Factors of Acute Kidney Injury Donors Affecting Outcomes of Kidney Transplantation From Deceased Donors

Jin Ah Kwon[a], Hojong Park[a,*], Sang Jun Park[a], Hong Rae Cho[a], Minsu Noh[a], Eun Kyoung Kwon[a], Gi Ppeum Kim[a], Kyung Sun Park[b], Jongha Park[b], and Jong Soo Lee[b]

[a]Department of Surgery, Ulsan University Hospital, University of Ulsan College of Medicine, Ulsan, South Korea; and [b]Division of Nephrology, Department of Internal Medicine, Ulsan University Hospital, University of Ulsan College of Medicine, Ulsan, South Korea

ABSTRACT

Background. This study aimed to investigate the outcomes of kidney transplantation (KT) from deceased acute kidney injury (AKI) donors and analyzed the factors affecting these outcomes.

Methods. All patients who underwent KT from deceased donors at our institution from 1998 to 2016 were retrospectively reviewed. Recipients were divided into the AKI and non-AKI donor groups. We analyzed delayed graft function (DGF), serum creatinine levels at 1 month and 1 year after KT, cold ischemia time, donors' initial and terminal serum creatinine levels, Kidney Donor Profile Index, and patient and graft survival in each group.

Results. Of 181 recipients, 30 received kidneys from 21 AKI donors, whereas the remaining 151 received kidneys from donors without AKI. DGF more frequently developed in the AKI donor group than in the non-AKI donor group (40% vs 7.28%; $P = .001$). Allograft functions at 1 month and 1 year after KT did not differ between the AKI and non-AKI donor groups (1 month: $P = .469$; 1 year: $P = .691$). Factors affecting DGF were recipient weight and donor AKI. Recipient factors affecting graft function at 1 year were recipient height, length of hospital stay, serum creatinine levels at 1 month and 6 months, and biopsy-proven acute rejection. Older donor age was the only donor factor that affected graft function at 1 year.

Conclusion. KT from deceased AKI donors showed a higher DGF rate but favorable patient and graft survival and graft functions. Donor AKI and recipient weight affected DGF, and only older donor age affected graft function at 1 year.

KIDNEY transplantation (KT) improves long-term survival and quality of life in patients with end-stage renal disease compared with dialysis [1]. In Korea, many patients on dialysis are registered for KT, and the time to allocation is approximately 90 ± 34 months after their registration for KT [2]. Physicians caring for donors occasionally transplant kidneys from expanded criteria donors (ECDs) or acute kidney injury (AKI) donors to increase the donor pool.

AKI is defined as an abrupt reduction in kidney function, resulting in the retention of urea and other nitrogenous waste products. AKI is thought to be a reversible condition; nevertheless, most centers are reluctant to use kidneys from AKI donors despite donor shortage owing to uncertainty about successful transplants, even though these kidneys are potentially viable [3]. Furthermore, there exists no established rule on whether kidneys from deceased AKI donors could be transplanted or not. However, recent studies reported the safety and acceptable short-term and long-term outcomes of KT from deceased AKI donors [4–13]. The present study aimed to investigate the outcomes of KT from deceased AKI donors and analyze the factors that could affect outcomes.

*Address correspondence to Hojong Park, MD, Department of Surgery, Ulsan University Hospital, 877 Bangeojinsunhwan-doro, Dong-gu, Ulsan 44033, South Korea. Tel: (+82) 52 250 7109; Fax: (+82) 52 250 7350. E-mail: hjpark@uuh.ulsan.kr

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MATERIAL AND METHODS

Patients and Clinical Data

All patients who underwent transplantation of deceased donor kidneys at our institution from January 1998 to December 2016 were retrospectively reviewed. Demographic details of donors and recipients were identified from medical records.

