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Utilization of Standard Criteria Donor and Expanded Criteria Donor Kidneys After Kidney Allocation System Implementation

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Background: Implementation of the Kidney Allocation System (KAS) changed how kidneys are allocated and the information on which organ utilization decisions are based. We aimed to evaluate how KAS implementation changed kidney utilization and recipient outcomes.

Material/Methods: Using the United Network for Organ Sharing database, we identified recipients of kidney transplants from donors with kidney donor profile index (KDPI) of 61–90% in the 5-years pre- and 18-months post-KAS implementation and examined patient and graft survival and donor kidney discard rates based on standard criteria donor (SCD) or expanded criteria donor (ECD) status.

Results: The proportion of ECD kidneys was unchanged pre- versus post-KAS. Post-KAS, SCD kidneys were less likely to be transplanted into young recipients while ECD kidneys were more likely to be transplanted. SCD kidneys in the post-KAS period conferred a 1.42 (95% CI: 1.18–1.73) times higher adjusted mortality and 2% lower 1-year survival (94.2% *vs.* 96.2%, $P<0.001$) but had unchanged graft failure compared to pre-KAS. For ECD kidneys, there was no difference in mortality or graft survival. The discard rate increased after KAS for both SCD and ECD kidneys ($P<0.05$) but was not different between SCD and ECD kidneys for any KDPI group.

Conclusions: After KAS implementation, patient survival for recipients of SCD kidneys was significantly worse.

MeSH Keywords: **Kidney Transplantation • Patient Selection • Tissue and Organ Procurement**

Abbreviations: **DCD** – donation after circulatory death; **ECD** – expanded criteria donor; **IQR** – interquartile range; **KAS** – kidney allocation system; **KDPI** – kidney donor profile index; **OPTN** – Organ Procurement and Transplantation Network; **PHS** – Public Health Service; **PRA** – panel reactive antibody; **SCD** – standard criteria donor; **UNOS** – United Network for Organ Sharing

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Background

Prior to December 4, 2014, deceased donor kidneys in the United States were classified as either standard criteria donor (SCD) or expanded criteria donor (ECD). ECD kidneys met either of the following criteria: 1) donor age more than or equal to 60 years, or 2) donor age 50 to 59 years, with at least 2 of the following criteria: serum creatinine more than 1.5 mg/dL, death due to cerebrovascular accident, or history of hypertension [1]. Although the SCD/ECD dichotomous system assisted in making decisions about organ acceptance and counseling patients about risk, the introduction of the kidney donor profile index (KDPI) allowed more granular quantification of the spectrum of risk associated with various donor factors [2]. Beginning March 26, 2012, a donor's KDPI was included as part of the organ offer in addition to the standard SCD/ECD classification but had limited effect on discard rates [3].

On December 4, 2014, the Kidney Allocation System (KAS) was implemented [4], which changed how kidneys were allocated and the importance of using KDPI when making organ utilization decisions. However, although ECD donors comprise approximately 15% of the donor pool, the KDPI for these kidneys is not limited to the highest 15% of KDPI (i.e., KDPI greater than 85%). In fact, there is significant discordance between KDPI and ECD, as some ECD kidneys have a KDPI in the 46–50% range, and some SCD kidneys have a KDPI greater than 95% [2,3]. Because of this observed discordance between ECD status and KDPI, we aimed to evaluate how implementation of KAS changed kidney utilization and recipient outcomes based on KDPI and ECD status.

Material and Methods

Data source

We conducted a retrospective cohort analysis of donors in the United Network for Organ Sharing (UNOS) Standard Analysis and Research file. United States donor and recipient data for this analysis was Organ Procurement and Transplantation Network (OPTN) data released March 31, 2017 based on data collected through March 31, 2017. UNOS, as the contractor for the OPTN, supplied these data. The interpretation and reporting of these data are the responsibility of the authors and in no way should be seen as an official policy of or interpretation by the OPTN or the United States government. This study was exempt from review as approved by the University of Washington Institutional Review Board.

Study population

We compared deceased donor kidneys that were transplanted in the United States between December 4, 2009 and

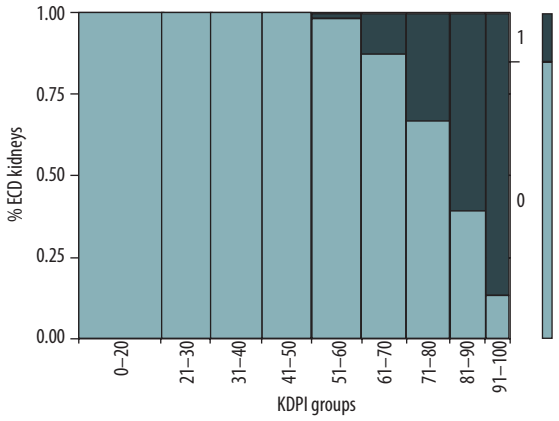

Figure 1. ECD status based on KDPI group. The proportion of ECD kidneys increased from 13.0% in the KDPI 61–70% group to 60.8% in the KDPI 81–90% group.

