Dual Kidney Allocation Score: A Novel Algorithm Utilizing Expanded Donor Criteria for the Allocation of Dual Kidneys in Adults

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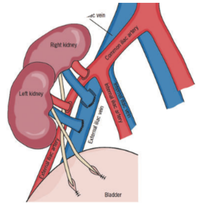
Background

Dual kidney transplantation (DKT) of expanded criteria donors is a cost intensive procedure to help increase the pool of available deceased organ donors. In studies to day, expanded criteria single kidney (eSKT) or dual kidney transplantation (DKT) have demonstrated equivalence, but a more rigorous allocation system is needed to optimize limited resources for improved operative outcomes.



Materials and Methods

We analyzed United Network for Organ Sharing (UNOS) data for 1,547 DKT and 26,381 eSKT performed between January 1994 and September 2013. Of thirty-six donor variables known at the time of listing, thirteen were significantly associated with graft survival by multivariable cox regression modeling. From these variables, we derived a weighted multivariable product score from calculated hazard ratios to model the benefit of transplantation as dual kidneys.

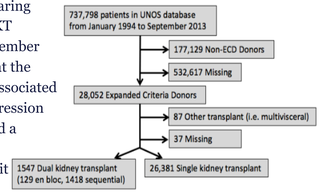


Figure 1: Exclusion criteria for analysis. UNOS: United Network for Organ Sharing; ECD: Expanded Criteria Donors

$$HR_{Rel} = HR_{eSKT} \div HR_{DKT}$$

$$DKAS = (HR_{Rel\text{-}Var1})^{Var1} \times (HR_{Rel\text{-}Var2})^{Var2} \times \ldots \times (HR_{Rel\text{-}Var})^{Var}$$

Results

Differences in graft survival between dual and single transplantation were strongly correlated with our allocation score. Donors with scores less than 2.1 transplanted as dual kidneys had a worsened median survival of 594 days (24%, p-value 0.031) and donors with scores greater than 3.9 had improved median survival of 1,107 days (71%, p-value 0.002). There were 17,733 eSKT (67%) and 1,051 DKT (67%) with scores in between these values and no differences in survival (p-value 0.676 and 0.185).

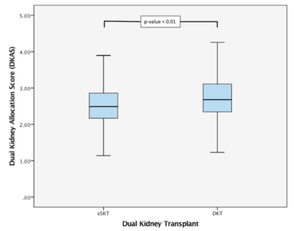


Figure 3: Box Plot Distribution of DKAS between eSKT and DKT. eSKT: expanded criteria single kidney transplant; DKT: Dual kidney transplant

Table 1: Factors associated with 5-year graft survival by multivariable cox proportional hazard model.

Donor Factor	Variable type	Missing (%)	ECD (±IQR, %)	B	SE	Wald	Exp (B)	*p*-value
Demographics								
Age (years)	Continuous	0 (0)	60 ± 9	0.024	0.002	195.576	1.024	<0.001
Gender—Male	Categorical	0 (0)	13629 (48.8)	0.06	0.021	7.864	1.062	0.005
Ethnicity—Black	Categorical	24 (0.1)	3260 (11.7)	0.148	0.032	21.553	1.160	<0.001
BMI (<18.5 kg/m²)	Categorical	368 (1.3)	588 (2.1)	0.191	0.066	8.231	1.210	0.004
Mechanism of Death—ICH	Categorical	17 (0.1)	22912 (82)	0.113	0.029	15.366	1.119	<0.001
Past Medical History								
Diabetes (0-5 years or unknown)	Categorical	234 (0.8)	2191 (7.8)	0.104	0.038	7.399	1.109	0.007
Diabetes (5-10 years)	Categorical	234 (0.8)	663 (2.4)	0.198	0.065	9.321	1.219	0.002
Diabetes (>10 years)	Categorical	234 (0.8)	643 (2.3)	0.18	0.066	7.463	1.197	0.006
Hypertension	Categorical	208 (0.7)	19423 (69.5)	0.109	0.024	19.641	1.115	<0.001
Cigarette use (>20 pack years)	Categorical	517 (1.9)	11743 (42)	0.078	0.021	13.893	1.081	<0.001
Laboratory Tests								
Terminal Creatinine (mg/dL)	Continuous	67 (0.24)	1.0 ± 0.5	0.02	0.007	8.070	1.020	0.005
BUN (mg/dL)	Continuous	67 (0.24)	15 ± 11	0.007	0.001	52.079	1.007	<0.001
Positive Hepatitis C Antibody Serology	Categorical	86 (0.3)	346 (1.2)	0.473	0.082	33.442	1.606	<0.001

