



Comparisons of clinical outcomes between hypertensive and normotensive living kidney donors: a prospective, multicenter nationwide cohort study

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Background: Living kidney donors with hypertension are potential candidates for solving the donor shortages in renal transplantation. However, the safety of donors with hypertension after nephrectomy has not been sufficiently confirmed.

Methods: A total of 642 hypertensive and 4,848 normotensive living kidney donors who were enrolled in the Korean Organ Transplantation Registry between May 2014 and December 2020 were included in this study. The study endpoints were a decreased estimated glomerular filtration rate (eGFR) and proteinuria.

Results: In the entire cohort, donors with hypertension had a lower eGFR before nephrectomy in comparison to normotensive donors which remained lower after kidney transplantation. The incidence of proteinuria in hypertensive donors increased during follow-up. In propensity score-matched analysis, the risk of eGFR being <60 mL/min/1.73 m² (hazard ratio [HR], 0.77; 95% confidence interval [CI], 0.50–1.19) or <45 mL/min/1.73 m² (HR, 0.50; 95% CI, 0.06–4.03) was not significantly increased in donors with hypertension. However, hypertensive donors were found to have a significantly higher risk of proteinuria than normotensive donors (HR, 2.28; 95% CI, 1.05–4.94). Similar findings were also observed in the analysis of the entire cohort, indicating that hypertensive donors had a significantly higher risk of proteinuria (adjusted HR, 1.77; 95% CI, 1.10–2.85), without a substantial increase in the risk of decreased renal function.

Conclusion: The risk of proteinuria after donation was substantially increased in donors with hypertension. These findings underscore the need for careful monitoring of proteinuria in hypertensive donors following donation.

Keywords: Glomerular filtration rate, Hypertension, Living donors, Kidney transplantation, Proteinuria

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Introduction

The number of patients requiring renal replacement therapy has increased over the past several years. Moreover, the demand for renal transplantation has simultaneously increased in patients with end-stage renal disease [1]. Patients waiting for renal transplantation face a substantial risk of mortality before receiving the organ due to an increase in the waiting time [2]. Nevertheless, the number of kidney donors is insufficient, and the imbalance between supply and demand for transplantation has consistently worsened [3]. To solve the problem of donor shortage, expansion of living kidney donors has been suggested due to the limited availability of deceased donor kidneys. The selection criteria for living kidney donors have expanded globally, and donors with certain medical conditions are also considered potential candidates [4,5].

Hypertension is the most common medical condition among adults worldwide [6]. Although hypertension is a major risk factor that damages renal function, patients with hypertension and minimal risk of kidney injury are considered living kidney donors. Several previous studies evaluated the safety of hypertensive donors after kidney donation [7-9]. However, these studies have limitations of heterogeneity and retrospective basis design, and they did not provide consistent findings regarding the safety of hypertensive donors. Therefore, concerns regarding the safety of living donors with hypertension have not dissipated [10,11]. Based on these findings, the existing guidelines provide a narrow indication of donors with hypertension for renal transplantation, and donors with hypertension are restrictively allowed because of the lack of safety assurance [12].

Therefore, this study aimed to examine the clinical outcomes of hypertensive living donors in a prospective, multicenter, nationwide cohort. We compared renal function and proteinuria between hypertensive and normotensive kidney donors after donation to determine whether renal safety was preserved in living donors with hypertension.

Methods

Ethical considerations

The study protocol was reviewed and approved by the

Institutional Review Board of each center (representative approval: Kyung Hee University Medical Center; approval number, 2020-01-045). Written informed consent was obtained from all the participants prior to the commencement of the study. All the procedures in this study were performed in accordance with the tenets of the Declaration of Helsinki.

Study population

Data were obtained from an online registry based on the electronic health records of the Korean Organ Transplantation Registry (KOTRY). KOTRY is a multicenter, nationwide database that was established in 2014 to improve the prognosis of organ transplant patients and to help develop nationwide policies for Korean organ transplant patients [13]. A total of 6,128 candidates were identified from the cohort who had donated kidneys for transplantation between May 2014 and December 2020. Living donors whose data regarding serum creatinine levels before transplantation were missing ($n = 30$), those who had proteinuria ($n = 89$), those with missing information regarding pretransplant proteinuria ($n = 290$), and those with incomplete or insufficient medical information ($n = 229$) were excluded from the study. A total of 5,490 donors were finally enrolled. The donors included in the study were categorized as hypertensive ($n = 642$) or normotensive ($n = 4,848$).