December 3, 2014 (termed the "pre-KAS era") with those that were transplanted between June 5, 2015 and December 31, 2016 (the "post-KAS era") based on the KAS implementation date of December 4, 2014. We chose a 5-year period before implementation and an 18-month period after implementation, with an intentional exclusion of the first 6-months after KAS implementation. This was to account for stabilization of decision-making when adjusting to the organ allocation system as well as the "bolus effect" of highly sensitized recipients and recipients with extended duration on dialysis that may have skewed the data [5]. ECD was defined as described in previous reports [1] and KDPI was defined as described by the OPTN [6]. We limited our study population to recipients of kidneys with a KDPI between 61% and 90%, as these 3 deciles had the highest proportion of SCD and ECD heterogeneity (Figure 1) [3]. The unit of measure was the kidney, except for the case of en-bloc kidneys, which were counted as one. Exclusion criteria included recipient age less than 18 years and multi-organ transplantation. Recipient and donor demographics were compared by ECD status in the pre- and post-KAS eras using chi-squared statistics and *t*-tests where appropriate.

Data were missing for less than 0.1% of all donor and recipient variables other than cause of death and cold ischemia time. Missing categorical variables were assigned the most common response and missing continuous variables were assigned the median value. Missing cause of death (n=401, 2.0%) was put into the model as "other", and missing cold ischemia time (n=203, 1.0%) was input with linear regression using distance, region, and HLA matching.

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Recipient selection

To examine how recipient selection changed after KAS implementation, we compared the proportion of donor kidneys transplanted into recipients grouped by decade pre- and post-KAS for ECD kidneys and SCD kidneys using chi-squared analysis.

Recipient outcomes

One-year patient and graft survival curves comparing ECD or SCD kidneys in the pre- and post-KAS implementation eras were calculated using Kaplan-Meier analyses and compared using the log-rank test. An analysis using Cox proportional hazards model was performed to determine the contributions of the recipient and donor variables on allograft and patient survival for SCD and ECD kidneys. The model included the following variables: recipient factors included age, gender, race, body mass index (BMI), diabetes, peripheral vascular disease panel reactive antibody (PRA) greater than or equal to 99%, previous transplantation, prior malignancy, years on dialysis, blood group; donor factors included age, gender, donation after circulatory death (DCD) status, hypertension, diabetes, cause of death, Public Health Service (PHS) increased risk, and cold ischemia time.

Changes in discard rates

All kidneys offered for transplantation were evaluated for discard by ECD status and KDPI in the pre- and post-KAS eras. To examine whether ECD status was utilized in decision-making regarding recipient selection in the post-KAS era, we compared SCD and ECD discard rates based on 5-point KDPI increments (e.g., KDPI 61–65%) using chi-squared analysis.

Statistical analysis

Analyses were conducted using JMP Pro 13.1.0 (SAS Institute Inc., Cary, NC, USA) statistical software. *P* values of 0.05 or less were considered significant.

Results

Study population

The proportion of ECD kidneys increased from 13.0% in the KDPI 61–70% group to 60.8% in the KDPI 81–90% group (Figure 1). For recipients of kidney transplants with donor KDPI between 61 and 90, there were 14 337 transplants in the pre-KAS era and 5350 transplants in the post-KAS era, with no change in the ECD proportion after implementation of KAS (34.3% pre-KAS *vs.* 33.0% post-KAS, *P*=0.08). Recipients of SCD kidneys in the post-KAS period were older (55.8±11.6 years *vs.* 53.7±12.4 years, *P*<0.001), more likely to be diabetic (40.0% *vs.* 36.5%,*P*<0.001), and have a history of malignancy (9.7% *vs.* 6.4%, *P*<0.001) than in the pre-KAS period (Table 1). ECD kidney recipients, however, were younger in the post-KAS period (59.9±10.1 years *vs.* 61.6±9.5 years, *P*<0.001) and more likely to be undergoing retransplantation (9.0% *vs.* 5.5%, *P*<0.001) than in the pre-KAS period (Table 2). Both ECD and SCD recipients in the post-KAS period had a higher proportion of PRA >99%, more years on dialysis, and longer cold ischemia time (all *P*<0.001). Median donor KDPI was unchanged for both SCD and ECD donors when comparing the pre- and post-KAS eras (SCD: 71% *vs.* 71%, *P*=0.14, ECD: 81% *vs.* 82%, *P*=0.62). Median donor age was unchanged for both SCD and ECD, although 10% of SCD donors both pre- and post-KAS were 4-years-old or younger.

Recipient selection

After KAS implementation, a lower proportion of SCD kidneys was transplanted into young recipients (18–40 years old, *P*<0.001) and a higher proportion was transplanted into recipients age 61–70 years (*P*<0.001). In contrast, a higher proportion of ECD kidneys was transplanted into young recipients (*P*=0.003 for age 18–30 years, and *P*=0.009 for age 41–50 years), and a lower proportion was transplanted into those older than 61 years of age (*P*=0.050 for age 61–70, *P*=0.002 for age >71 years) (Table 3).

Recipient outcomes

In the multivariate Cox model, for SCD kidneys, the post-KAS era conferred a 1.42 times higher mortality risk (95% CI: 1.18–1.73, *P*=0.007) but unchanged graft failure risk (HR 1.003, 95% CI: 0.86–1.16, *P*=0.96) when compared to the pre-KAS era (Supplementary Table 1). However, for ECD kidneys, there was no difference in either mortality or graft failure in the post-KAS era when compared to the pre-KAS era (mortality aHR 1.26, 95% CI: 0.98–1.63, *P*=0.08, graft failure aHR 1.06, 95% CI: 0.87–1.29, *P*=0.54) (Supplementary Table 2). Unadjusted Kaplan-Meier analysis of patient and graft survival showed similar results, with SCD patient survival decreasing from 96.2% in the pre-KAS era to 94.2% in the post-KAS era (*P*<0.001) (Figure 2).

