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Evaluating non-utilization of deceased donor kidneys in Korea

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Considering the low deceased donation rates despite increasing rates of end-stage kidney disease in Asia, minimizing donor kidney discard is important. This study aimed to investigate the current situation of donor kidney discard in Korea. This nationwide study included deceased donor kidneys of candidates for kidney transplantation (KT) between 2013 and 2018 in Korea. Kidney discard was defined as no procurement or discarding after procurement of kidneys. Among 5592 deceased donor kidneys, no-procurement, single-procurement, and double-procurement were 385, 63, and 5144, respectively. All unilaterally procured kidneys, except for one, were transplanted. Bilaterally procured kidneys were accompanied by two KT (n = 5058), one KT with the other kidney discarded (n = 33), or both kidneys discarded (n = 20). The overall kidney discard rate was 7.9%. The cause of non-procurement was universally organ damage, and the common causes of kidney discard after procurement were organ damage, absence of available candidates, and malignancy. While the kidney donor profile index was higher in the discarded group than in the KT group, a large overlap was observed. The risk factors for kidney non-utilization were old age, hypertension, diabetes mellitus, high serum creatinine levels, low hemoglobin levels, and non-cerebrovascular causes of death. KT using contralateral kidney in the discard group showed graft failure and mortality rates comparable to those of KT in the no-discard group. The discard rate of deceased donor kidneys was low, and the discard of one kidney does not necessarily rule out the utilization of contralateral kidney, especially in Korea with a long waiting time.

Keywords Deceased donor kidney transplantation, Donor kidney discard, Graft outcome, Kidney donor profile index, Risk factor, Waiting time

Kidney transplantation (KT) has a significant survival advantage and better quality of life compared with dialysis[1]. The incidence of end-stage kidney disease and its increasing rates are higher in Asian countries than in Western countries; for example, 18.8 per million population (pmp) in Korea[2]. However, deceased donation rates in Asian countries are much lower than those in Western countries; for example, the donation rate in Korea was 8.56 pmp, whereas that in the United States (US) and Spain were 41.60 and 40.80 pmp in 2021, respectively[3]. Donors per death and donors per eligible death in Korea were 1,608 and 2,242 per million death (pmd) in 2019, which is lower than those in the US (4,314 and 5,567 pmd) and Spain (5,569 and 7,063 pmd)[1,3–6]. Consequently, the number of people waiting for KT in Korea continues to increase steadily, from 12,463 in 2012 to 31,055 in 2021. In parallel, the average waiting time for Korean deceased donor kidney transplant (DDKT) patients has increased steadily, from 1,955 days in 2017 to 2,275 days in 2021.

The discrepancy between the demand and supply of deceased donor kidneys has led to the utilization of expanded criteria donor (ECD) kidneys with a high kidney donor profile index (KDPI)[7,8]. The ECD DDKT has shown a lower long-term mortality risk than remaining on dialysis while wait-listing for standard-criteria donor DDKT in selected subgroups of wait-listed patients[9,10]. France has attempted to aggressively increase the number of DDKTs using kidneys with high KDPI[11]. The Eurotransplant Senior Program uses kidneys from donors aged > 65 years, allocates them to waitlisted patients of similar age, and has similar graft and patient survival rates with decreased waiting times compared to the standard allocation program[12].

For the maximal utilization of deceased donors with active utilization of ECD kidneys, the discarding of deceased donor kidneys should be minimized. However, the discard rate of deceased donor kidneys in Western countries remains significant, increasing from 17.9% in 2011 to 26.7% in 2022 in the US[13]. The risk factors for discard were old age, high body mass index (BMI), diabetes mellitus (DM), and hypertension[13]. The discard rates were also higher in kidneys from donation after circulatory death (DCD, 33.9%) and with a KDPI ≥ 85%

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(71.3%)[13]. The increasing trend of kidney discard could be attributed to the aging population and increased prevalence of DM and obesity[14]. Considering the present organ shortage, investigating the current situation of kidney discards and the associated risk factors in Korea is necessary. This study aimed to address this issue using the Korean national database, and compared the post-transplant outcomes of KTs that used the contralateral kidney and discarded the other kidney with KTs that used both kidneys.

Results

Current status of kidney discards

The annual proportion of kidney non-utilization, including both non-procurement and post-procurement discards, remained similar (6–10%) from 2013 to 2018 in Korea (Fig. 2A). The total number of kidneys that were not procured for transplant ($n = 385$) was higher than those that were discarded after procurement ($n = 54$), which included discarding of both kidneys ($n = 20$) and one kidney ($n = 34$) (Fig. 1; Table 1).

The cause of non-procurement was universally organ damage, where the Korean kidney donor risk index (K-KDRI) and terminal serum creatinine levels were higher than those of other causes of non-procurement (Table 1). For discard after procurement, organ damage was the most common cause, followed by a lack of available recipients, probable concurrent malignancy in the kidneys or other sites, and anatomical abnormalities (Table 1).

Baseline clinical characteristics of the kidney non-utilization group compared with the kidney transplantation group

Baseline clinical characteristics of deceased donor kidneys were compared between the non-utilization group ($n = 439$) and transplantation group ($n = 5153$) (Table 2). The transplantation group was younger (47.0 vs. 50.6 years), and had lower rates of DM (10.1% vs. 30.3%), or hypertension (24.4% vs. 45.1%) than those observed within the non-utilization group ($P < 0.001$). Transplanted kidneys were more procured from donors who died from cerebrovascular accidents (CVA), were smokers, had higher hemoglobin levels (10.3 vs. 9.5 g/dL), had lower creatinine levels (1.5 vs. 3.7 mg/dL), and with lower Korean KDPI (K-KDPI) scores (43.6 vs. 64.9) as well as lower US-KDPI scores (74.5 vs. 88.4) than those observed with discarded kidneys ($P < 0.001$).

