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Histopathologic Findings on Implantation Renal Allograft Biopsies Correlate with Kidney Donor Profile Index and 30-Day Serum Creatinine

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Abstract

Background: Kidney Donor Profile Index (KDPI) is a numerical estimate of deceased donor kidney quality that uses 10 donor factors but does not consider histopathologic findings. We examined whether KDPI and its component donor factors correlate with the degree of histopathologic changes seen in implantation renal allograft biopsies.

Methods: All deceased donor kidney transplants at our institution from 07/01/2016 to 03/15/2017 that had an implantation biopsy were included. The biopsies were graded based on Banff criteria for interstitial fibrosis, tubular atrophy, arterial intimal fibrosis, and arteriolar hyalinosis, as well as percent glomerulosclerosis. Linear and logistic regression were used to assess correlation between histopathologic findings and KDPI and the ability of these variables to predict 30-day serum creatinine and delayed graft function (DGF).

Results: 134 recipients from 107 donors were included. All histopathologic features examined significantly correlated with KDPI, with arteriolar hyalinosis correlating most strongly. Arteriolar hyalinosis was also associated with the most component donor factors of KDPI. Histopathologic findings alone or in combination with KDPI predicted 30-day serum creatinine but not DGF. Using KDPI in combination with degree of interstitial fibrosis and tubular atrophy was the best predictor of 30-day serum creatinine.

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Conclusion: Histopathologic changes seen in implantation renal allograft biopsies correlate with KDPI and predict 30-day serum creatinine. Using a combination of donor histopathologic findings and KDPI may be the best predictors of short-term graft function.

Introduction

The Kidney Donor Profile Index (KDPI) is a numerical estimate of expected deceased donor kidney quality relative to other recovered kidneys [1, 2]. It uses 10 donor factors, including elements of donor demographics (age, height, weight, ethnicity), medical history (hypertension, diabetes, hepatitis C status), and factors related to donor death (cause of death, terminal serum creatinine, brain or cardiac death). These factors together were found in the derivation of this index to be predictive of the risk of graft failure. Kidneys from donors with lower KDPI are expected to function longer, while kidneys from donors with higher KDPI are expected to have shorter half-lives. The KDPI does not include any information about biopsy findings of deceased donor kidneys, and thus far the association between the KDPI and the donor kidney's histopathologic characteristics have yet to be determined. Moreover, the utility of using histopathologic findings in combination with KDPI to predict graft outcome has not been thoroughly explored.

Several studies have examined whether procurement biopsy findings are predictive of graft outcome, but the results are often conflicting [3-10]. A systematic review exploring this topic found that there were no consistent associations between donor biopsy findings and post-transplant outcomes, mainly due to the large degree of variability between study quality, how biopsy findings were reported, which post-transplant outcomes were examined, and what statistical methods were used [11]. In terms of the histopathologic findings, many of these studies are plagued by poor data quality given the technical difficulties of preparing high quality frozen sections, challenges in accurately interpreting frozen sections, the lack of higher sensitivity special stains, and the lack of renal pathology expertise. Furthermore, these studies are largely underpowered to determine the significance of moderate to severe histopathologic changes in donor biopsies since such organs are often discarded and thus not included in outcome studies [10]. More recent publications suggest that using implantation biopsies may be a better way to explore the relevance of donor-derived histologic findings on graft outcome [9, 12]. The main rationale is that such biopsies are typically processed as formalin-fixed, paraffin embedded tissue, the standard method to produce high quality histologic sections.

In this study, we examined the relationship of histopathologic features of implantation biopsies to KDPI and early transplant outcome. Our first aim was to determine whether a correlation exists between the KDPI and donor histopathologic characteristics. A correlation here would support the robustness of the predictive ability of the KDPI and suggest that the predictive ability of the KDPI may be linked or partially mediated by its correlation with histologic findings. Our second aim was to find the components of the KDPI that are associated with histologic abnormalities, thus defining potential histopathologic mediators for donor-derived clinical disease. Our final aim was to assess if using histopathologic characteristics alone or in combination with KDPI were predictive of early graft function in the form of 30-day serum creatinine and occurrence of delayed graft function (DGF). If

histopathologic findings in implantation biopsies are indeed useful for predicting graft outcome, the implication would be that further exploration of using procurement biopsy data in combination with KDPI may allow better and safer utilization of high risk deceased donor kidneys.