Discard rates

Discard rates for SCD kidneys increased from 23.9% to 27.1% after KAS implementation (*P*<0.001) and for ECD kidneys, the discard rate increased from 31.2% to 33.3% (*P*=0.04). When matching based on KDPI, there was no difference in discard rate based on ECD status (Table 4, Figure 3).

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Table 1. SCD kidney donor and recipient characteristics pre- and post-KAS.

	Pre-KAS n=9424	Post-KAS n=3587	*P*
Recipient factors			
Age (years, ±SD)	53.7±12.4	55.8±11.6	**<0.001**
Male	5541 (58.8%)	2137 (59.6%)	0.42
Race			**0.04**
White	3703 (39.3%)	1203 (33.5%)	**<0.001**
Black	3423 (36.3%)	1331 (37.1%)	0.41
Hispanic	1391 (14.8%)	670 (18.7%)	**<0.001**
Asian	755 (8%)	292 (8.1%)	0.84
Other	152 (1.6%)	91 (2.5%)	**<0.001**
BMI	28.1±5.4	28.2±5.3	0.41
Diabetes	3436 (36.5%)	1434 (40.0%)	**<0.001**
Peripheral vascular disease	594 (6.3%)	241 (6.7%)	0.4
PRA ≥99%	192 (2.0%)	243 (6.8%)	**<0.001**
Previous transplant	1068 (11.3%)	429 (12.0%)	0.31
Any prior malignancy	602 (6.4%)	348 (9.7%)	**<0.001**
On dialysis (years, ±SD)	3.9±3.5	4.9±3.4	**<0.001**
Blood group			**0.04**
A	3313 (35.2%)	1168 (32.6%)	
AB	473 (5%)	177 (4.9%)	
B	1340 (14.2%)	519 (14.5%)	
O	4298 (45.6%)	1723 (48%)	
Donor factors			
KDPI (median (IQR)	71% (65–78%)	71% (65–77%)	0.14
Age (years, median(IQR))	48 (42–54)	48 (41–55)	0.34
Male	4745 (50.3%)	1755 (48.9%)	0.15
DCD	2167 (23.0%)	1023 (28.5%)	<0.001
Hypertension	4353 (46.2%)	1724 (48.1%)	0.06
Diabetes	1497 (15.9%)	526 (14.7%)	0.09
Cause of death			**<0.001**
Anoxia	2973 (31.6%)	1475 (41.1%)	
Cerebrovascular	4201 (44.6%)	1271 (35.4%)	
Head trauma	2002 (21.2%)	702 (19.6%)	
Other	248 (2.6%)	139 (3.9%)	
PHS increased risk	767 (8.1%)	491 (13.7%)	**<0.001**
Cold ischemia time (hours, ±SD)	18.1±9.2	18.7±8.9	**<0.001**

DCD – donation after circulatory death; KAS – kidney allocation system; PHS – Public Health Service; PRA – panel reactive antibody.

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Table 2. ECD kidney donor and recipient characteristics pre- and post-KAS.

	Pre-KAS n=4913	Post-KAS n=1763	*P*
Recipient factors			
Age (years, ±SD)	61.6±9.5	59.9±10.1	**<0.001**
Male	3152 (64.2%)	1102 (62.5%)	0.2
Race			
White	2235(45.5%)	687 (39.0%)	**<0.001**
Black	1449 (29.5%)	584 (33.1%)	**0.005**
Hispanic	731 (14.9%)	317 (18.0%)	**0.002**
Asian	397 (8.1%)	145 (8.2%)	0.9
Other	101 (2.1%)	30 (1.7%)	0.41
BMI	28.6±5	28.9±5.2	**0.009**
Diabetes	2452 (49.9%)	870 (49.4%)	0.68
Peripheral vascular disease	440 (9.0%)	166 (9.4%)	0.6
PRA ≥99%	29 (0.6%)	78 (4.4%)	**<0.001**
Previous transplant	268 (5.5%)	159 (9.0%)	**<0.001**
Any prior malignancy	463 (9.4%)	194 (11.0%)	0.06
On dialysis (years, ±SD)	3.5±3	4.7±3.2	**<0.001**
Blood group			0.29
A	1781 (36.3%)	678 (38.5%)	
AB	228 (4.6%)	88 (5%)	
B	627 (12.8%)	223 (12.7%)	
O	2277 (46.4%)	774 (43.9%)	
Donor factors			
KDPI (median (IQR)	81% (74–86%)	82% (74–86%)	0.62
Age (years, median(IQR))	68 (53–62)	58 (53–62)	
Male	2231 (45.4%)	817 (46.3%)	0.5
DCD	343 (7.0%)	215 (12.2%)	**<0.001**
Hypertension	3391 (69.0%)	1197 (67.9%)	0.38
Diabetes	496 (10.1%)	145 (8.2%)	**0.02**
Cause of death			**<0.001**
Anoxia	592 (12.1%)	297 (16.9%)	
Cerebrovascular	3625 (73.6%)	1185 (67.2%)	
Head trauma	655 (13.3%)	252 (14.3%)	
Other	51 (1.0%)	29 (1.6%)	
PHS increased risk	207 (4.2%)	107 (6.1%)	**0.005**
Cold ischemia time (hours, ±SD)	17.9±9.2	19.4±9	**<0.001**

DCD – donation after circulatory death; KAS – kidney allocation system; PHS – Public Health Service, PRA – panel reactive antibody.