Donor-related risk factors affecting kidney non-utilization

When the numbers of unfavorable donor characteristics were compared, the number for the non-utilization group was 3.22 ± 1.70 (mean ± standard deviation), which was higher than that of the transplantation group

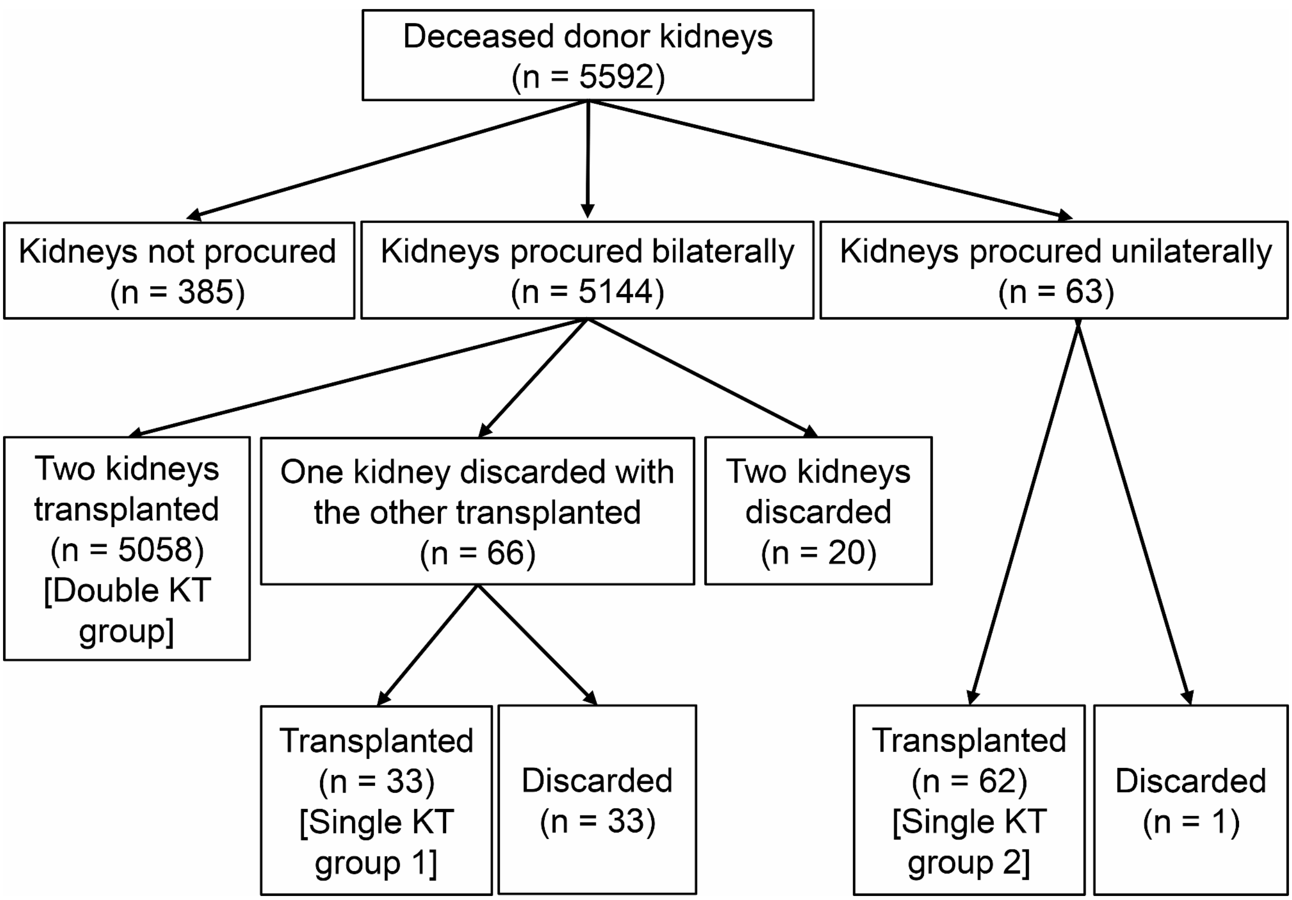

Fig. 1. Study profile. KT, kidney transplantation.

	Organ damage	No available recipient	Malignancy	Anatomical abnormality	Extended ischemia	
N (%)	421 (95.9)	7 (1.6)	7 (1.6)	3 (0.7)	1 (0.2)	*P* value
Non-utilization type						< 0.001
Double discard after procurement	16	0	4	0	0	
Single discard	20	7	3	3	1	
No procurement	385	0	0	0	0	
Organ quality						
K-KDRI	1.36 ± 0.34	1.17 ± 0.31	1.13 ± 0.03	1.04 ± 0.22	2.23	0.038
K-KDPI	64.18 ± 28.79	54.71 ± 29.96	53.75 ± 3.77	43.66 ± 24.58	99	0.407
Terminal Cr (mg/dL)	3.92 ± 2.68	2.19 ± 1.70	1.36 ± 0.58	2.41 ± 2.22	0.58	0.011

Table 1. Causes of kidney discard according to discard type and organ quality. Continuous variables are displayed as mean ± standard deviation. N, number; K-KDRI, Korean kidney donor risk index; K-KDPI, Korean kidney donor profile index; Cr, serum creatinine levels.

Variables	Transplantation (*N* = 5153)	Non-utilization (*N* = 439)	*P* value
Age (year), mean ± SD	47 ± 14.7	50.6 ± 15.4	< 0.001
Sex (female), N (%)	1672 (32.4%)	149 (34.0%)	0.556
BMI (kg/m^2), mean ± SD	23.5 ± 3.7	23.9 ± 4.0	0.017
Hypertension, N (%)	1258 (24.4%)	198 (45.1%)	< 0.001
Diabetes mellitus, N (%)	519 (10.1%)	133 (30.3%)	< 0.001
HBsAg, N (%)	94 (1.8%)	0 (0%)	0.008
Anti-HCV, N (%)	10 (0.2%)	0 (0%)	0.737
Death due to CVA, N (%)	2226 (43.2%)	167 (38.0%)	< 0.001
CPR, N (%)	2462 (47.8%)	219 (49.9%)	0.424
Smoker, N (%)	2381 (46.2%)	159 (36.2%)	< 0.001
Hb (g/dL), mean ± SD	10.3 ± 16.4	9.5 ± 1.6	< 0.001
Serum creatinine levels just before procurement (mg/dL), mean ± SD	1.5 ± 1.2	3.7 ± 2.5	< 0.001
US-KDRI	1.5 ± 0.5	1.9 ± 0.7	< 0.001
US-KDPI	74.5 ± 21.8	88.4 ± 16.3	< 0.001
K-KDRI	1.1 ± 0.3	1.4 ± 0.4	< 0.001
K-KDPI	43.6 ± 25.1	64.9 ± 28.2	< 0.001

Table 2. Comparison of baseline characteristics of deceased donor kidneys between transplantation and non-utilization groups. SD, standard deviation; N, number; BMI, body mass index; CVA, cerebrovascular accident; CPR, cardiopulmonary resuscitation; Hb, hemoglobin; US-KDRI, United States' kidney donor risk index; US-KDPI, United States' kidney donor profile index; K-KDRI, Korean kidney donor risk index; K-KDPI, Korean kidney donor profile index.