Patients and Methods

Patients

This study was approved by the Institutional Review Board of the University of California, Davis. All deceased donor kidney transplants at our institution from 07/01/2016 to 03/15/2017 that had an implantation renal allograft biopsy were included. At our institution, implantation biopsies are performed either immediately prior to or shortly after kidney implantation. Most deceased donor kidneys are preserved on hypothermic machine perfusion for a period of time pre-implantation. All patients receive anti-thymocyte globulin induction per our center's protocol. Clinical information about donors and recipients were obtained from United Network of Organ Sharing (UNOS) and from the recipient's electronic medical record, respectively. DGF was defined as the need for dialysis within 7 days post-transplantation with subsequent recovery of renal function.

Biopsy Analysis

Implantation biopsies were obtained using a biopsy needle or via wedge resection. Each biopsy was formalin-fixed, paraffin-embedded, and stained with hematoxylin and eosin (H&E), periodic acid-Schiff (PAS), and Masson trichrome. All biopsies were read and graded by one renal pathologist (KYJ). The biopsies were graded according to Banff 2015 and Banff Preimplantation Kidney Biopsy guidelines, including assessment of interstitial fibrosis (ci), tubular atrophy (ct), arteriosclerosis (cv), arteriolar hyalinosis (ah) and percent glomerulosclerosis [10, 13]. Implantation biopsies of donors where both kidneys were transplanted at our center were graded as a single combined biopsy; thus, grades are identical between the two kidneys from the same donor. Similarly, the total number of sclerosed and non-sclerosed glomeruli across both kidneys were tabulated and the resulting single percentage of glomerulosclerosis was applied to both kidneys from the same donor.

Statistical Analysis

KDPI groups were defined as 0-20%, 21-50%, 51-85%, and 86-100%. Donor and recipient characteristics were compared by KDPI groups using Fisher's exact test for categorical variables and analysis of variance (ANOVA) for continuous variables. Distribution of KDPI and 30-day serum creatinine were compared by histopathologic grades for ci, ct, ah, and cv as well as percentage of glomerulosclerosis. Correlation between histopathologic grades and KDPI was assessed through ordinal logistic regression using the KDPI as an ordinal dependent variable, as well as by linear regression with the KDPI as the continuous dependent variable. Logistic regression was used to assess the ability of KDPI and/or histopathologic grades to predict DGF. The odds ratios between components of the KDPI with individual histopathologic components were computed from ordinal logistic regression. Linear regression was used to assess the correlation between percent glomerulosclerosis and individual components of the KDPI. We computed the c-statistic, Akaike information

criterion, and Bayesian information criterion to assess the discrimination capability of different predictors and models [14]. For the 95% confidence interval of the c-statistic, we employed a bootstrap method with 100 replicates [15]. Stata 14 SE (College Station, TX) and SAS 9.4 (Cary, NC) were used for statistical analyses.

Results

Characteristics of donors and recipients by KDPI

The distribution of donor and recipient characteristics by KDPI groups is shown in Table 1. A total of 107 unique donors were included in this study whose kidneys were implanted into 134 recipients. There were significant differences in donor age, ethnicity, height, cause of death, hypertension history, diabetes history and smoking history between KDPI groups. Significant differences in cause of death are noted between the highest and lowest KDPI groups: the highest KDPI group had the highest percentage of cerebrovascular accident (CVA)/stroke as the cause of death (5 of 9, 56%) while the lowest KDPI group had the highest percentage of head trauma as the cause of death (10 of 19, 52%). These trends are consistent with the way that the KDPI is calculated. There was no significant difference in the percentage of male donors, Public Health Services (PHS) increased risk donors, or donor blood type distribution between KDPI groups. Although deceased after cardiac death (DCD) status is part of the KDPI calculation, we found no significant difference in the rates of DCD donors between KDPI groups. Of note, none of the high KDPI donors were DCD, which is an intentional practice by our center when selecting donor kidneys.