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Table 3. Comparison of recipient age groups by ECD status pre- and post-KAS.

Age groups	n (%) pre KAS	n (%) post KAS	% Difference	*p*
SCD				
18–30	486 (5.2%)	122 (3.4%)	–0.01760	**<0.001**
31–40	1032 (11.0%)	277 (7.7%)	–0.03230	**<0.001**
41–50	1916 (20.3%)	661 (18.4%)	–0.01930	0.13
51–60	2873 (30.5%)	1089 (30.4%)	–0.00130	0.85
61–70	2510 (26.6%)	1175 (32.8%)	0.06130	**<0.001**
71+	607 (6.4%)	263 (7.3%)	0.00890	0.17
ECD				
18–30	29 (0.6%)	24 (1.4%)	0.0077	**0.003**
31–40	111 (2.3%)	52 (3.0%)	0.0069	0.12
41–50	463 (9.4%)	205 (11.6%)	0.0221	**0.009**
51–60	1379 (28.1%)	534 (30.3%)	0.0222	0.08
61–70	2153 (43.8%)	724 (41.1%)	–0.0275	**0.050**
71+	778 (15.8%)	224 (12.7%)	–0.0313	**0.002**

ECD – expanded criteria donor; KAS – kidney allocation system; SCD – standard criteria donor.

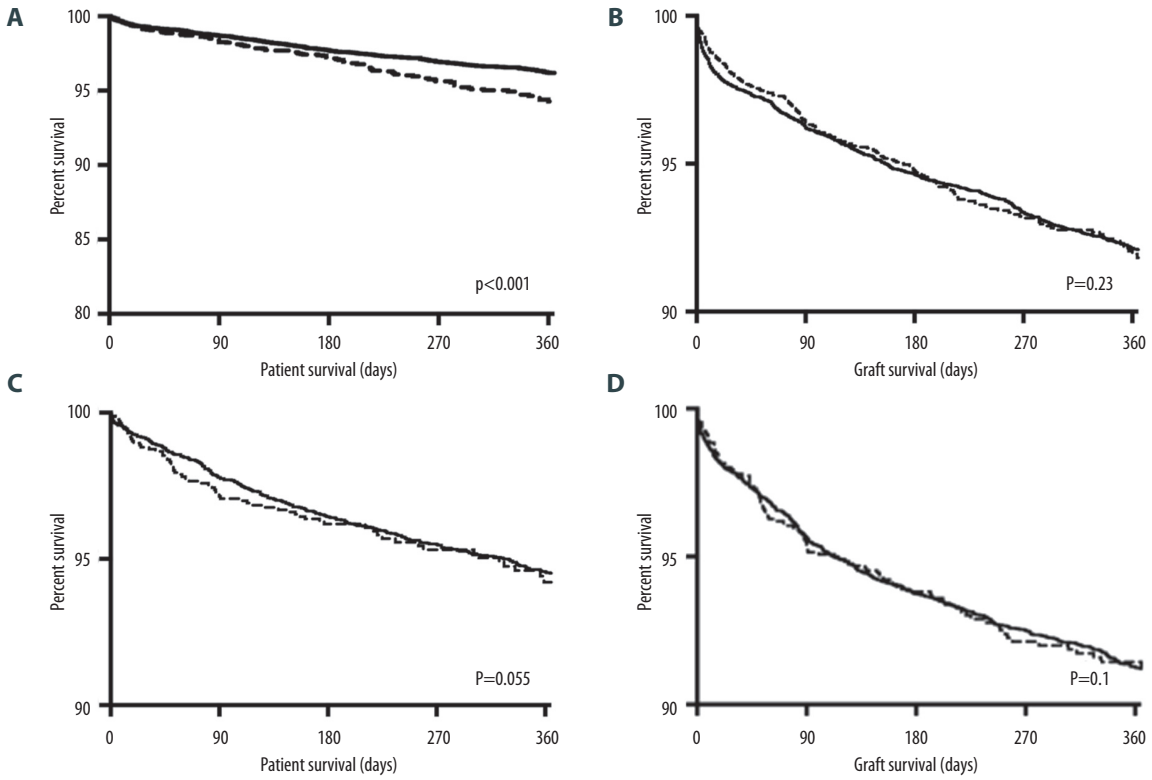

Figure 2. Patient and graft survival by ECD status pre- and post-KAS. (**A**) 1-year patient survival, SCD kidneys. There was a significant decrease in survival at one year – 96.2% pre-KAS versus 4.2% post-KAS (*P*<0.001). (**B**) There was no difference in 1-year graft survival for SCD kidneys in the pre- and post-KAS eras. (**C**) There was no difference in 1-year patient survival for ECD kidney recipients comparing pre- and post-KAS. (**D**) There was no difference between ECD kidney graft survival at 1-year for pre- and post-KAS kidneys. Solid lines: pre-KAS, dashed line: post-KAS.

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Table 4. Kidney discard by KDPI group and ECD status in the post-KAS era.