Patients were divided into 2 groups—namely, an AKI donor group and a non-AKI donor group. AKI was defined using the Kidney Disease: Improving Global Outcomes criteria [14] as (a) an increase in serum creatinine level $\geq$ 0.3 mg/dL within 48 hours; or (b) an increase in serum creatinine level to $\geq$ 1.5 times the baseline value, which is known or presumed to have occurred within the prior 7 days; or (c) urine volume $<$ 0.5 mL/kg/h for 6 hours. The AKI donor group consisted of recipients who received kidneys from AKI donors, whereas the non-AKI donor group consisted of recipients who received kidneys from non-AKI donors. Recipients were assigned to either the ECD group or non-ECD group. ECDs were defined as donors aged $\geq$ 60 years or donors aged $>$ 50 years with at least 2 of the following: history of hypertension, serum creatinine level $>$ 1.5 mg/dL, or cerebrovascular accident as the cause of death. The ECD group consisted of recipients who received kidneys from ECDs, whereas the non-ECD group consisted of recipients who received kidneys from non-ECDs.

Antithymocyte globulin or basiliximab was selected as the immunosuppressant for induction. Maintenance therapy involved a combination of a calcineurin inhibitor, mycophenolate mofetil, and corticosteroids. We analyzed the donors' characteristics (age, sex, comorbidities, serum creatinine level at admission, terminal creatinine level, Kidney Donor Risk Index, Kidney Donor Profile Index [KDPI], zero biopsy results) and recipients' data (sex, age, weight, height, length of hospital stay, cause of end-stage renal disease, diabetes, hypertension, duration of renal replacement therapy, BK virus nephropathy, panel-reactive antibody, cold ischemia time (CIT), and number of HLA mismatches).

Clinical Outcomes

Outcome was evaluated by analyzing delayed graft function (DGF); serum creatinine levels at 1 month, 6 months, and 1 year after KT; biopsy-proven acute rejection; graft survival; death; and follow-up duration. Graft survival was compared between the ECD and non-ECD groups and determined from the date of transplantation until either death, return to dialysis, or end of the study period. DGF was defined as the need for at least one hemodialysis session during the first week after KT.

During the study period, preimplantation biopsy was performed starting from 2012. The pathology results of the biopsy were divided as normal, acute tubular necrosis (ATN), and chronic change. We examined the effect of the biopsy results on graft survival. Factors affecting DGF and graft function at 1 month and 1 year were analyzed.

Statistical Analysis

Statistical analysis was performed using R version 3.5.1 (R Foundation for Statistical Computing, Vienna, Austria). The Mann–Whitney U test and χ^2 test were used for continuous and categorical variables, respectively. Kaplan-Meier curves and estimates of survival data were used to account for differing survival times. Univariate and multivariate logistic regression analyses were used for DGF, whereas univariate and multivariate linear regression analyses were used for serum creatinine levels at 1 month and 1 year. Statistical significance was set at $P < .05$.

Table 1. Donors' Characteristics

Donor	Non-AKI (n = 151)	AKI (n = 30)	*P* Value
Age, y	44.34 ± 15.61	47.30 ± 12.94	.454
Sex, n (%)			
Female	40 (26.49)	7 (23.33)	.895
Male	111 (73.51)	23 (76.67)	
Weight, kg	64.09 ± 11.61	70.77 ± 14.43	.048
Diabetes mellitus, n (%)	13 (8.72)	4 (13.33)	.657
Hypertension, n (%)	42 (28.19)	9 (30.00)	.999
Serum creatinine, mg/dL			
At admission	1.02 ± 0.28	1.40 ± 0.93	.005
Peak	1.25 ± 0.49	3.46 ± 1.65	< .001
Terminal	0.84 ± 0.29	2.91 ± 1.63	< .001
Kidney Donor Profile Index (%)	60.46 ± 26.04	68.90 ± 23.21	.097
Kidney Donor Risk Index	1.19 ± 0.35	1.34 ± 0.44	.099
Zero biopsy, n (%)			.013
Normal	55 (78.57)	9 (45.00)	
Acute tubular necrosis	7 (10.00)	6 (30.00)	
Chronic change	8 (11.43)	5 (25.00)	
ECD, n (%)			.892
Non-ECD	90 (60.00)	17 (56.67)	
ECD	60 (40.00)	13 (43.33)	

Continuous variables are presented as mean ± standard deviation.
Abbreviations: AKI, acute kidney injury; ECD, expanded criteria donor.