As expected with regard to recipient characteristics, there was a clear difference in mean recipient age across KDPI groups with the recipients of the highest KDPI kidneys having the highest mean age. Significance differences were also observed between KDPI groups for whether the kidney was pumped by machine perfusion prior to transplant and for prevalence of DGF.

Distribution of KDPI and 30-day serum creatinine by histopathologic findings

The distribution of KDPI and 30-day serum creatinine based on histopathologic findings is presented in Table 2 and a graphical representation of this data is shown in Figure 1. A clear trend of increasing mean KDPI is observed for donors with increasing severity of all histopathologic variables evaluated (ci, ct, ah, cv, and percent glomerulosclerosis). A similar trend for mean 30-day serum creatinine is noted across histopathologic grades for ci, ct, and ah, although cv did not demonstrate significance for this trend. Of note, one recipient who received a kidney with KDPI of 82% did not survive to 30 days post-transplantation and thus did not have a 30-day serum creatinine.

More severe histopathologic findings predict higher KDPI

The odds ratios obtained by ordinal logistic regression modeling of KDPI groups as a categorical outcome variable against histopathologic findings is shown in Table 3. An odds ratio above 1 can be interpreted as increased odds of being in a higher KDPI group when comparing the higher histopathologic grade with the lower histopathologic grade. For example, in the univariate model, ci+ct≥2 resulted in an odds ratio of 4.63 (2.21, 9.72),

meaning those with ci+ct≥2 had 4.63 times the odds of being in a higher KDPI group than those with ci+ct<2. Of the histopathologic components examined, the odds ratio for ah resulted in the highest odds ratio at 8.92 (4.13, 19.45). This association yielded a c-statistic of 0.78 (0.71, 0.86) which was higher than the c-statistics of other histopathologic variables. This strong association was dampened to an odds ratio of 6.21 (2.66, 14.51) when the other histopathologic variables were adjusted for in the multivariable model but remained statistically significant (p<0.001).

The linear regression modeling of KDPI as a continuous outcome variable against histopathologic findings is shown in Table 4. Modeling by linear regression allows quantification of the degree of KDPI change that each increase in histopathologic grade confers. Similar to the ordinal logistic regression modeling described in Table 3, univariate linear regression also resulted in statistically significant regression coefficients between all histopathologic variables and KDPI, but only ah remained significant in the multivariable model. An increase in ah from 0 to 2 increased KDPI by 16.37 percentage points (p=0.006) in the multivariable model. Further increase in ah from 0 to 3 increased KDPI by 22.07 percentage points (p=0.009).

Association between components of KDPI and histopathologic findings

Table 5 shows how individual components of KDPI is associated with histopathologic characteristics on the implantation biopsies. Donor history of hypertension was the strongest predictor of higher histopathologic grades across nearly all categories: odds ratio of 3.44 (CI: 1.46, 8.10) for ci or ct, odds ratio of 7.00 (CI: 3.16-15.50) for ah, and odds ratio of 3.74 (CI: 1.77, 7.92) for cv. Donor history of CVA/stroke was similarly predictive of higher histopathologic grades and was more predictive than hypertension for ci or ct (OR=4.20, CI: 1.56, 11.30) and cv (OR=4.12, CI: 1.62, 10.43). Diabetes history in the donor resulted in the highest OR at 7.68 (CI: 2.10, 28.10) for prediction of higher ah on implantation biopsy. However, donor diabetes history was not predictive of cv or ci/ct. Instead, cv was significantly predicted by donor hypertension history (OR 3.72, CI: 1.77-7.92). Of all the histopathologic findings assessed, ah was predicted by the most number of KDPI components (age, height, weight, CVA/stroke history, hypertension history, and diabetes history). When multivariable ordinal logistic modeling was used for each histopathologic category, ci or ct, ah and cv were all predicted only by donor age (ci or ct: OR=1.06, p=0.009; ah: OR=1.06, p=0.001; cv: OR=1.05, p=0.004). When multivariable linear regression was used for glomerulosclerosis, only donor age remained significantly correlated with higher glomerulosclerosis percentage (β coefficient = 0.2, p=0.03).