(1.53 ± 1.28; $P < 0.001$; Fig. 2B), indicating that more kidneys from donors with unfavorable characteristics were discarded. Kidney discard rates were higher in donors with K-KDPI ≥ 61, whereas discard rates were low in donors with K-KDPI < 40 (Fig. 2C). However, considerable overlap in the K-KDPI of the kidneys between the discard and transplantation groups was observed.

In the univariable analysis, a high K-KDPI was associated with a 1.03-fold higher risk of kidney discard per 1 point increase (Table 3). In the multivariable logistic regression analysis that excluded the K-KDPI, old age, hypertension, DM, death due to non-CVA, high serum creatinine levels, and low serum hemoglobin levels were independent risk factors for kidney discard (Table 3).

Comparison of clinical characteristics among the kidney transplantation groups according to the kidney discard pattern

The transplantation groups were classified into 3 groups: double KT after bilateral procurement (double KT group), single KT after bilateral procurement (single KT group 1), and single KT after unilateral procurement (single KT group 2). Compared with donors in the double KT group, those in the single KT groups (single KT groups 1 and 2) had a higher rate of hypertension, higher creatinine levels, higher K-KDPI, older recipients, and longer cold ischemic time (CIT) (Table 4).

When the graft survival rates were compared between the double KT and single KT groups, no significant difference existed between the two groups ($P = 0.288$, log-rank test, Fig. 3A). Patient survival rates did not differ between the two groups ($P = 0.254$, log-rank test, Fig. 3B).

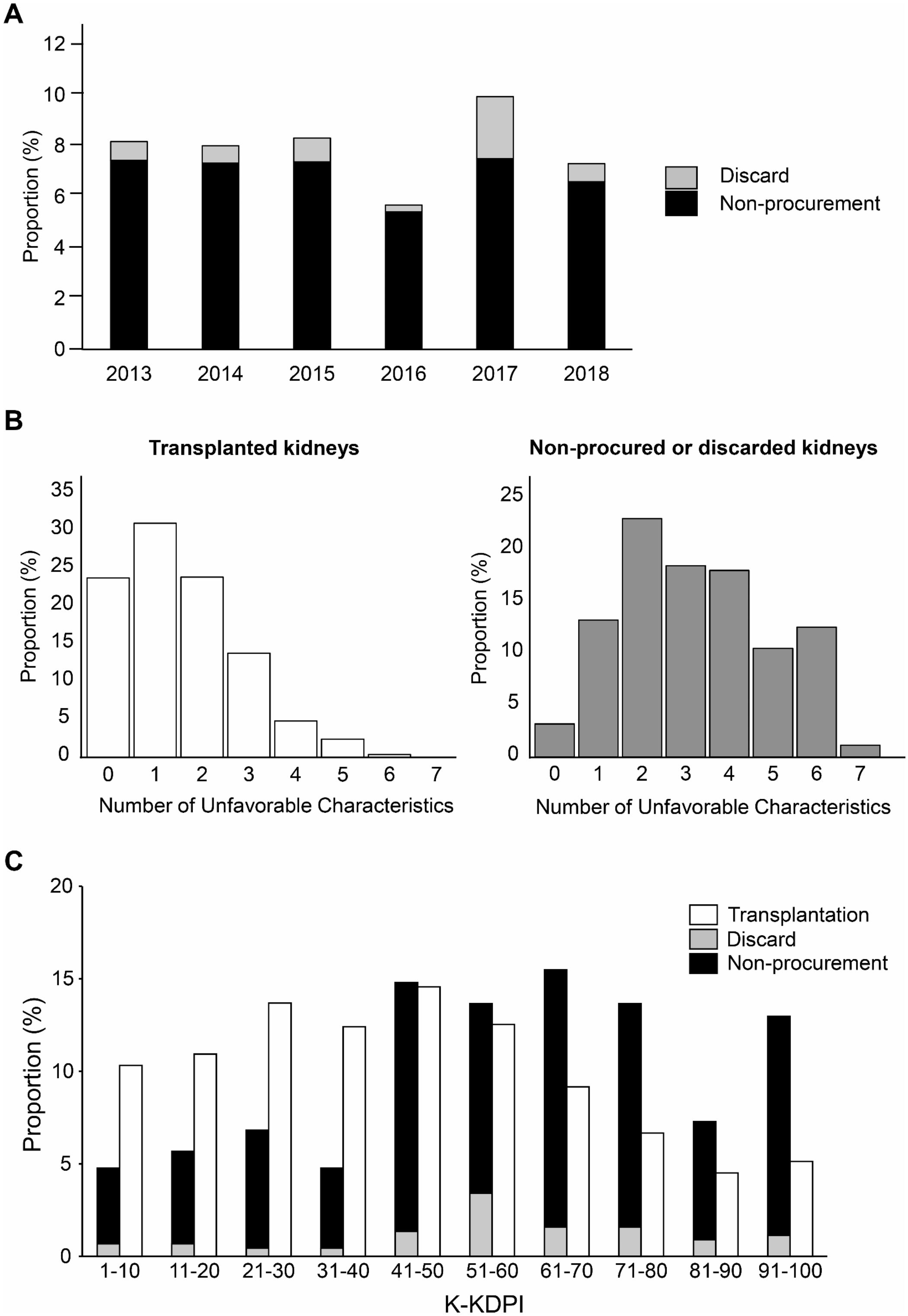

Fig. 2. Kidney discard pattern according to time, unfavorable donor characteristics, and K-KDPI. (**A**) Temporal trend of kidney discard rates. Black and gray boxes indicate rates (%) of non-procurement and discard after procurement of deceased donor kidneys, respectively. (**B**) Number of unfavorable donor characteristics in transplanted and non-procured or discarded kidneys. (**C**) Kidney discard rates according to the K-KDPI. Proportions of transplanted kidneys (white), kidneys not procured (black), and discarded kidneys after procurement (gray) are displayed according to the K-KDPI intervals. K-KDPI, Korean kidney donor profile index.