Clinical parameters and outcomes

We collected the following data of donors before transplantation: age, sex, body mass index (BMI), smoking history, diabetes mellitus (DM), history of cardiovascular (CV) disease, systolic blood pressure (SBP), diastolic blood pressure (DBP), and blood and urine laboratory investigation results. The blood pressure was measured while they were hospitalized during kidney transplantation, and the subsequent follow-up blood pressure was measured on the outpatient basis. The protocols of each hospital were utilized during blood pressure measurements. Data on fasting blood glucose (FBG) levels were collected from 4,874 donors. A hypertensive donor in this study was defined as a patient previously diagnosed with hypertension or who was taking antihypertensive medication at the time of donor evaluation. Donor renal function was monitored

from the time of discharge to 1, 2, 3, 4, and 5 years after discharge. Renal function was evaluated based on estimated glomerular filtration rate (eGFR) and proteinuria. CKD-EPI (Chronic Kidney Disease Epidemiology Collaboration) formula was used to assess eGFR [14]. Proteinuria was considered positive if any of the following were present: 1) >300 mg/24 hr of urine or mg/gCr urine protein-to-creatinine ratio measured in either spot urine or 24 hours urine collection; 2) >30 mg/24 hr of urine or mg/gCr urine albumin-to-creatinine ratio measured in either spot urine or 24 hours urine collection; or 3) more than 1+ proteinuria measured in spot urine dipstick test. Among these tests, 4,688 individuals (85.4%) obtained pretransplant quantitative data through urine chemistry testing. In addition, the occurrence of medical complications such as DM, CV disease, and end-stage renal disease were also evaluated during the entire follow-up period.

The study endpoints were decreased renal function, eGFR slope, and proteinuria during the follow-up period. A mild decrease in renal function was defined as eGFR less than 60 mL/min/1.73 m², and a moderate decrease in renal function was indicated with eGFR less than 45 mL/min/1.73 m² at the follow-up point. The slope of eGFR was defined as the regression coefficient between eGFR and time in units of mL/min per 1.73 m²/yr. Medical complications, including new-onset DM, CV events, and end-stage renal disease were evaluated. CV events were defined as instances of acute myocardial infarction, congestive heart failure, ventricular arrhythmia, sudden cardiac arrest, cerebral infarction, or hemorrhage.

Statistical analysis

Baseline characteristics and parameters were presented as mean ± standard deviation or as number of patients and percentages. Differences between the two groups were identified using the Student t test. The chi-square test or Fisher exact test was used to compare the categorical variables, as appropriate. Cumulative event rates were estimated using the Kaplan-Meier method and compared using the log-rank test. Cox proportional hazard models were used to identify independent variables related to proteinuria and eGFR <60 or 45 mL/min/1.73 m². Multivariable models included parameters that were significantly associated with weight in the univariable test and the following

clinically fundamental parameters: age, sex, BMI, DM, previous CV history, and predonation eGFR.

In addition to the conventional methods of survival analysis, we constructed a propensity score-matched cohort to compare the risk of decreased renal function and proteinuria between hypertensive and normotensive donors after kidney transplantation. The variables included in the logistic regression model used for propensity score estimation were: age, sex, smoking history, BMI, DM, history of CV disease, predonation eGFR of the donors, uric acid levels, and total cholesterol levels. Propensity score matching between hypertensive and normotensive donors was performed using 1:4 nearest-neighbor matching. Participants with matched propensity scores were compared using the Kaplan-Meier method and Cox regression model. All statistical analyses were performed using IBM SPSS for Windows version 23.0 (IBM Corp.) or R software version 3.6.2 (R Foundation for Statistical Computing). Statistical significance was set at $p < 0.05$.

Results

Baseline characteristics

Table 1 presents the baseline characteristics and clinical parameters of the renal transplant donors based on presence of hypertension in the entire cohort. Donors with hypertension were older, predominantly male, and had higher BMI in comparison to normotensive donors. The proportion of donors with history of CV disease and DM was higher among donors with hypertension. Donors with hypertension had lower eGFR and serum cholesterol levels, whereas FBG and uric acid levels were higher.

Baseline SBP and DBP was significantly higher in donors with hypertension. When comparing the blood pressure of hypertensive and normotensive donors annually from predonation to 5 years posttransplantation, both SBP and DBP were consistently higher in donors with hypertension than in normotensive donors (Supplementary Fig. 1, available online). Fig. 1 shows the renal function trends in hypertensive and normotensive donors. The eGFR of donors with hypertension was reduced in the predonation state and remained decreased after donation in comparison to the normotensive donors. The incidence of proteinuria in donors with hypertension was significantly higher at 12 months

Table 1. Baseline characteristics and clinical parameters of kidney donors based on the presence of hypertension