RESULTS

Donors' characteristics are summarized in Table 1. Of 181 recipients, 30 received kidneys from 21 AKI donors (AKI donor group), whereas the remaining 151 received kidneys from donors without AKI (non-AKI donor group). A total of 73 patients received kidneys from ECDs. The mean age of non-AKI and AKI donors was 44.34 ± 15.61 and 47.30 ± 12.94 years, respectively ($P = .454$). Furthermore, the mean KDPI was 60.46% ± 26.04% and 68.90% ± 23.21% in the non-AKI and AKI donor groups, respectively ($P = .097$). No differences in donors' age and sex, diabetes, hypertension, KDPI, and number of ECDs were observed between the non-AKI and AKI donor groups. The AKI donor group had significantly higher donor weight ($P = .048$) and serum creatinine level at admission, peak creatinine level, and terminal creatinine level than the non-AKI donor group ($P = .005$, $P < .001$, and $P < .001$, respectively). Zero biopsy indicated a higher percentage of normal kidney tissues (78.57% vs 45%) and a lower percentage of tissues exhibiting ATN and chronic change in the non-AKI donor group (ATN: 10% vs 30%, chronic change: 11.43% vs 25%) ($P = .013$).

Table 2 presents recipients' characteristics. No difference in all factors except for age was noted between the non-AKI and AKI donor groups, with recipients in the AKI donor group being significantly older ($P = .044$).

Clinical outcomes of recipients are presented in Table 3. Upon analyzing clinical outcomes, 23 patients with DGF were identified, and a higher percentage of DGF was observed in the AKI donor group (7.28% vs 40%, $P = .001$). However, there was no difference in serum creatinine levels at 1 month, 6 months, and 1 year between both groups.

Table 2. Recipients' Characteristics

Recipient	Non-AKI (n = 151)	AKI (n = 30)	*P* Value
Age, y	46.90 ± 11.65	51.47 ± 11.40	.044
Sex, n (%)			.521
Female	68 (45.03)	11 (36.67)	
Male	83 (54.97)	19 (63.33)	
Diabetes mellitus, n (%)	43 (28.48)	13 (43.33)	.164
Hypertension, n (%)	114 (75.50)	25 (83.33)	.489
Weight, kg	61.55 ± 11.91	61.70 ± 13.41	.957
Height, cm	163.63 ± 8.88	164.70 ± 8.96	.507
Cause of ESRD, n (%)			.751
Glomerulonephritis	35 (23.18)	6 (20.00)	
Diabetes mellitus	34 (22.52)	9 (30.00)	
Hypertension	11 (7.28)	3 (10.00)	
Others	71 (47.02)	12 (40.00)	
Retransplant, n (%)	8 (5.3)	3 (10)	.458
Duration of dialysis, y	7.24 ± 5.24	5.83 ± 4.19	.155
Panel-reactive antibody, n (%)			.358
Negative	69 (45.70)	18 (60.00)	
Positive	42 (27.81)	6 (20.00)	
No data	40 (26.49)	6 (20.00)	
Number HLA mismatches	3.75 ± 1.57	3.63 ± 1.47	.513
Cold ischemia time, min	307.60 ± 173.27	314.70 ± 186.79	.749
Length of hospital stay, d	27.11 ± 11.10	31.67 ± 16.21	.125
ABO, n (%)			.558
A	48 (31.79)	11 (36.67)	
AB	20 (13.25)	6 (20.00)	
B	42 (27.81)	8 (26.67)	
O	41 (27.15)	5 (16.67)	
Cytomegalovirus IgG, n (%)			.602
Negative	1 (0.66)	0 (0.00)	
Positive	138 (91.39)	29 (96.67)	
No data	12 (7.95)	1 (3.33)	
BK virus nephropathy, n (%)			.260
Negative	147 (97.35)	28 (93.33)	
Positive	4 (2.65)	2 (6.67)	

Continuous variables are presented as mean ± standard deviation.
Abbreviations: AKI, acute kidney injury; ESRD, end-stage renal disease.