Glomerulosclerosis was significantly predicted by donor age, being of Asian descent, history of hypertension, history of diabetes, and death by CVA/stroke. Every 10-year increase in donor age resulted in a 2.5% increase in glomerulosclerosis. Donors with a history of hypertension had 6.41% more glomerulosclerosis than those without hypertension history, and donors with diabetes had 7.63% more glomerulosclerosis than those without diabetes history. Donors that died of CVA/stroke had 6.40% more glomerulosclerosis than those that died of anoxia. Interestingly, Asian donors had almost 10% more glomerulosclerosis than white donors.

Predicting 30-day serum creatinine and DGF using KDPI and histopathologic findings

The 133 recipients who survived at least 30-days post-transplantation had a mean 30-day serum creatinine of 1.74 mg/dL with a standard deviation of 1.41 mg/dL. In univariate analyses of histopathologic grades and KDPI as predictors of 30-day serum creatinine, all histopathologic findings as indicated in Table 6 as well as KDPI showed significant association with the exception of cv≥2. R^2 was highest at 0.22 for ci+ct≥4, much greater than R^2 of 0.11 for KDPI alone. As indicated in Table 6, analysis with three different multivariable linear regression models using either histopathologic variables alone (model #1) or a combination of histopathologic variables and KDPI (models #2 and #3) yielded greatly improved R^2 values compared to KDPI alone (R^2 of 0.26, 0.29, and 0.27 for models #1, #2, and #3, respectively). In these multivariable models, ci+ct≥4 and KDPI consistently remained significantly associated with 30-day serum creatinine. In model #3, having ci+ct≥4 was associated with an increase in 30-day serum creatinine by 2.13 mg/dL while having a KDPI 10% points greater was associated with an increase in 30-day serum creatinine by 0.14 mg/dL. These data indicate that the combination of histopathologic findings alone or histopathologic findings in combination with KDPI was far superior to KDPI alone in predicting 30-day serum creatinine. Furthermore, the likelihood ratio test comparing the multivariable model with KDPI (model #2) versus the multivariable model without KDPI (model #1) revealed a p-value of 0.036, indicating that the addition of KDPI to the multivariable model significantly adds to the model's predictive ability for 30-day serum creatinine.

DGF occurred in 56 (42%) of the 134 kidney recipients. Univariate logistic regression modeling showed that none of the histopathologic variables were predictive of DGF. Similarly, the KDPI was also not predictive of DGF by univariate linear regression modeling. However, when the KDPI was binned into KDPI groups as a categorical variable, it was predictive of DGF development. Being in KDPI group of 21-50% led to a 3.86-fold increase in odds of having DGF (95% CI:1.15-12.97) and being in KDPI group of 51-80% led to a 4.87-fold increase in odds of developing DGF, when compared to KDPI group of 0-20% (CI: 1.44-16.47).

Discussion

Limited data is available in the literature about the relationship between KDPI and donor kidney histopathologic findings. In this study, we addressed this question and found a correlation between the KDPI and baseline histopathologic findings of the donor kidney. More specifically, the degree of interstitial fibrosis and tubular atrophy, arteriolar hyalinosis, arteriosclerosis, and glomerulosclerosis were more severe with increasing KDPI. Prior work by Sanchez-Escuredo and colleagues examining the KDPI in relation to the Remuzzi score (which includes glomerulosclerosis, tubular atrophy, interstitial fibrosis and arteriosclerosis) did not find an association between the KDPI and Remuzzi score components except for borderline association with arteriosclerosis [4]. Their study did not evaluate arteriolar hyalinosis since this feature is not part of the Remuzzi score. Also, their study had very few patients with moderate interstitial fibrosis or tubular atrophy and only one patient with severe arteriosclerosis. In contrast, our cohort includes a larger representation of donor

kidneys with more severe baseline pathology, giving us more power to identify the relationship between these histopathologic findings and the KDPI.