KDPI group	SCD discard n (%)		ECD discard n (%)		*P*
61–65	227	(18.5%)	13	(13.5%)	0.27
66–70	275	(22.1%)	35	(16.7%)	0.08
71–75	282	(27.1%)	80	(22.3%)	0.08
76–80	246	(29.4%)	153	(32.5%)	0.26
81–85	290	(36.8%)	251	(34.7%)	0.42
86–90	174	(45.3%)	390	(42.9%)	0.42

ECD – expanded criteria donor; KDPI – kidney donor profile index; SCD – standard criteria donor.

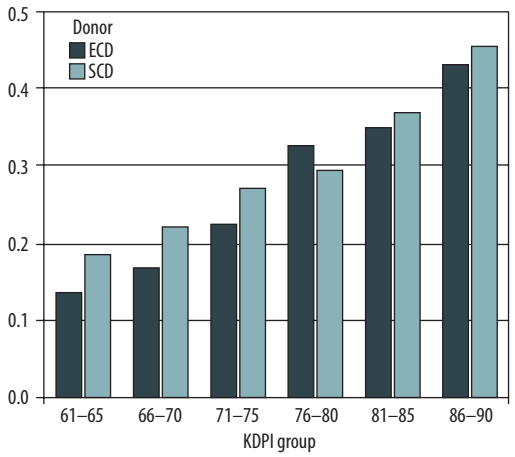

Figure 3. Discard rates by KDPI and ECD status in the post-KAS era. For each 5-point KDPI grouping, there is no difference in the discard rate between ECD and SCD kidneys.

Discussion

Implementation of KAS was intended to make better use of available kidneys, more equitably match donor and recipient expected outcomes, and increase transplants for difficult-to-match patients. By some measures, KAS has been successful in achieving these aims, including transplanting a much higher proportion of recipients with high PRA or longer dialysis times. However, implementation has had some unintended consequences, with an increase in overall discard rate (especially for those KDPI >85%), and higher rates of delayed graft function for all levels of KDPI [5]. Importantly, 3-year overall patient survival is significantly worse in the post-KAS era when including all KDPI strata [5].

In our study of a subpopulation of kidney recipients – those receiving a kidney from a donor with a KDPI of 61–90% in which the proportion of KDPI and ECD discordance was high – we demonstrated that implementation of KAS resulted in a 2% absolute decrease in 1-year survival for recipients of SCD kidneys. Perhaps helping to explain this, SCD kidneys were being transplanted into older and sicker recipients with a 42% higher adjusted mortality risk and unchanged graft survival. ECD kidneys, however, were being transplanted into younger patients, with unchanged 1-year patient and graft survival. We found kidney discard to be independent of ECD status. Causing us to ask, is a 2% increase in death clinically significant? In 2016, there were approximately 2200 kidney transplants in the SCD post-KAS group, and hence this additional 2% increase in the death rate would translate to 44 additional deaths per year. The cumulative effect of this over time means almost 150 deaths between KAS implementation and today.

Although longevity matching was not a component of the new allocation system at this level of KDPI, the significantly worse outcomes for SCD recipients and the potentially inappropriate use of ECD kidneys in young recipients leads us to conclude that it should be considered. While neither KDPI nor SCD/ECD perfectly reflects the risk associated with a certain kidney, labeling kidneys with a number (KDPI) instead of SCD or ECD status likely changes how we view them and who we consider appropriate recipients. Prior discussions about the labeling effect have mainly centered on the discard rate of high KDPI kidneys (KDPI >85%) and loss aversion [7] as a possible explanation for the subsequent decline in use of these organs. However, we theorize that labeling is having the opposite effect here: labeling ECD kidneys with a low KDPI has resulted in increased use and higher likelihood of choosing younger recipients.

Decision-making by physicians and surgeons about organ utilization and recipient selection is complex, and how KDPI and ECD status is taken into account is difficult to assess in a retrospective study. Our analysis demonstrated that discard rates for both SCD and ECD kidneys increased significantly in the post-KAS era, but SCD and ECD kidneys were discarded at the same rate when matched by KDPI, suggesting that ECD status

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is not a factor in organ discard. Woodside et al. reported this same result in a retrospective study performed prior to both KDPI labeling and KAS implementation [8]. Likewise, Bae et al. demonstrated that introduction of KDPI labeling prior to implementation of KAS had no effect on the discard rate in the overall population, and only increased the odds of discard in one subgroup (SCD and KDPI >85% kidneys) [3]. In an interesting study, Stewart et al. analyzed organ discards during a period of erroneously high KDPI calculation. They demonstrated that the rate of discard was higher than what was expected based on the true KDPI, but lower than the projected rate based on the provided KDPI. This suggests that clinicians did not rely solely on the KDPI when making decisions about organ discard [9].

KDPI is not a perfect model and as such has limitations. The average C-statistic of the receiver operating characteristic curve of the model is 0.62, indicating reasonable discriminatory power, but the model does not discriminate well between kidneys close together on the KDPI spectrum [2]. Further support of this is an essentially flat curve between KDPI of 20% and 80% [10]. KDPI was developed and validated based on adult donors, and as such is not considered to be a good predictor of graft survival for pediatric donors [11]. In our population, 10% of the SCD donors were 4-years-old or younger. In a single-center analysis of retroactive application of KAS, Ramanathan et al. found a statistically significant lower 1-year patient survival (98.8% pre-KAS *vs.* 95.5% post-KAS <*P*=0.048) and no change in 1-year graft survival [12]. In another study that evaluated changes in the year before and the year after KAS implementation, there was a non-statistically significant decrease in 6-month graft survival (95.83% pre-KAS *vs.* 95.37% post-KAS, *P*=0.2006) and no comment on patient survival [13]. However, this study did not exclude the 6-months immediately post-KAS implementation, and hence showed the effect of highly sensitized patient and long-dialysis wait time patients. Although KDPI does increase granularity and potentially interpretability compared to the SCD/ECD classification, and in one study KDPI was found to be a predictor of GFR at one year [14], it still remains limited in its ability to distinguish between donors within the range of our study.