We analyzed the recipient and donor factors that could affect clinical outcomes using univariate and multivariate analyses (Tables 4 and 5). The factors affecting DGF were recipient weight and donor AKI; DGF more often developed when the recipient was heavier and the donor had AKI. We analyzed the factors that could affect serum

Table 3. Clinical Outcomes

	Non-AKI (n = 151)	AKI (n = 30)	*P* Value
Delayed graft function, n (%)			.001
Negative	140 (92.72)	18 (60.00)	
Positive	11 (7.28)	12 (40)	
Serum creatinine (mg/dL)			
at 1 month	1.25 ± 0.45	1.30 ± 0.43	.469
at 6 months	1.35 ± 0.79	1.18 ± 0.36	.402
at 1 year	1.38 ± 1.06	1.24 ± 0.40	.691
Biopsy-proven acute rejection, n (%)			.34
Negative	116 (76.82%)	26 (86.67%)	
Positive	35 (23.18%)	4 (13.33%)	
Graft failure, n (%)	8 (5.30%)	2 (6.67%)	.999
Death, n (%)	3 (1.99%)	2 (6.67%)	.413
Graft survival (months)	67.81 ± 42.08	53.73 ± 47.44	.036
Follow-up period (months)	69.42 ± 42.97	54.63 ± 48.84	.033

Continuous variables are presented as mean ± standard deviation.
Abbreviation: AKI, acute kidney injury.

Table 4. Multivariate analysis of Factors Affecting Clinical Outcomes (Recipients)

	DGF				sCr at 1 Mo				sCr at 1 Y			
	OR	Lower	Upper	*P* Value	Coef.	Lower	Upper	*P* Value	Coef.	Lower	Upper	*P* Value
Recipient												
Age												
Sex (female)												
(male)					0.158	0.073	0.244	< .001				
Height									0.004	0.02	0.007	.002
Weight	1.039	1.002	1.080	.041	0.007	0.004	0.011	< .001				
PRA												
DM												
DGF no												
yes					0.188	0.076	0.299	.001				
Length of hospital stay									0.003	0.000	0.005	.022
sCr at 1 mo									0.132	0.026	0.237	.015
sCr at 6 mo									0.614	0.517	0.710	< .001
Biopsy-proven AR (within 1 y)									0.075	0.009	0.141	.026
Cold ischemia time					0.033	0.011	0.054	.003				
Number of HLA mismatches					0.037	0.012	0.062	.004				

Abbreviations: AR, acute rejection; DGF, delayed graft function; DM, diabetes mellitus; OR, odds ratio; PRA, panel-reactive antibody; sCr, serum creatinine.

creatinine level at 1 month after transplantation. The factors affecting high serum creatinine level at 1 month were male sex, heavier recipient weight, more DGF, longer CIT, higher number of HLA mismatches, and higher KDPI. The recipient factors that affected graft function at 1 year after transplantation were recipient height, length of hospital stay, serum creatinine levels at 1 month and 6 months, and biopsy-proven acute rejection. Older donor age was the only donor factor that affected graft function at 1 year; the older the donor, the higher the serum creatinine level was at 1 year after transplantation.