Parameters	Univariable analysis Crude OR (95% CI)	P value	Multivariable analysis Adjusted OR (95% CI)	P value
Age (year)	1.03 (1.02–1.03)	< 0.001	1.01 (1.00-1.02)	0.040
Female sex	1.07 (0.87–1.31)	0.522		
BMI (kg/m^2)	1.03 (1.01–1.06)	0.011	0.97 (0.94–0.99)	0.054
Hypertension	2.54 (2.09–3.10)	< 0.001	1.72 (1.33–2.23)	< 0.001
Diabetes mellitus	3.88 (3.11–4.85)	< 0.001	2.62 (1.98–3.47)	< 0.001
Death due to CVA	0.81 (0.66–0.99)	0.036	0.74 (0.58–0.93)	0.010
Terminal Cr (mg/dL)	1.86 (1.76–1.97)	< 0.001	1.87 (1.77–1.99)	< 0.001
Terminal Hb (g/dL)	0.83 (0.78–0.88)	< 0.001	0.83 (0.78–0.89)	< 0.001
CPR	1.09 (0.90–1.32)	0.396	-	-
K-KDPI	1.03 (1.03–1.04)	< 0.001	-	-

Table 3. Risk factors of kidney non-utilization analyzed by logistic regression analysis. OR, odds ratio; CI, confidence interval; BMI, body mass index; CVA, cerebrovascular accident; CPR, cardiopulmonary resuscitation; Cr, creatinine; Hb, hemoglobin; K-KDPI, Korean kidney donor profile index.

Variables	Double KT after bilateral procurement [double KT] (N = 5058)	Single KT after bilateral procurement [single KT1] (N = 33)	Single KT after unilateral procurement [single KT2] (N = 62)	P value
Donor-related factors				
Age (year)	47 ± 14.7	50.0 ± 18.3	46.8 ± 16.5	0.499
Sex (female), N (%)	1638 (32.4%)	13 (39.4%)	21 (33.9%)	0.673
BMI	23.5 ± 3.7	23.8 ± 4.2	23.9 ± 3.7	0.582
HBV, N (%)	94 (1.9%)	0 (0.0%)	0 (0.0%)	0.407
HCV, N (%)	10 (0.2%)	0 (0.0%)	0 (0.0%)	0.910
Death due to CVA	2186 (43.2%)	18 (54.5%)	22 (35.5%)	0.198
DCD, N (%)	6 (0.1%)	0 (0.0%)	0 (0.0%)	0.945
CPR, N (%)	2420 (47.8%)	12 (36.4%)	30 (48.4%)	0.419
Hypertension, N (%)	1222 (24.2%)	15 (45.5%)	21 (33.9%)	0.004
Diabetes mellitus, N (%)	508 (10.0%)	5 (15.2%)	6 (9.7%)	0.620
Hemoglobin (g/dL)	10.4 ± 16.6	9.7 ± 1.4	9.7 ± 1.7	0.923
Creatinine (mg/dL)	1.5 ± 1.2	2.0 ± 1.4	2.4 ± 1.7	< 0.001
K-KDPI	43.5 ± 25.0	52.9 ± 27.7	47.5 ± 26.8	0.047
Recipient-related factors				
Age (year)	50.1 ± 11.2	52.8 ± 9.9	53.3 ± 12.4	0.035
Sex (female), N (%)	1944 (38.4%)	9(27.3%)	19(30.6%)	0.195
HBV, N (%)	311 (6.1%)	1 (3.0%)	2 (3.2%)	0.482
HCV, N (%)	87 (1.7%)	0 (0.0%)	0 (0.0%)	0.436
Hypertension, N (%)	5005 (99.2%)	33(100.0%)	61 (98.4%)	0.664
Diabetes mellitus, N (%)	4240 (84.1%)	28 (68.8%)	55 (88.7%)	0.605
Dialysis duration (year)	4.0 ± 2.9	3.8 ± 2.6	3.8 ± 2.6	0.778
Re-transplantation, N (%)	437 (8.6%)	2 (6.1%)	4 (6.5%)	0.724
Transplantation-related factors				
Number of HLA mismatch	3.2 ± 1.2	3.6 ± 1.3	3.4 ± 1.1	0.344
Cold ischemic time (min)	260 ± 132.2	265.6 ± 99.6	210.6 ± 108.8	0.038
Outcomes of recipients				
Graft failure, N (%)	208 (4.1%)	1 (3%)	5 (8.1%)	0.288
Death, N (%)	346 (6.9%)	1 (3%)	4 (6.3%)	0.172

Table 4. Comparison of clinical characteristics according to transplantation groups. Continuous variables are displayed as mean ± standard deviation. N, number; BMI, body mass index; HBV, hepatitis B virus; HCV, hepatitis C virus; CVA, cerebrovascular accident; DCD, donation after circulatory death; CPR, cardiopulmonary resuscitation; K-KDPI, Korean kidney donor profile index; HLA, human leukocyte antigen.

Impact of the transplantation group according to kidney discard on graft failure and mortality

The K-KDPI increased the risk of graft failure (hazard ratio [HR], 1.008; 95% confidence interval [CI], 1.003–1.013; $P = 0.003$; Table 5). The multivariable Cox regression analysis for graft failure after excluding the K-KDPI demonstrated that older donors, DCD, younger recipients, male recipients, and a higher number of human leukocyte antigen (HLA) mismatches had a higher risk of graft failure, while the transplantation group according to kidney discard did not have a significant impact on graft failure. Compared with the double KT group, the single KT group did not have a higher risk of graft failure (HR 1.671; 95% CI 0.740–3.770; $P = 0.216$; Table 5).

