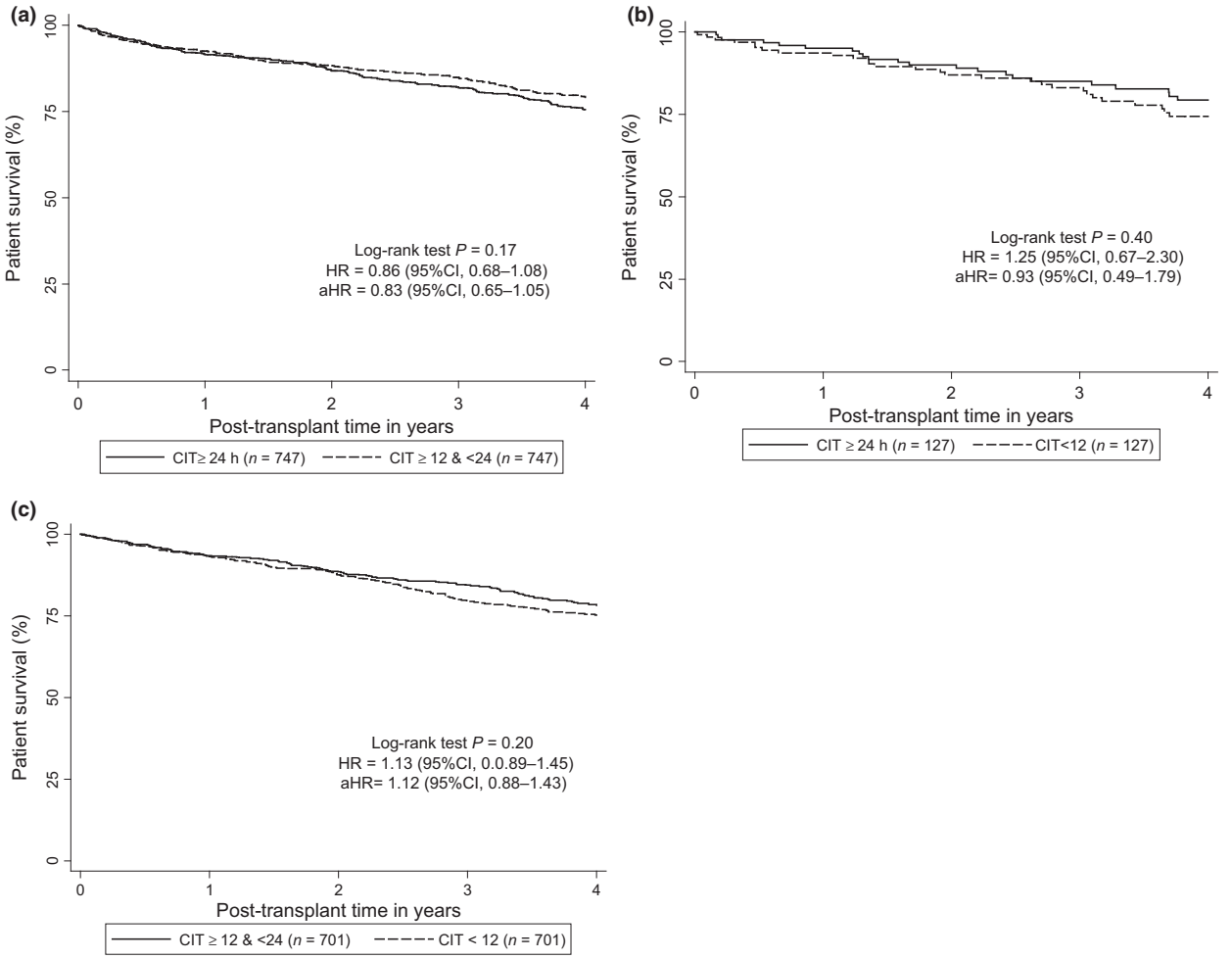

Figure 5 Kaplan–Meier analysis of patient survival between mate kidneys for groups 1 (a), 2 (b), and 3 (c).

Early outcomes following the implementation of new KAS are now reported [18,19]. The study by Massie *et al.* [18] compared deceased donor kidney transplants between January 1, 2014 and December 3, 2014 (pre-KAS era) to DDK transplants between December 4, 2014 and August 31, 2015 (post-KAS era). The analysis found an increase in the odds of discard by 29% in the post-KAS era for kidneys with KDPI ≥70. This was despite an increase in regional import of kidneys from 8.8% to 12.5% and national import from 12.7% to 19.1%. There was also a 6% increase in median CIT from 15.8 to 16.8 h which was found to be fully mediated by the increase in regional and national imports. The incidence of DGF increased from 24.8% to 29.9%. A subsequent study that included DDK transplants in the first 12 months of post-KAS corroborated these initial findings [19]. This analysis showed a reduction in the transplantation of kidneys with KDPI 86–100% locally in the same DSA from 69.2% to 50.9% presumably due to the combined local/regional distribution of these kidneys. Proportion of patients with CIT >24 h increased from 18.2% to 21.3%. There was also an 18.7% decrease observed for transplants with kidneys from donors aged 65 or greater. These kidneys generally have a higher KDPI. Data on CIT and discard rates specific to kidneys with KDPI of 86–100% were not reported by either study. However, it is reassuring to see the trend in a decrease in overall discard rate as we gain more experience with the new KAS. Compared to pre-KAS era, there was a significant increase in discard rate in the study by Massie *et al.* [18] looking at first 9 months post-KAS (18.2% vs. 19.7%, $P < 0.001$) and the difference reduced to borderline statistical significance in the study by Stewart *et al.* [19] that included additional 3 more months of post-KAS era transplants (18.5% vs. 19.4%, $P = 0.05$). If this trend continued, the hope was that we would see a reduction in the discard rate for high KDPI kidneys with passage of time

which was one of the aims of the new KAS to improve organ utilization. A learning curve regarding the use of KDPI scoring system and fear of inferior outcomes possibly played a role toward the increase in discard rate of high KDPI kidneys in the immediate post-KAS era. However, a recent UNOS report describing the 2-year impact of KAS still showed a high discard rate around 60% during post-KAS year 2 for kidneys with KDPI ranging from 86% to 100% [20]. Decreased pumping of these kidneys likely contributed to this high discard rate [21]. Elevation of high-risk patients such as those with long dialysis vintage to the top of the waiting list with the new KAS implementation also possibly contributed to the higher discard for high KDPI kidneys as centers might be reluctant to transplant these lower quality kidneys into such patients due to concern for suboptimal outcomes [22]. To improve utilization of high KDPI kidneys, Health Resources & Service Administration has sponsored the Collaborative Innovation and Improvement Network (COIIN) project at UNOS which is currently ongoing [23].

Retrospective nature of the analysis is a study limitation. We did not have details on the doses of immunosuppressive agents which can impact graft outcomes. Despite the use of a multivariate model, residual confounders can still exist. Details on anatomical variability of the organs or data regarding surgical damage at the time procurement were not available that can potentially impact graft outcomes. Because of relatively smaller number of patients in each group, we cannot exclude type 2 error. However, the use a mate kidney model correcting for donor variables adds to the validity of our findings.

In conclusion, our analysis highlights the importance of minimizing CIT along with pump perfusion in "marginal" DDK kidneys with KDPI ≥85% destined for regional sharing to reduce the risk for DGF development and its attended adverse consequences on long-term graft outcomes.

Authorship

MSS: designed research, performed research, analyzed data and wrote paper. BC: designed research, analyzed data and wrote paper. AT: performed statistical analysis. KKS: designed research, performed research, analyzed data and wrote paper.

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Conflict of interest

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