Multivariable models of our data show that the severity of arteriolar hyalinosis remained statistically significant in terms of predicting higher KDPI, which reflects our observation that arteriolar hyalinosis was predicted by the greatest number of KDPI components. While the severity of interstitial fibrosis, tubular atrophy, and arteriosclerosis correlated with donor age, donor stroke status, and donor hypertension history; arteriolar hyalinosis further correlated with both donor height and weight, as well as donor diabetic status. Arteriolar hyalinosis has been shown by Matignon and colleagues to predict DGF in a report of 172 deceased donor biopsies [5]. While we did not find such a correlation in our cohort, we did find significant correlation between arteriolar hyalinosis and 30-day serum creatinine. Of note, our cohort had a significant proportion of donors with ah≥2 (35%), of which 14% of all donors had ah=3 on implantation biopsy while the study by Matignon and colleagues had only 9% of donors with ah≥2 and none with ah=3. Furthermore, our study population has higher rates of thymoglobulin induction and hypothermic machine perfusion, as well as longer cold ischemia times than Matignon's study cohort. Overall, the literature is conflicting about the potential impact of arteriolar hyalinosis on short and long-term graft outcomes. Some of the variation in the literature may be related to inconsistencies in reporting of arteriolar lesions and adjustment for confounders [11, 16-18].

To our knowledge, this study is the first to explore whether specific components of the KDPI are correlated with particular donor kidney histopathologic characteristics. We found that donor history of hypertension as well as death due to CVA/stroke were the strongest predictors of more severe histopathologic features across all variables examined and that donor history of diabetes was highly predictive of having more severe arteriolar hyalinosis on implantation biopsy. In multivariable modeling, age was the donor characteristic that was most predictive of donor histopathology after adjustment for all other KDPI components. These correlations suggest a potential mechanism by which the KDPI may be predictive of graft outcomes. In theory, if histopathologic components reflect actual kidney damage for which the components of the KDPI only predict risk, these histopathologic changes should be more relevant to outcomes.

With regard to short-term outcome, this study demonstrates a consistent independent correlation between having at least moderate interstitial fibrosis and tubular atrophy scores (ci+ct≥4) with 30-day serum creatinine. In fact, ci+ct≥4 was the best predictor of 30-day creatinine and was superior to all other histopathologic variables examined as well as the KDPI. Furthermore, using a combination of interstitial fibrosis and tubular atrophy severity and KDPI yielded the best model for predicting 30-day serum creatinine. These findings are in contrast to previously published literature about interstitial fibrosis and tubular atrophy and graft function [11, 17, 19]. However, our study includes biopsies with higher ci and ct scores than most previously published studies. Therefore, our data may be able to better detect a relationship between interstitial fibrosis/tubular atrophy and graft outcomes than other studies where interstitial fibrosis and tubular atrophy are very limited in the degree of severity. It is also possible that histopathologic findings may have more impact on early graft outcomes in the setting of longer cold ischemia times and more severe ischemia reperfusion

injury. Since our cold ischemia times tend to be longer than other published series, it is possible that in the presence of more baseline acute injury in our grafts, the histologic findings of increased chronicity identifies grafts that will have impaired renal function at 30 days.

The findings in this study will need independent and external validation, ideally in a larger cohort of patients. Long-term outcomes will need to be explored further, as well as histopathologic changes in the allograft kidney over time. Additionally, the possibility of combining the KDPI and donor kidney histopathologic findings to create a clinico-pathologic score for more accurate and robust prediction of graft outcomes is an area in need of further exploration.