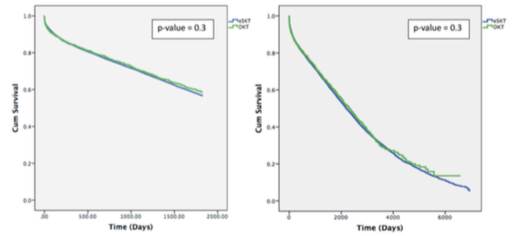
BMI: Body Mass Index; ICH: Intracranial hemorrhage; BUN: Blood Urea Nitrogen

Table 2: Hazard ratio for full follow up and subgroup analysis for eSKT and DKT.

Donor Factor	eSKT (n=26381) HR_{eSKT} (95% CI)	p-value	DKT (n=1547) HR_{DKT} (95% CI)	p-value	HR_{Rel}
Demographics					
Age (years)	1.027 (1.024-1.031)	<0.001	1.014 (1.001-1.027)	0.037	1.013
Gender—Male	1.070 (1.025-1.117)	0.002	1.010 (0.842-1.211)	0.915	1.059
Ethnicity—Black	1.172 (1.099-1.250)	<0.001	1.078 (0.839-1.383)	0.558	1.087
BMI (<18.5 kg/m²)	1.200 (1.047-1.375)	0.011	1.501 (0.973-2.315)	0.066	0.799
Mechanism of Death—ICH	1.122 (1.059-1.190)	<0.001	1.175 (0.933-1.479)	0.171	0.956
Past Medical History					
Diabetes (0-5 years or unk)	1.136 (1.052-1.227)	0.001	0.822 (0.594-1.138)	0.237	1.382
Diabetes (5-10 years)	1.212 (1.061-1.384)	0.005	1.333 (0.854-2.082)	0.206	0.909
Diabetes (>10 years)	1.169 (1.019-1.341)	0.027	1.516 (1.036-2.219)	0.032	0.771
Hypertension	1.114 (1.060-1.170)	<0.001	1.238 (1.014-1.513)	0.036	0.900
Cigarette use (>20 pack years)	1.098 (1.053-1.145)	<0.001	0.838 (0.698-1.007)	0.059	1.310
Laboratory Tests					
Terminal Creatinine (mg/dL)	1.018 (1.004-1.033)	0.014	1.055 (1.007-1.104)	0.023	0.965
BUN (mg/dL)	1.008 (1.006-1.010)	<0.001	1.000 (0.992-1.008)	0.959	1.008
Positive Hep C Ant Serology	1.634 (1.387-1.925)	<0.001	1.588 (0.747-3.373)	0.229	1.029

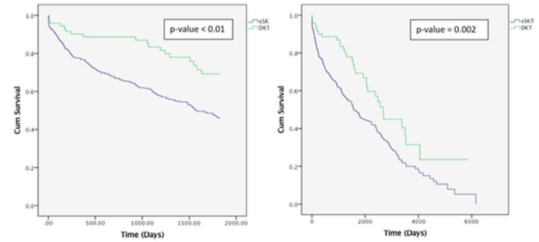
ECD: Expanded criteria donor; eSKT: expanded criteria single kidney transplant; DKT: dual kidney transplant; HR: Hazard Ratio

$$DKAS = 1.013^{Age} \times 1.059^{Male} \times 1.087^{Eth\text{-}Back} \times 0.799^{BMI<18.5} \times 0.956^{MOD\text{-}ICH} \times 1.382^{DM0\text{-}5} \times 0.909^{DM5\text{-}10} \times 0.771^{DM>10} \times 0.900^{HTN} \times 1.310^{Cig} \times 0.965^{Creat} \times 1.008^{BUN} \times 1.029^{HepCAb}$$