The K-KDPI also increased the risk of patient death (HR 1.013; 95% CI 1.009–1.017; $P = 0.001$; Table 6). The multivariable Cox regression analysis for patient death, excluding K-KDPI, demonstrated that female or diabetic donors, old aged or male recipients of old age, diabetic recipients, and long CIT had a higher risk of patient death, whereas the transplantation group according to kidney discard did not have a significant impact on mortality (HR 0.864; 95% CI 0.352–2.116; $P = 0.749$; Table 5).

Discussion

This study showed that the kidney discard rate was 6–10% in Korea, a country with severe organ shortage. High K-KDPI scores, old age, hypertension, DM, death due to non-CVA, high serum creatinine levels, and low serum hemoglobin levels were associated with a higher risk of kidney discard. KT with a discarded contralateral kidney had graft failure and mortality rates similar to those of KT without a discarded contralateral kidney.

The discard rates of deceased donor kidneys in the US were 14.9%, 17.9%, 19.0%, and 26.7% in 2000, 2011, 2015, and 2022, respectively, indicating an increasing trend[13,14]. The discard rates reported in the United Kingdom (UK) and the Eurotransplant program were 12% and 11%, respectively[15,16]. The UK discard rates had also increased by 2012, but with increased utilization of DCD and proportions of donors with unfavorable prognosis, such as old age, the discard rate has remained stationary since 2013[15,17,18]. The higher discard rates in the US might be attributed to the widely used pre-implantation kidney biopsy in the country[14,19]; however, this interpretation has not yet been well-established. The kidney discard rates in this Korean study was lower than those in the US, UK, and Eurotransplant program. Because discard rates in this study included non-procurement as well as discard after procurement, discard rates after procurement in Korea were only 1.0%, which is notably lower than those in Western countries. These results might be attributed to the less aggressive practice for potential donor notification and organ utilization in Korea with a low donation rate compared with that in the Western countries. When the US-KDPI scores of the KT and non-utilization groups in this study were compared with those in the US and French cohorts, the scores of the Korean cohort (74.5 for KT, 88.4 for discard) appeared similar to those of the US (45 for KT, 77 for discard) and French (60 for KT, 80 for discard) cohorts, suggesting that the low discard rate in this study was not attributed to better donor quality in Korea[11]. Instead, we speculate that missing potential upstream donors and a much more serious organ shortage in Korea might have led Korean transplantation centers to use deceased donor kidneys more aggressively than that observed in Western countries. However, non-utilization of DCD, and uncommon utilization of pre-implant kidney biopsy, might also have contributed to the low discard rates[19–21]. Pre-implantation kidney biopsy is not popular outside the US, because its value has not been confirmed (for example, the poor predictive value of results provided by an on-call pathologist with limited training in renal pathology)[14,22–26]. Furthermore, the kidney discard rates seemed to remain low throughout the study period in Korea, which is contrasting to rates in the US and UK[14,15,18].

A US nationwide study reported that kidneys with a higher KDPI and more undesirable donor characteristics were more likely to be discarded[14]. Specific donor-related risk factors included old age (> 50 years), obesity (BMI > 35 kg/m^2), the African American race, hypertension, DM, death due to CVA, terminal serum creatinine > 2 (mg/dL), DCD, positive hepatitis C (HCV), high KDPI (> 85%), smoking of > 20 cigarette packs per year, drug usage, and alcoholism[14]. Similarly, high K-KDPI and donor characteristics such as old age, hypertension, DM, high serum creatinine levels, and low hemoglobin levels were observed to be risk factors of kidney non-utilizaiton in this study. Interestingly, non-CVA-related deaths had a higher risk for kidney non-utilization than CVA-related deaths in Korea, which contradicts to the US data, although the reasons for this result are unclear. The non-utilization group in this study included both non-procurement and post-procurement discards, while other studies included only the post-procurement discard group. The proportion of non-CVA-related deaths (62.6%), especially that of hypoperfusion-related organ damage due to progressive underlying diseases other than CVA and head trauma (33.0%) in the non-procurement group were higher than those in the post-procurement discard group (57.7% for non-CVA related death, 18.5% for other progressive underlying diseases), which might have contributed to difference in the risk of CVA-related death for kidney non-utilization between studies. The number of unfavorable donor characteristics and K-KDPI values were higher in the non-utilization group than that in the transplantation group. Taken together, unfavorable donor factors and the K-KDPI were the major risk factors for donor kidney discard, suggesting a concern that poor graft outcomes from poor donor kidney quality are the main reason for kidney discard.

Previous studies have shown that KT using kidneys that had been declined by other centers showed acceptable outcomes[27–29]. A US multicenter study showed that acute kidney injury (AKI) in donors did not increase the risk of graft failure, suggesting the active utilization of kidneys with AKI and minimization of the discard of kidneys with a potentially tolerable prognosis[30,31]. A UK study also demonstrated that a 20% increase in 1-year graft failure in the AKI group may be better than the 37% increase in graft failure after DDKT following dialysis for longer than 1 year while waiting for a donor kidney without AKI[32]. A US study showed acceptable 1-year graft survival rates of 85.0–87.9% after KT using single kidneys with discarded contralateral kidney[14]. Another UK study compared short-term outcomes of KT between the standard National Kidney Allocation Scheme (NKAS), which uses kidneys with good prognostic factors, and the UK Kidney Fast-Track Scheme