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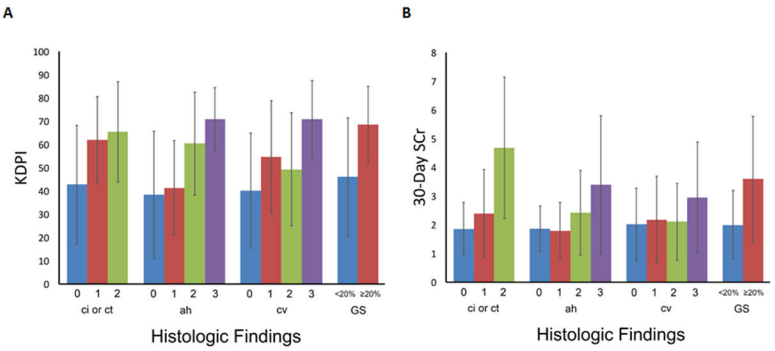

Figure 1: Mean KDPI and 30-day serum creatinine based on histopathologic findings.

A) Mean KDPI and B) 30-day serum creatinine of recipients based on implantation biopsy histopathologic findings. Error bars indicate standard deviation. All histologic categories showed $p<0.05$ except cv for 30-day serum creatinine.

Table 1:

Characteristics of donors and recipients by Kidney Donor Profile Index group.

		KDPI				
	All	**0-20%**	**21-50%**	**51-85%**	**86-100%**	***p***
Donors, N	**107**	**19**	**38**	**41**	**9**	
Age, years	37 (15)	22 (5)	33 (10)	45 (13)	45 (26)	<0.001
Male gender	65	63	68	68	44	0.56
Ethnicity						0.03
White	64	53	66	73	33	
Black	8	5	11	2	33	
Hispanic	19	32	21	12	11	
Asian	7	10	0	10	22	
Other	2	0	2	2	0	
Blood type						0.25
A	27	37	24	32	0	
B	22	16	21	22	33	
O	50	42	55	44	67	
AB	2	5	0	2	0	
Height, cm	169 (19)	173 (6)	172 (14)	169 (18)	146 (42)	0.002
Weight, kg	79 (23)	76 (18)	81 (18)	80 (25)	74 (41)	0.72
Circulatory death	30	21	39	32	0	0.09
Cause of death						<0.001
Anoxia	44	42	45	44	44	
CVA/Stroke	24	0	8	44	56	
Head Trauma	30	52	45	12	0	
Other	2	5	3	0	0	
Terminal SCr, mg/dL	1.72 (1.49)	0.97 (0.71)	1.87 (1.75)	1.76 (1.41)	2.50 (1.38)	0.05
PHS increased risk	17	21	21	15	0	0.51
Hypertension history	37	0	18	66	67	<0.001
Diabetes history	7	0	0	10	44	<0.001
Smoking history	16	0	8)	29	22	0.007
Recipients, N	**134**	**22**	**52**	**50**	**10**	
Age, years	52 (16)	39 (15)	49 (15)	59 (13)	62 (14)	<0.001
Male gender	58	59	60	52	80	0.44
Duration of dialysis, years	3.7 (2.5)	3.2 (1.3)	4.0 (2.7)	3.8 (2.9)	4.4 (1.3)	0.36
History of previous transplant(s)	10	14	14	8	0	0.66
History of diabetes	33	14	29	42	50	0.06
Cold ischemia time, hours	29 (10)	24 (12)	31 (12)	28 (8)	28 (7)	0.05
Pumped	82	59	87	84	100	0.01
Delayed graft function	42	18	46	52	20	0.02

CVA, cerebrovascular accident; KDPI, Kidney Donor Profile Index; PHS, Public Health Service; SCr, serum creatinine.

Continuous variables are reported as mean (standard deviation), categorical variables as percentage.

None of the donors were hepatitis C positive, thus this data was not included.

Table 2:

Distribution of Kidney Donor Profile Index and 30-day serum creatinine based on histopathologic findings.