There were several limitations to our study. Decision-making about organ utilization, recipient selection, and organ discard is very complex, including variables at the patient, transplant center, organ procurement organization, and regional level for which we could not account. In our study, the post-KAS time frame had a 6-month delay to allow for system stabilization, but a steady state for highly sensitized recipients and long dialysis time recipients was likely not yet reached. At 1 month after KAS implementation, 17.7% of recipients were highly sensitized (PRA 99–100%), and this proportion declined to 12.6% at 6 months. In the intervening 18 months, the proportion varied between 9.5% and 13.4%, with a plateau of around 10% [5]. To account for this, we adjusted for PRA 99–100%, which was actually a much lower proportion of the study population (6.8% post-KAS SCD, 4.4% post-KAS ECD) than the overall population (around 10%). Likewise, for recipients with more than 10 years on dialysis, the proportion peaked at 18.6% at 1 month after KAS implementation, dropped to 8.9% at 6 months, and plateaued around 6% (range 4.1–9.1% between months 7 and 24) [5]. Although we would have liked to delve into reasons why the distribution of SCD and ECD kidneys into different age groups changed (recipient factors such as time on dialysis, PRA, and estimated post-transplant survival) the numbers in these groups were too small to allow sub-group analysis. In addition, the study was conducted on 1-year follow-up data, and hence we are unable to comment on the long-term mortality and graft failure that may lead to different conclusions.

Conclusions

In this study, we aimed to examine changes that resulted from KAS implementation in terms of organ usage and outcomes in kidneys with KDPI of 61–90%. We found that recipient selection changed for both SCD and ECD kidneys at the expense of worse patient survival at 1 year for SCD recipients and perhaps inappropriate use of ECD kidneys in younger recipients. In addition, we found that ECD status did not appear to be a factor related to organ discard. Although some of the intentions of KAS implementation were fulfilled, these results raise concerns about the validity and application of KDPI in decision-making in a subpopulation of higher KDPI kidneys. We must ensure that such inadvertent outcomes are taken into consideration for any further revisions to the kidney donor allocation system. Further studies should focus on longer-term patient and graft outcomes as data becomes available.

Conflicts of interest

None.

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Supplementary Tables

Supplementary Table 1A. Cox model for patient survival for SCD donor recipients.

	Univariable analysis			Multivariable analysis		
	RR (95% CI)		*P*	RR (95% CI)		*P*
After KAS	1.65	(1.35–2.01)	**<0.001**	1.42	(1.18–1.73)	**0.007**
Recipient age	1.05	(1.04–1.055)	**<0.001**	1.04	(1.03–1.05)	**0.001**
Female	0.77	(0.69–0.86)	**<0.001**	0.86	(0.77–0.96)	**0.009**
Race						
Asian	0.44	(0.33–0.56)	**<0.001**	0.45	(0.35–0.59)	**<0.001**
Black	0.77	(0.68–0.86)	**<0.001**	0.79	(0.69–0.89)	**<0.001**
Hispanic	0.66	(0.56–0.78)	**<0.001**	0.65	(0.54–0.78)	**<0.001**
Other	0.88	(0.58–1.34)	0.55	0.78	(0.52–1.19)	0.25
White	Ref					
BMI	1.01	(1.005–1.02)	**0.003**	0.99	(0.98–1.006)	0.37
Diabetes mellitus	2.01	(1.81–2.23)	**<0.001**	1.63	(1.46–1.83)	**<0.001**
Peripheral vascular disease	2.01	(1.68–2.38)	**<0.001**	1.35	(1.13–1.61)	**0.001**
PRA ≥99	1.07	(0.75–1.48)	0.69	1.16	(0.81–1.65)	0.41
Previous transplant	0.97	(0.82–1.15)	0.77	1.28	(1.07–1.53)	**0.007**
Prior malignancy	1.69	(1.41–2.01)	**<0.001**	1.15	(0.96–1.38)	0.13
Years on dialysis	1.03	(1.02–1.05)	**<0.001**	1.06	(1.05–1.08)	**<0.001**
Blood group						
A	1.08	(0.96–1.21)	0.18	1.05	(0.93–1.18)	0.46
B	0.95	(0.73–1.22)	0.71	1.10	(0.94–1.29)	0.23
AB	1.09	(0.93–1.27)	0.29	1.01	(0.78–1.31)	0.91
O	Ref					
Donor factors						
Age	1.01	(1.009–1.02)	**<0.001**	1.004	(1.0003–1.01)	**0.03**
Female	0.96	(0.87–1.07)	0.48	0.95	(0.86–1.06)	0.39
DCD status	1.03	(0.91–1.16)	0.62	0.96	(0.85–1.09)	0.55
Hypertension	1.14	(1.03–1.27)	**0.01**	1.02	(0.92–1.14)	0.68
Diabetes mellitus	1.15	(1.002–1.32)	**0.046**	1.07	(0.93–1.24)	0.33
Cause of death						
Anoxia	Ref					
Head Trauma	0.88	(0.76–1.02)	0.08	0.89	(0.77–1.04)	0.16
CVA	0.93	(0.82–1.05)	0.24	0.93	(0.82–1.06)	0.28
Other	1.07	(0.77–1.44)	0.69	1.08	(0.78–1.48)	0.65
PHS increased risk	1.13	(0.94–1.35)	0.21	1.08	(0.89–1.30)	0.42
Cold Ischemia time (h)	1.004	(0.99–1.01)	0.14	1.003	(0.99–1.01)	0.33

DCD – donation after circulatory death; KAS – kidney allocation system; PHS – Public Health Service; PRA – panel reactive antibody.