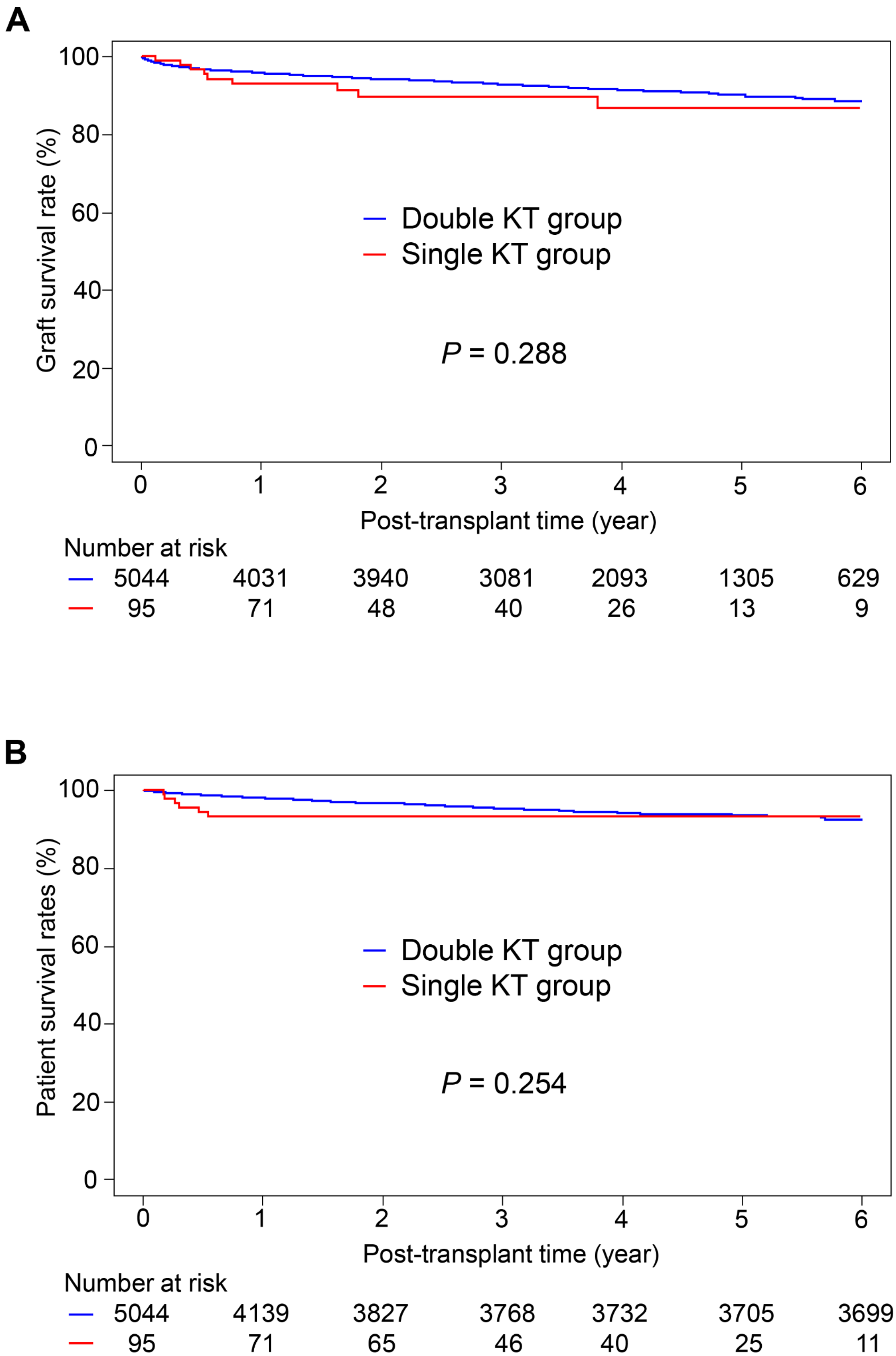

Fig. 3. Comparison of graft and patient survival rates between the transplantation groups according to kidney discard. (**A**) Graft survival rates of the double and single KT groups. (**B**) Patient survival rates of the double and single KT groups. *P* values between the double and single KT groups by Log-rank test. KT, kidney transplantation.

(KFTS), which simultaneously offers kidneys with unfavorable characteristics to all transplant centers that have opted to participate in the KFTS to minimize discarded kidneys[18]. The 1-year graft survival rates were similar between the two groups (NKAS, 94% vs. KFTS, 95%)[18]. Furthermore, our study compared short-term post-transplant outcomes between KT using a single kidney with a discarded contralateral kidney and KT using

Parameters	Univariable analysis		Multivariable analysis	
	Crude HR (95% CI)	*P* value	Adjusted HR (95% CI)	*P* value
Donor-related factors				
Age (year)	1.013 (1.003–1.023)	0.007	1.016 (1.005–1.027)	0.002
Sex (female), N (%)	1.225 (0.928–1.618)	0.151	1.212 (0.918–1.602)	0.173
BMI	1.005 (0.969–1.042)	0.766	-	-
HBV, N (%)	0.516 (0.127–2.100)	0.356	-	-
HCV, N (%)	-		-	-
Death due to CVA	1.089 (0.832–1.425)	0.532	-	-
DCD, N (%)	8.250 (2.049–33.220)	0.003	5.913 (1.459–23.958)	0.012
CPR, N (%)	0.990 (0.757–1.296)	0.945	-	-
Hypertension, N (%)	1.146 (0.845–1.555)	0.379	-	-
Diabetes mellitus, N (%)	1.082 (0.696–1.683)	0.724	-	-
Hemoglobin (g/dL)	0.998 (0.984–1.012)	0.795	-	-
Creatinine (mg/dL)	1.030 (0.925–1.147)	0.589	-	-
K-KDPI	1.008 (1.003–1.013)	0.003	-	-
Recipient-related factors				
Age (year)	0.989 (0.978–1.001)	0.074	0.983 (0.972–0.996)	0.009
Sex (female), N (%)	0.707 (0.530-.0944)	0.189	0.719 (0.538–0.961)	0.025
HBV, N (%)	0.849 (0.446–1.616)	0.189	-	-
HCV, N (%)	1.424 (0.573–3.542)	0.446	-	-
Hypertension, N (%)	0.611 (0.195–1.192)	0.397	-	-
Diabetes mellitus, N (%)	1.184 (0.813–1.726)	0.377	-	-
Dialysis duration (year)	1.011 (0.966–1.058)	0.635	-	-
Re-transplantation, N (%)	2.010 (0.904–4.469)	0.086	1.300 (0.854–1.980)	0.220
Transplantation-related factors				
Number of HLA mismatch	1.154 (1.029–1.294)	0.014	1.143 (1.019–1.283)	0.022
Cold ischemic time (min)	0.999 (0.998–1.001)	0.529	-	-
Transplantation group (ref: double KT group)	1.603 (0.712–3.610)	0.254	1.671 (0.740–3.770)	0.216