We analyzed patient and graft survival in AKI and non-AKI kidney transplant recipients and observed no statistically significant differences between both groups (Fig 1). The graft survival rate in AKI and non-AKI kidney transplant recipients was 96.6% and 98.7% at 1 year, 96.6% and 94.8% at 5 years, respectively ($P = .532$). The patient survival rate in AKI and non-AKI kidney transplant recipients was 96.6% and 99.3% at 1 year, 93.1% and 97.7% at 5 years, respectively ($P = .116$). We also compared graft survival in ECD and non-ECD kidney transplant recipients between the AKI and non-AKI donor groups and observed no statistically significant differences between both groups (Figs 2 and 3).

DISCUSSION

This study on KT from deceased AKI donors showed favorable outcomes. When the kidneys from AKI donors were transplanted, DGF developed more frequently in the AKI donor group. However, no difference in serum creatinine levels at 1 month, 6 months, and 1 year was observed between the AKI and non-AKI donor groups. The factors affecting DGF were recipient weight and donor AKI; DGF more often developed when the recipient was heavier and the donor had AKI.

Table 5. Multivariate Analysis of Factors Affecting Clinical Outcomes (Donors)

	DGF				sCr at 1 Mo				sCr at 1 Y			
	OR	Lower	Upper	*P* Value	Coef.	Lower	Upper	*P* Value	Coef.	Lower	Upper	*P* Value
Donor												
Age									0.002	0.001	0.004	< .001
Sex (female)												
(male)												
Weight												
Donor AKI no												
yes	8.869	3.335	24.48	< .001								
HTN												
KDPI					0.004	0.002	0.005	< .001				
KDRI												
ECD no												
yes												
Zero biopsy												

Abbreviations: AKI, acute kidney injury; DGF, delayed graft function; ECD, expanded criteria donor; HTN, hypertension; KDPI, Kidney Donor Profile Index; KDRI, Kidney Donor Risk Index; OR, odds ratio; sCr, serum creatinine.

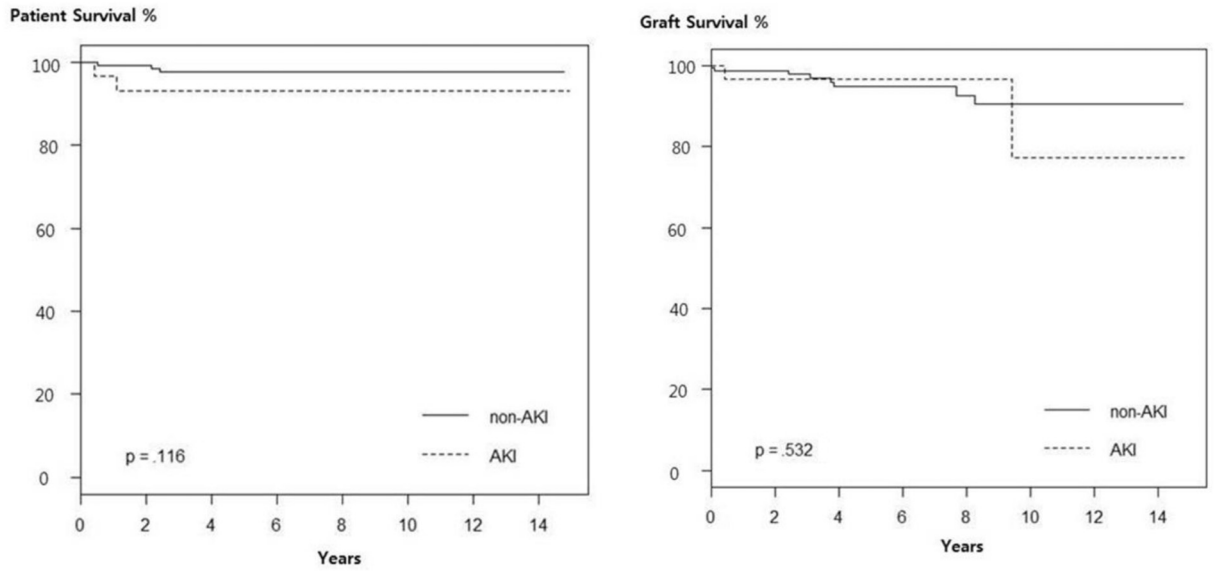

Fig 1. Kaplan-Meier curve illustrating patient and graft survival in AKI versus non-AKI kidney transplant recipients. No significant difference was observed between the 2 groups. AKI, acute kidney injury.