Years	0	1	2	3	4	5	10	15
DKT Events	19	248	334	420	489	545	719	741
DKT At Risk	1525	1167	1025	840	665	524	92	8
eSKT Events	335	4261	5836	7105	8325	9380	12232	12946
eSKT At Risk	25996	19632	16238	13356	10649	8323	1947	309

Figure 2: Kaplan-Meier comparison of eSKT vs. DKT graft survival for 5 year (right) and full follow up (left). p-value determined by log rank analysis. eSKT: expanded criteria single kidney transplant; DKT: dual kidney transplant



Years	0	1	2	3	4	5	10	15
DKT Events	0	7	8	11	14	18	30	31
DKT At Risk	71	62	53	47	36	30	6	1
eSKT Events	8	115	156	179	201	227	271	280
eSKT At Risk	508	339	265	218	174	125	18	2

Figure 5: Kaplan-Meier comparison of eSKT vs. DKT graft survival for 5 year (right) and full follow up (left) for DKAS values >3.9. p-value determined by log rank analysis. eSKT: expanded criteria single kidney transplant; DKT: dual kidney transplant

Conclusions

Our analysis shows that current allocation does not optimize the benefit of dual transplantation and we provide a new outcomes-based risk score to standardize organ allocation for dual kidney transplantation.

Table 3: Median survival for donors stratified by DKAS.

DKAS	N (%)		Median Survival Days (95% CI)		p-value	DKT Median Survival Difference (95% CI)
	eSKT	DKT	eSKT	DKT		
< 2.1	5200 (20)	153 (10)	2446 (2342-2549)	1852 (1234-2469)	0.031	**-24% (-50 – 1.2)**
2.1-2.7	11620 (44)	595 (38)	2296 (2231-2360)	2396 (2102-2690)	0.676	--
2.7-3.3	6153 (23)	456 (29)	2007 (1920-2093)	2119 (1870-2368)	0.185	--
3.3-3.9	1689 (6.4)	178 (12)	1920 (1782-2795)	2473 (1997-2949)	0.005	**+29% (2.3 – 55)**
> 3.9	516 (2.0)	71 (4.6)	1569 (1277-1861)	2676 (2292-3060)	0.002	**+71% (30 – 111)**

Median survival reported in days; derived from Kaplan-Meier analysis. P-value derived from log rank analysis. DKAS: Dual Kidney Allocation Score; eSKT: expanded criteria single kidney transplant; DKT: dual kidney transplant; SE: Standard error

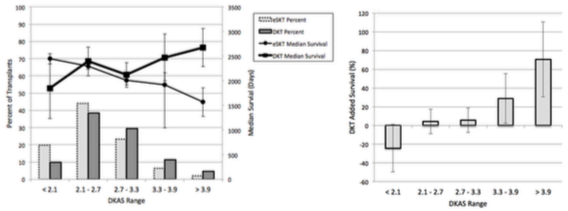


Figure 4: Improved Median Survival when stratified by DKAS. Left: DKT and eSKT transplants (bars) and median graft survival (lines) for donors stratified by DKAS value. Right: Differences in percent median survival for DKT transplants over SKT for donors stratified by DKAS value. Error bars represent 95% confidence interval. DKT: Dual Kidney Transplant; eSKT: Single Kidney Transplant; DKAS: Dual Kidney Allocation Score.

Acknowledgements and References

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Ekser B, Furian L, Broggiato A, Silvestre C, Pierobon ES, Baldan N, et al. Technical aspects of unilateral dual kidney transplantation from expanded criteria donors: Experience of 100 patients. Am J Transplant. 2010;10(9):2000–7