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Supplementary Table 1B. Cox model for graft survival for SCD donor recipients.

	Univariable analysis			Multivariable analysis		
	RR (95% CI)		*P*	RR (95% CI)		*P*
After KAS	1.07	(0.93–1.25)	0.32	1.003	(0.86–1.16)	0.96
Recipient age	1.01	(1.006–1.014)	**<0.001**	1.008	(1.004–1.01	**<0.001**
Female	0.86	(0.79–0.94)	**<0.001**	0.89	(0.82–0.98)	**0.01**
Race						
Asian	0.60	(0.49–0.73)	**<0.001**	0.61	(0.50–0.75)	**<0.001**
Black	1.08	(0.99–1.18)	0.1	1.01	(0.92–1.12)	0.8
Hispanic	0.81	(0.71–0.92)	**0.002**	0.74	(0.65–0.86)	**<0.001**
Other	0.98	(0.70–1.37)	0.91	0.90	(0.64–1.25)	0.52
White	Ref					
BMI	1.01	(1.006–1.02)	**0.001**	1.004	(0.99–1.01)	0.38
Diabetes mellitus	1.32	(1.21–1.43)	**<0.001**	1.24	(1.13–1.36)	**<0.001**
Peripheral vascular disease	1.47	(1.26–1.71)	**<0.001**	1.29	(1.11–1.52)	**0.001**
PRA ≥99	0.99	(0.75–1.28)	0.93	0.92	(0.70–1.22)	0.57
Previous transplant	1.17	(1.03–1.32)	**0.02**	1.24	(1.09–1.42)	**0.001**
Prior malignancy	1.27	(1.09–1.48)	**0.003**	1.15	(0.99–1.35)	0.07
Years on dialysis	1.04	(1.03–1.05)	**<0.001**	1.05	(1.04–1.06)	**<0.001**
Blood group						
A	0.96	(0.87–1.05)	0.35	1.01	(0.91–1.07)	0.58
B	1.04	(0.92–1.18)	0.57	1.05	(0.93–1.18)	0.47
AB	0.85	(0.69–1.04)	0.12	0.91	(0.74–1.12)	0.38
O	Ref					
Donor factors						
Age	1.004	(1.002–1.007)	**<0.001**	1.0004	(0.99–1.003)	0.77
Female	0.99	(0.91–1.07)	0.75	1.01	(0.93–1.10)	0.76
DCD status	1.05	(0.95–1.15)	0.37	1.05	(0.95–1.17)	0.31
Hypertension	1.19	(1.10–1.29)	**<0.001**	1.11	(1.02–1.21)	**0.02**
Diabetes mellitus	1.18	(1.06–1.31)	**0.002**	1.13	(1.01–1.27)	**0.03**
Cause of death						
Anoxia	Ref					
Head Trauma	0.86	(0.76–0.97)	**0.02**	0.88	(0.78–0.99)	**0.05**
CVA	1.02	(0.93–1.12)	0.71	1.01	(0.91–1.12)	0.84
Other	1.25	(0.98–1.57)	0.07	1.22	(0.96–1.55)	0.1
PHS increased risk	1.06	(0.91–1.22)	0.44	1.07	(0.92–1.24)	0.39
Cold Ischemia time (h)	1.006	(1.002–1.01)	**0.003**	1.007	(1.002–1.01)	**0.002**

DCD – donation after circulatory death; KAS – kidney allocation system; PHS – Public Health Service; PRA – panel reactive antibody.

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Supplementary Table 2A. Cox model for patient survival for ECD donor recipients.