Histologic Component	Score	N	KDPI, %	p-value (KDPI)	30-day SCr*, mg/dL	p-value (30-day SCr)
ci or ct	0	96	42.8 (25.4)	<0.001	1.85 (0.93)	<0.001
	1	27	62.1 (18.5)		2.39 (1.53)	
	2	11	65.4 (21.5)		4.68 (2.46)	
	3	0	-		-	
ah	0	43	38.4 (27.3)	<0.001	1.86 (0.79)	<0.001
	1	44	41.3 (20.4)		1.79 (0.98)	
	2	28	60.4 (22.2)		2.42 (1.47)	
	3	19	70.9 (13.5)		3.39 (2.41)	
cv	0	60	40.2 (24.7)	0.002	2.02 (1.25)	0.20
	1	28	54.6 (24.2)		2.17 (1.52)	
	2	32	49.3 (24.3)		2.11 (1.34)	
	3	14	70.9 (16.6)		2.95 (1.93)	
GS	<20%	119	46.1 (25.3)	0.001	1.99 (1.20)	<0.001
	≥20%	15	68.6 (16.4)		3.60 (2.18)	

ah, arteriolar hyalinosis; ci, interstitial fibrosis; ct, tubular atrophy; cv, arterial intimal fibrosis; GS, glomerulosclerosis; SCr, serum creatinine.

Continuous variables are reported as mean (standard deviation).

p-values obtained via Fisher's exact test for categorical variables and ANOVA for continuous variables.

* One 30-day creatinine value is missing due to patient death within 30 days post-transplant.

Table 3:

Ordinal logistic regression modeling of Kidney Donor Profile Index groups based on histopathologic findings.

Histologic Component	Univariate Models			Multivariable Model		
	OR (95% CI)	p-value	c-statistic (95% CI)	OR (95% CI)	p-value	c-statistic (95% CI)
ci + ct ≥ 2	4.63 (2.21, 9.72)	<0.001	0.72 (0.64, 0.80)	1.43 (0.56, 3.62)	0.46	0.71 (0.66, 0.79)
ah ≥ 2	8.92 (4.13, 19.45)	<0.001	0.78 (0.71, 0.86)	6.21(2.66, 14.51)	<0.001	
cv ≥ 2	2.54 (1.29, 4.97)	0.007	0.64 (0.54, 0.73)	1.24 (0.60, 2.58)	0.56	
GS ≥ 20%	1.10 (1.05, 1.13)	<0.001	0.76 (0.67, 0.85)	1.05 (0.99, 1.12)	0.12	

ah, arteriolar hyalinosis; ci, interstitial fibrosis; CI, confidence interval; ct, tubular atrophy; cv, arterial intimal fibrosis; GS, glomerulosclerosis; OR, odds ratio.

Categorical outcome variable of Kidney Donor Profile Index groups defined as 0-20%, 21-50%, 51-85%, and 86-100%.

Table 4:

Linear regression modeling of Kidney Donor Profile Index based on histopathologic findings.

Histologic Component		Univariate Models			Multivariable Model		
		Coefficient	p-value	R^2	Coefficient	p-value	R^2
ci or ct	1	19.27	<0.001	0.13	2.77	0.64	0.31
	2	22.52	0.04		−6.82	0.49	
ah	1	2.90	0.55	0.23	3.04	0.53	
	2	21.97	<0.001		16.37	0.006	
	3	32.53	<0.001		22.07	0.009	
cv	1	14.41	0.009	0.14	8.80	0.11	
	2	9.05	0.085		1.92	0.72	
	3	30.66	<0.001		9.22	0.30	
GS *		0.98	<0.001	0.14	0.69	0.01	

ah, arteriolar hyalinosis; ci, interstitial fibrosis; ct, tubular atrophy; cv, arterial intimal fibrosis; GS, glomerulosclerosis.

* GS was treated as a continuous variable.