The results of this study are almost similar to those of previous reports. Heilman et al [10] divided 162 AKI donor transplant recipients into the standard criteria donor group and ECD group and compared the 2 groups. Although DGF occurred more often in the AKI donor group, no difference in graft function was observed between the standard criteria donor and ECD groups at 1 year [10]. Lee et al [5] analyzed 156 deceased donors and divided them into the AKI and non-AKI donor groups. DGF developed more frequently in the AKI donor group; however, there was no difference in DGF according to AKI stage, as defined by the Acute Kidney Injury Network criteria. Moreover, no difference in graft function at 1 year was noted. They suggested that long-term outcome of non-transplanted kidneys would not be affected by AKI, which could also be applied to the outcome of allografts from AKI donors [5]. Conversely, some reports

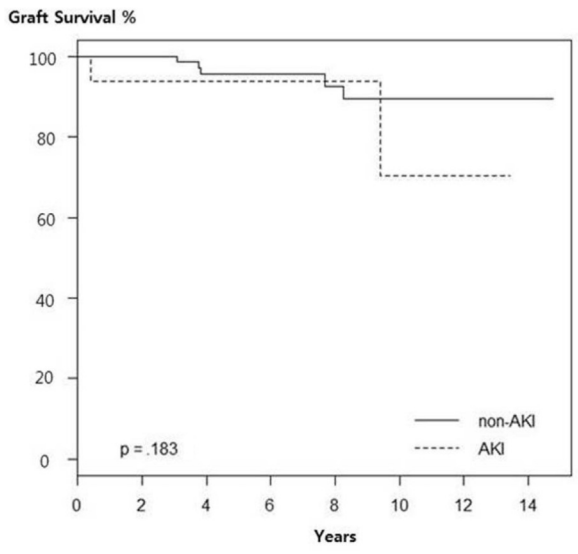

Fig 2. Kaplan-Meier curve illustrating graft survival in non-ECD kidney transplant recipients between the AKI and non-AKI donor groups. No significant difference was observed between the 2 groups. AKI, acute kidney injury; ECD, extended criteria donor.

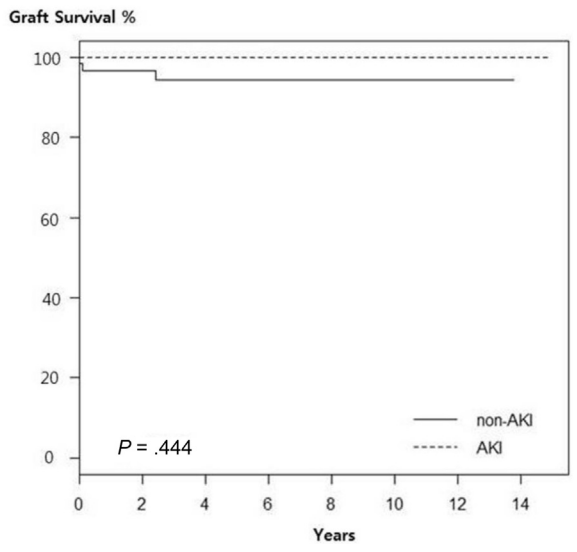

Fig 3. Kaplan-Meier curve illustrating graft survival in ECD kidney transplant recipients between the AKI and non-AKI donor groups. No significant difference was observed between the 2 groups. AKI, acute kidney injury; ECD, extended criteria donor.

suggested comparable outcomes for KT from deceased AKI donors, but they recommended that caution should be exercised for stage 3 AKI donors [15,16].