	Univariable analysis			Multivariable analysis		
	RR (95% CI)		*P*	RR (95% CI)		*P*
After KAS	1.29	(0.99–1.65)	0.055	1.26	(0.98–1.63)	0.08
Recipient age	1.05	(1.04–1.05)	**<0.001**	1.05	(1.04–1.06)	**<0.001**
Female	0.95	(0.84–1.08)	0.44	1.03	(0.91–1.18)	0.56
Race						
Asian	0.91	(0.73–1.15)	0.47	0.79	(0.62–1.01)	0.06
Black	0.80	(0.69–0.93)	**0.003**	0.77	(0.66–0.89)	**0.001**
Hispanic	0.87	(0.73–1.04)	0.13	0.73	(0.61–0.89)	**0.001**
Other	0.85	(0.52–1.30)	0.48	0.82	(0.52–1.30)	0.39
White	Ref					
BMI	1.003	(0.99–1.02)	0.99	1.003	(0.99–1.02)	0.61
Diabetes mellitus	1.61	(1.43–1.82)	**<0.001**	1.65	(1.45–1.88)	**<0.001**
Peripheral vascular disease	1.49	(1.23–1.80)	**<0.001**	1.32	(1.09–1.61)	**0.005**
PRA ≥99	1.23	(0.62–2.17)	0.52	1.29	(0.67–2.47)	0.44
Previous transplant	0.95	(0.72–1.24)	0.73	1.33	(1.0003–1.77)	**0.049**
Prior malignancy	1.26	(0.104–1.52)	**0.02**	0.98	(0.81–1.19)	0.86
Years on dialysis	1.05	(1.03–1.07)	**<0.001**	1.09	(1.08–1.12)	**<0.001**
Blood group						
A	1.09	(0.95–1.24)	0.22	1.11	(0.97–1.28)	0.12
B	0.97	(0.79–1.17)	0.75	1.05	(0.86–1.27)	0.64
AB	1.11	(0.84–1.45)	0.44	1.21	(0.91–1.59)	0.19
O	Ref					
Donor factors						
Age	1.02	(1.005–1.03)	**0.003**	1.01	(0.99–1.03)	**0.1**
Female	0.99	(0.89–1.13)	0.99	1.01	(0.89–1.15)	0.82
DCD status	0.86	(0.67–1.10)	0.24	0.81	(0.63–1.06)	0.12
Hypertension	0.98	(0.87–1.12)	0.78	1.07	(0.92–1.25)	0.36
Diabetes mellitus	1.07	(0.88–1.29)	0.48	1.11	(0.91–1.35)	0.32
Cause of death						
Anoxia	Ref					
Head Trauma	0.92	(0.74–1.17)	0.53	0.88	(0.69–1.11)	0.28
CVA	0.86	(0.72–1.03)	0.096	0.88	(0.73–1.05)	0.16
Other	0.82	(0.43–1.42)	0.51	0.73	(0.41–1.33)	0.31
PHS increased risk	0.78	(0.56–1.08)	0.14	0.81	(0.58–1.12)	0.19
Cold Ischemia time (h)	1.006	(0.99–1.01)	0.055	1.94	(1.12–3.37)	**0.02**

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Supplementary Table 2B. Cox model for graft survival for ECD donor recipients.

	Univariable analysis			Multivariable analysis		
	RR (95% CI)		*P*	RR (95% CI)		*P*
After KAS	1.29	(0.99–1.65)	0.055	1.26	(0.98–1.63)	0.08
Recipient age	1.05	(1.04–1.05)	**<0.001**	1.05	(1.04–1.06)	**<0.001**
Female	0.95	(0.84–1.08)	0.44	1.03	(0.91–1.18)	0.56
Race						
Asian	0.91	(0.73–1.15)	0.47	0.79	(0.62–1.01)	0.06
Black	0.80	(0.69–0.93)	**0.003**	0.77	(0.66–0.89)	**0.001**
Hispanic	0.87	(0.73–1.04)	0.13	0.73	(0.61–0.89)	**0.001**
Other	0.85	(0.52–1.30)	0.48	0.82	(0.52–1.30)	0.39
White	Ref					
BMI	1.003	(0.99–1.02)	0.99	1.003	(0.99–1.02)	0.61
Diabetes mellitus	1.61	(1.43–1.82)	**<0.001**	1.65	(1.45–1.88)	**<0.001**
Peripheral vascular disease	1.49	(1.23–1.80)	**<0.001**	1.32	(1.09–1.61)	**0.005**
PRA ≥99	1.23	(0.62–2.17)	0.52	1.29	(0.67–2.47)	0.44
Previous transplant	0.95	(0.72–1.24)	0.73	1.33	(1.0003–1.77)	**0.049**
Prior malignancy	1.26	(0.104–1.52)	**0.02**	0.98	(0.81–1.19)	0.86
Years on dialysis	1.05	(1.03–1.07)	**<0.001**	1.09	(1.08–1.12)	**<0.001**
Blood group						
A	1.09	(0.95–1.24)	0.22	1.11	(0.97–1.28)	0.12
B	0.97	(0.79–1.17)	0.75	1.05	(0.86–1.27)	0.64
AB	1.11	(0.84–1.45)	0.44	1.21	(0.91–1.59)	0.19
O	Ref					
Donor factors						
Age	1.02	(1.005–1.03)	0.003	1.01	(0.99–1.03)	0.1
Female	0.99	(0.89–1.13)	0.99	1.01	(0.89–1.15)	0.82
DCD status	0.86	(0.67–1.10)	0.24	0.81	(0.63–1.06)	0.12
Hypertension	0.98	(0.87–1.12)	0.78	1.07	(0.92–1.25)	0.36
Diabetes mellitus	1.07	(0.88–1.29)	0.48	1.11	(0.91–1.35)	0.32
Cause of death						
Anoxia	Ref					
Head Trauma	0.92	(0.74–1.17)	0.53	0.88	(0.69–1.11)	0.28
CVA	0.86	(0.72–1.03)	0.096	0.88	(0.73–1.05)	0.16
Other	0.82	(0.43–1.42)	0.51	0.73	(0.41–1.33)	0.31
PHS increased risk	0.78	(0.56–1.08)	0.14	0.81	(0.58–1.12)	0.19
Cold Ischemia time (h)	1.006	(0.99–1.01)	0.055	1.94	(1.12–3.37)	**0.02**

DCD – donation after circulatory death; KAS – kidney allocation system; PHS – Public Health Service; PRA – panel reactive antibody.

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