Table 5:

Prediction for histopathologic findings based on Kidney Donor Profile Index components.

	ci or ct	ah	cv	GS (%)
KDPI Components		**OR[a] (95% CI)**		**β[b] (95% CI)**
Age	1.07 (1.03, 1.11)	1.09 (1.06, 1.12)	1.07 (1.04, 1.10)	0.25 (0.13, 0.37)
Height	1.01 (0.98, 1.03)	1.03 (1.01, 1.05)	1.02 (0.99, 1.04)	0.02 (−0.08, 0.13)
Weight	1.01 (0.99, 1.03)	1.03 (1.01, 1.04)	1.01 (1.00, 1.03)	0.03 (−0.06, 0.11)
Ethnicity				
White	Baseline	Baseline	Baseline	Baseline
Black	0.66 (0.13, 3.38)	0.31 (0.08, 1.21)	0.93 (0.26, 3.23)	−0.53 (−7.59, 6.52)
Hispanic	0.86 (0.28, 2.68)	0.19 (0.07, 0.55)	0.74 (0.28, 1.98)	−3.41 (−8.47, 1.64)
Asian	3.77 (0.83, 17.06)	1.90 (0.42, 8.66)	3.66 (0.75, 17.90)	9.90 (2.47, 17.33)
Other	*	*	0.57 (0.48, 6.78)	−3.02 (−17.29, 11.24)
Cause of Death				
Anoxia	Baseline	Baseline	Baseline	Baseline
CVA/Stroke	4.20 (1.56, 11.30)	3.52 (1.38, 8.90)	4.12 (1.62, 10.43)	6.40 (1.55, 11.26)
Head Trauma	0.40 (0.11, 1.38)	0.64 (0.28, 1.44)	0.38 (0.15, 0.97)	−0.66 (−5.21, 3.90)
Other	*	0.40 (0.03, 5.11)	1.18 (0.08, 17.25)	−5.06 (−19.40, 9.28)
Terminal creatinine	0.95 (0.72, 1.26)	0.93 (0.73, 1.17)	0.98 (0.78, 1.22)	−0.14 (−1.49, 1.20)
Hypertension history	3.44 (1.46, 8.10)	7.00 (3.16, 15.50)	3.74 (1.77, 7.92)	6.41 (2.50, 10.33)
Diabetes history	4.13 (0.93, 18.21)	7.68 (2.10, 28.10)	1.46 (0.43, 4.89)	7.63 (0.22, 15.05)
Circulatory death	0.79 (0.31, 2.00)	0.92 (0.44, 1.94)	0.66 (0.31, 1.40)	−1.50 (−5.83, 2.83)

ah, arteriolar hyalinosis; ci, interstitial fibrosis; ct, tubular atrophy; cv, arterial intimal fibrosis; CVA, cerebrovascular accident; GS, glomerulosclerosis; KDPI, Kidney Donor Profile Index; OR, odds ratio.

[a]OR calculated by univariate ordinal logistic regression.

[b]Beta coefficient obtained by linear regression.

*n too small to calculate

Table 6:

Linear regression modeling of 30-day serum creatinine based on histopathologic findings and/or Kidney Donor Profile Index.

Models		**ci + ct ≥ 2**	**ci + ct ≥ 4**	**ah ≥ 2**	**cv ≥ 2**	**GS**	**KDPI**
Univariate	Coefficient	1.13	2.38	0.98	0.29	0.051	0.018
	p-value	<0.001	<0.001	<0.001	0.27	<0.001	<0.001
	R2	0.13	0.22	0.11	0.01	0.12	0.11
Multivariable Model #1	Coefficient	-	1.84	0.57	-	0.01	
	p-value	-	<0.001	0.02	-	0.33	
	R2	0.26					
Multivariable Model #2	Coefficient	-	1.89	0.36	-	0.006	0.01
	p-value	-	<0.001	0.16	-	0.66	0.04
	R2	0.29					
Multivariable Model #3	Coefficient	-	2.13	-	-		0.014
	p-value	-	<0.001	-	-		0.002
	R2	0.27					

ah, arteriolar hyalinosis; ci, interstitial fibrosis; ct, tubular atrophy; cv, arterial intimal fibrosis; GS, glomerulosclerosis; KDPI, Kidney Donor Profile Index.