Table 5. Risk factors of graft failure according to transplantation groups. HR, hazard ratio; CI, confidence interval; N, number; BMI, body mass index; HBV, hepatitis B virus; HCV, hepatitis C virus; CVA, cerebrovascular accident; DCD, donation after circulatory death; CPR, cardiopulmonary resuscitation; K-KDPI, Korean kidney donor profile index; HLA, human leukocyte antigen; ref, reference; KT, kidney transplantation.

bilateral kidneys. The single KT group had a lower 1-year graft survival rate than the double KT group. Pre-transplant risky conditions and lower kidney quality in the single KT group might have contributed to the lower early graft survival rates; however, graft survival rate beyond 1 year seemed to be similar between the two groups, and no significant differences existed in the overall graft or patient survival rates between groups. However, the requirement for a complicated arterial reconstruction due to abnormal anatomy, parenchymal injury from trauma, or high CIT might have yielded a suboptimal result. Dual KT, in which two ECD kidneys are received simultaneously, could be another strategy to maintain good outcomes while minimizing kidney discard[33]. Taken together, these results support the idea that we can utilize kidneys with unfavorable risk factors more actively and still obtain acceptable outcomes instead of discarding them.

Certain subgroups of waitlisted patients could have better survival by receiving ECD kidneys of relatively poor quality than the remaining patients waiting for standard-criteria donor kidneys[9,34]. The survival benefits of ECD kidneys were also observed in Korea, with longer waiting times than those in Western countries[35,36]. Therefore, we should assess suitable candidates for ECD kidneys, such as old patients with DM who have recently registered for DDKT, and educate them to accept ECD kidneys with a relatively better prognosis instead of remaining on dialysis.

The most common cause of kidney discard is organ damage; however, many kidneys are discarded due to causes unrelated to organ quality, such as no available recipients and suspicious or confirmed malignancy in the kidneys or donors. No available candidates might be the result of an inefficient allocation system rather than poor quality of the donor kidney, suggesting that these kidneys could have been used if the system was improved[14,37]. Furthermore, we found several overlaps in the K-KDPI and quality of donor kidneys between transplanted and discarded kidneys, suggesting that some discarded kidneys could have been used. Interestingly, geographical and central variations existed in discard rates in the US, implying that some of the kidneys may have been unnecessarily discarded[14,15,38,39]. In fact, 20% of the discarded kidneys were suitable for transplantation upon reassessment[15]. In this study, approximately 62% of transplant centers used contralateral single kidneys while

Parameters	Univariable analysis		Multivariable analysis	
	Crude HR (95% CI)	*P* value	Adjusted HR (95% CI)	*P* value
Donor-related factors				
Age (year)	1.024 (1.016–1.032)	< 0.001	1.002 (0.992–1.012)	0.650
Sex (female), N (%)	1.106 (0.888–1.376)	0.368	1.367 (1.034–1.808)	0.028
BMI	1.029 (1.002–1.057)	0.036	1.017 (0.978–1.057)	0.421
HBV, N (%)	0.954 (0.421–2.160)	0.911	-	-
HCV, N (%)	6.011 (2.220–16.263)	< 0.001	4.079 (0.566–29.395)	0.162
Death due to CVA	1.038 (0.842–1.280)	0.724	-	-
DCD, N (%)	2.530 (0.355–18.011)	0.354	-	-
CPR, N (%)	1.063 (0.944–1.433)	0.154	-	-
Hypertension, N (%)	1.224 (0.969–1.544)	0.089	0.805 (0.572–1.134)	0.216
Diabetes mellitus, N (%)	1.749 (1.315–2.327)	< 0.001	1.629 (1.099–2.413)	0.014
Hemoglobin (g/dL)	0.957 (0.903–1.014)	0.141	-	-
Creatinine (mg/dL)	1.090 (1.008–1.178)	0.029	1.082 (0.978–1.197)	0.124
K-KDPI	1.013 (1.009–1.017)	< 0.001	-	-
Recipient-related factors				
Age (year)	1.075 (1.062–1.087)	< 0.001	1.063 (1.046–1.080)	< 0.001
Sex (female), N (%)	0.637 (0.506–0.801)	< 0.001	0.742 (0.558–0.987)	0.040
HBV, N (%)	0.996 (0.610–1.549)	0.986	-	-
HCV, N (%)	1.288 (0.628–2.640)	0.489	-	-
Hypertension, N (%)	3.022 (0.424–21.520)	0.269	-	-
Diabetes mellitus, N (%)	2.022 (1.399–2.865)	< 0.001	1.978 (1.202–3.255)	0.007
Dialysis duration (year)	1.024 (0.989–1.060)	0.178	-	-
Re-transplantation, N (%)	2.271 (0.266–0.727)	0.001	0.756 (0.421–1.359)	0.351
Transplantation-related factors				
Number of HLA mismatch	1.079 (0.989–1.177)	0.085	1.114 (0.997–1.245)	0.055
Cold ischemic time (min)	1.001 (1.000–1.002)	0.020	1.001 (1.000–1.002)	0.018
Transplantation group (ref: double KT group)	1.431 (0.738–2.770)	0.288	0.864 (0.352–2.116)	0.749

Table 6. Risk factors of mortality according to transplantation groups. HR, hazard ratio; CI, confidence interval; N, number; BMI, body mass index; HBV, hepatitis B virus; HCV, hepatitis C virus; CVA, cerebrovascular accident; DCD, donation after circulatory death; CPR, cardiopulmonary resuscitation; K-KDPI, Korean kidney donor profile index; HLA, human leukocyte antigen; ref, reference; KT, kidney transplantation.

38% did not, suggesting that the policies of individual centers may influence utilization of contralateral single kidneys.