Some studies reported poor graft survival for allografts from AKI donors [4,17]. However, most studies have shown a higher DGF rate but acceptable patient and graft survival and graft functions for kidneys from AKI donors [4–13]. There seems to be a difference in opinion on graft function according to AKI stage. In this study, evaluation of graft function according to AKI stage was not separately performed, as injury severity was not constantly related to Acute Kidney Injury Network stage.

AKI in deceased donors mainly occurs during their stay at the intensive care unit. Prerenal azotemia, rhabdomyolysis, and the use of nephrotoxic agents and high-dose inotropic agents were thought to be the main causes of AKI in these potential donors [6]. AKI is often caused by ischemic and nephrotoxic insult but is reversible [4,17]. Ischemic injury primarily leads to proximal tubular damage. Proximal tubular regeneration results from the coordination of cellular proliferation, migration, and hypertrophy of a new population of proximal tubular cells [4,18].

A unique aspect of our study is that affecting factors were identified using multivariate analysis. Factors affecting DGF and serum creatinine levels at 1 month and 1 year were analyzed. The factors that affected DGF were recipient weight and donor AKI; DGF more often developed when the recipient was heavier and when the donor had AKI. Factors affecting high serum creatinine level at 1 month were male sex, heavier recipient weight, more DGF, longer CIT, higher number of HLA mismatches, and higher KDPI. The recipient factors that affected graft function at 1 year were recipient height, length of hospital stay, serum creatinine levels at 1 month and 6 months, and biopsy-proven acute rejection. Older donor age was the only donor factor that affected graft function at 1 year.

Other studies have reported on affecting factors. A previous study indicated donor age as an important factor affecting DGF [12]. Jun et al [19] suggested that the Kidney Donor Risk Index could be used as a predictor of short-term clinical outcome after KT from deceased AKI donors. In our study, biopsy-proven acute rejection certainly affected the results at 1 year, which had reported various results in the literature. Orlando et al [20] reported the effect of prolonged CIT on the outcome of AKI renal grafts and stratified the outcomes according to the duration of CIT. According to increasing CIT, DGF rates were statistically significantly increased. Nonetheless, death-censored graft survival was not adversely affected by prolonged CIT. In our study, the serum creatinine level at 1 month was higher with longer CIT. However, prolonged CIT did not affect the serum creatinine level at 1 year.

In our experience, it is judged that serum creatinine level at admission is important when selecting an acceptable kidney. We have recently performed preimplantation zero biopsy; nevertheless, checking frozen biopsy samples can be difficult, and it is questionable how accurately chronic change can be detected by examining them. According to Heilman et al [21], the role of preimplantation histopathology is an area of debate. Which histologic parameters (glomerulosclerosis, interstitial fibrosis, arteriosclerosis, hyaline arteriolosclerosis) are the most important for graft function and survival remain an unsettled issue [21]. Kayler et al [4] suggested that an elevated creatinine level might be more likely to indicate underlying parenchymal chronic changes that are not reversible in ECD. Most importantly, considerable caution is thought to be necessary for patients and their caregivers.

The present study has several limitations. First, this study was a retrospective, single-institution study, and selection bias was unavoidable. Second, there were various causes of AKI, but the exact cause had not been analyzed. Third, a small number of patients were included in the study. Fourth, our study had a relatively short follow-up period; with long-term follow-up, there may be many additional variables to consider such as BK virus nephropathy and acute or chronic rejection.

CONCLUSIONS

KT from deceased AKI donors showed a higher DGF rate but favorable patient and graft survival and graft functions. The factors affecting DGF were donor AKI and recipient weight, whereas the factors affecting graft function at 1 year were recipient height, length of hospital stay, serum creatinine levels at 1 month and 6 months, and biopsy-proven acute rejection. Older donor age was the only donor factor that affected graft function at 1 year. Kidneys from AKI donors can be transplanted with careful prediction, and this may be an effective approach to increase the donor pool and shorten the waiting list.

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