To minimize unnecessary discarding, organ allocation and utilization systems should be improved. The UK introduced the KFTS in 2012, where kidneys that were declined by five centers or had 6 hours of CIT were simultaneously offered to participating centers in the KFTS to minimize discard rates. The Eurotransplant program adopted the Senior Program and rescue allocation, which offers kidneys regionally if they are declined by five centers[12,15,40]. Although kidney discard rates were lower in Korea than in Western countries, there were also cases of unnecessary discards, such as those discarded due to the lack of available recipients. Considering the more severe organ shortage in Korea than in Western countries, a new allocation system to minimize unnecessary kidney discarding is important. Enhancing the efficiency of donor utilization by matching the K-KDPI and the Korean estimated post-transplant survival (K-EPTS) is underway, and further studies are needed to propose fast allocation schemes for deceased donor kidneys with unfavorable risk factors for discard.

This study had several limitations. First, it is a retrospective, registry-based study; therefore, it lacks detailed information on various donor- and recipient-related factors as well as immunosuppressive regimens, and we could not exclude the risk of information bias. Information regarding the causes of kidney discard was also limited. Although the real causes of kidney discard are often multifactorial, only a single dominant cause is briefly provided by individual transplantation centers to the Korean Network for Organ Sharing (KONOS). Second, the results of this study cannot be generalized because the patterns of kidney discard were based on the practice patterns and characteristics of KT in Korea. Further studies are necessary to address these limitations.

Nevertheless, this study showed nationwide discard patterns of deceased donor kidneys outside the Western countries using a large number of cases. Our findings contribute to the understanding of discard practices in countries with low donation rates, and to the development of improved systems to minimize unnecessary discards.

In conclusion, the discard rate of deceased donor kidneys was low in Korea and discard of one kidney does not necessarily rule out utilization of the contralateral kidney, especially in Korea with a long waiting time.

Methods

Study population

We used the Korean national data on deceased kidney donors and transplantation recipients from the KONOS and the National Health Insurance data Sharing Service (NHISS). The NHISS provided comorbidity and graft failure information for DDKT recipients, which were merged with transplantation-related data from the KONOS. This study was conducted in accordance with the Declaration of Helsinki and the Declaration of Istanbul. This study was approved by the Institutional Review Board of Severance Hospital (4-2021-1358). The requirement for informed consent was waived because we used national databases publicly available from the KONOS and NHISS.

This registry included 5,592 deceased donor kidneys that were candidates for DDKT between January 1, 2013 and December 31, 2018 (Fig. 1). Generally, the two kidneys were procured from a deceased donor. The kidneys that were not procured for DDKT were classified as "not procured" ($n=385$). The procured kidneys were classified as "procured bilaterally" ($n=5,144$) or "procured unilaterally" ($n=63$) depending on whether the paired kidneys were procured together or not. For the bilaterally procured kidneys, the two kidneys were either transplanted into two recipients ($n=5,058$; double KT group), one kidney was transplanted while the other kidney was discarded ($n=33$; single KT group 1), or both kidneys were discarded ($n=20$). After unilateral procurement, single kidneys were either transplanted ($n=62$; single KT group 2) or discarded ($n=1$). Cases of kidney discard included both no-procurement and discard after procurement.

Prognostic factors

We collected donor-related data, such as age, sex, height, body weight, serology of hepatitis B and C viruses, cause of death including CVA, DCD, hypertension, DM, serum creatinine levels, and serum hemoglobin levels. In this study, we calculated the K-KDRI and the K-KDPI, which have been used since September 2021 to assess the quality of deceased donor kidneys and define ECD kidneys in Korea[41]. The K-KDRI was calculated using the following formula: exponential (0.01194 × [age-47] – 0.00991 × [height-166 cm] + 0.36007 × [1 for patients with DM or 0 for patients without DM] + 0.04905 × [serum creatinine level – 1.5 mg/dL]).

Recipient-related data included age, sex, serology of hepatitis B and C viruses, hypertension, DM, dialysis duration, and retransplantation. We also collected transplantation-related data, such as the number of HLA mismatches, CIT, and post-transplant outcomes, including patient death and kidney graft failure. The KT groups were classified into double and single KT groups, which included single KT 1 and 2 groups.

We also calculated the number of the following seven unfavorable donor characteristics that were reported to be associated with kidney discard: age > 50 years, BMI > 35 kg/m^2, hypertension, DM, death due to CVA, terminal serum creatinine levels > 2 mg/dL, DCD, HCV, and KDPI[11].

Outcomes

The primary outcome was donor discard, including both non-procurement and post-procurement discard. We aimed to assess the current status of kidney discards and prognostic factors in donors for kidney discard. The secondary outcomes were death and death-censored kidney graft failure. We compared post-transplant outcomes between the double and single KT groups, and assessed whether the KT group, according to procurement and discard, had a significant impact on mortality or graft failure.

Statistical analysis

The results of continuous variables were expressed as mean with standard deviation, and those of categorical variables were expressed as frequency with proportion. Continuous variables were analyzed using analysis of variance, Student's t-test, and the Mann–Whitney U test, as appropriate. Categorical variables were analyzed using the chi-square test or Fisher's exact test, as appropriate. Logistic regression analysis was performed to assess the prognostic factors for donor kidney discarding and the odds ratios, 95% CI, and *P* values were calculated. Overall patient and graft survival rates were analyzed using the Kaplan–Meier method and comparison among the transplantation groups were done using the log-rank test. Cox regression analysis was performed to assess whether post-transplant outcomes would differ according to the transplantation group, which was defined by the pattern of kidney discard, and were presented as HR, 95% CI, and *P* value. Multivariable analysis was performed using basic demographic factors and variables with $P<0.100$ in the univariable analysis. Statistical significance was set at $P<0.05$. Statistical analyses were performed using the R Studio version 4.2.3 (R Foundation for Statistical Computing).

Data availability

Data supporting the findings of this study are available from the corresponding author upon reasonable request.

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Author contributions
S.O., K.K., and J.Y. participated in research design. S.O., K.K., O.N., J.H., T.Y.K. and J.Y. participated in the performance of the research. S.O., K.K., N.O., and J.Y. participated in data analysis. S.O., K.K., and J.Y. participated in the writing of the paper. All authors reviewed and approved the manuscript.

Declarations

Competing interests
The authors declare no competing interests.

Additional information

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