Characteristic	Normotensive donors	Hypertensive donors	p-value
No. of patients	4,848	642	
Age (yr)	46.3 ± 11.8	56.1 ± 8.0	<0.001
Male sex	2,020 (41.7)	321 (50.0)	<0.001
Body mass index (kg/m ²)	24.1 ± 3.2	25.7 ± 3.0	<0.001
Smoking			
Never	3,622 (74.7)	465 (72.4)	
Current	844 (17.4)	94 (14.6)	<0.001
Ex-smoker	382 (7.9)	83 (12.9)	
Diabetes mellitus	48 (1.0)	23 (3.6)	<0.001
Previous history of CVD	31 (0.6)	18 (2.8)	<0.001
SBP (mmHg)	122 ± 14	130 ± 14	<0.001
DBP (mmHg)	76 ± 10	81 ± 9	<0.001
eGFR (mL/min/1.73 m ²)	102.0 ± 14.0	93.6 ± 12.2	<0.001
FBG (mg/dL)	102 ± 17	109 ± 22	<0.001
Uric acid (mg/dL)	5.0 ± 1.4	5.3 ± 1.4	<0.001
Total cholesterol (mg/dL)	192 ± 35	182 ± 38	<0.001

Data are expressed as number only, mean ± standard deviation, or number (%).

CVD, cardiovascular disease; DBP, diastolic blood pressure; eGFR, estimated glomerular filtration rate; FBG, fasting blood glucose; SBP, systolic blood pressure.

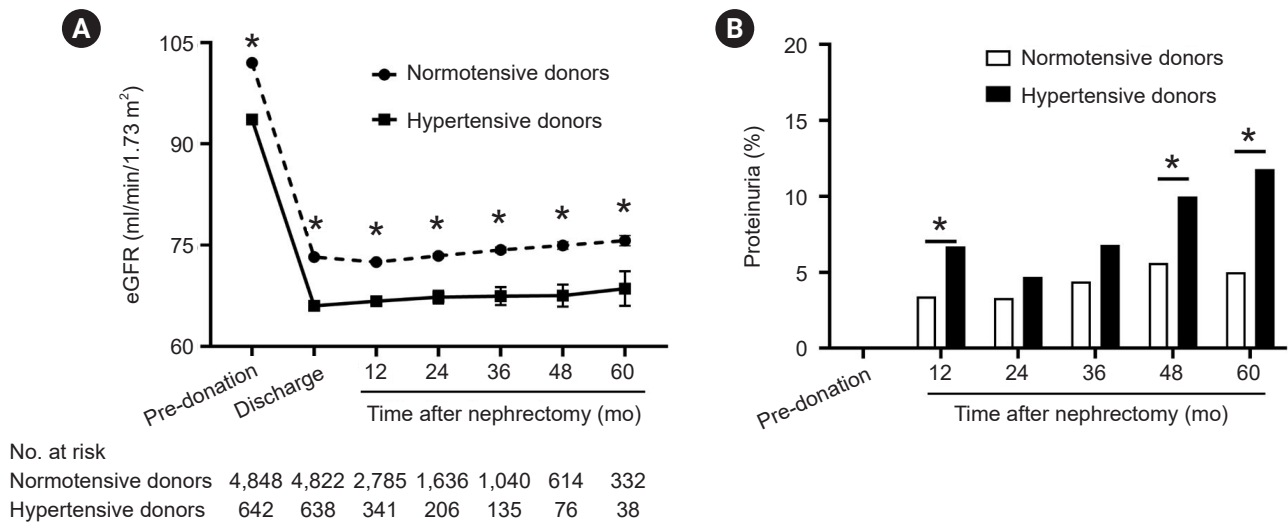


Figure 1. Trends in postdonation of normotensive and hypertensive donors in the entire cohort. (A) Trends in renal function. (B) Trends in proteinuria.

eGFR, estimated glomerular filtration rate.

*p < 0.05, statistically significant.

postdonation. Moreover, a trend of increasing incidence of proteinuria even after 48 to 60 months was observed.

Comparison of hypertensive and normotensive donors in the propensity score-matched cohort

The baseline characteristics showed significant differences

between normotensive and hypertensive living donors. Therefore, we utilized 1:4 propensity score matching to reduce potential selection bias. In the propensity score-matched cohort, a total of 1,910 patients remained, consisting of 127 hypertensive donors and 508 normotensive living donors. The baseline characteristics were effectively balanced between the two matched groups (Supplementa-
ry Table 1, available online).

The cumulative event rates of decreased renal function and proteinuria are shown in Fig. 2. The results of the Kaplan-Meier analysis indicated no significant difference in the incidence of mild or moderate decrease in renal function between hypertensive donors and normotensive donors. However, in the hypertensive donors, a statistically significant increase in the occurrence of proteinuria was observed compared to the normotensive donors.

We investigated the incidence and hazard ratio (HR) of hypertensive donors for decreased renal function and proteinuria during the mean follow-up period (Table 2). The association between hypertensive donors and the risk of mild decreased renal function was not statistically significant (HR, 0.77; 95% CI, 0.50–1.19; $p = 0.24$). It was found similar patterns were observed for the risk of moderate decreased renal function (HR, 0.50; 95% CI, 0.06–4.03; $p = 0.52$). We compared the eGFR slope between the hypertensive and normotensive donors. Hypertensive donors did not exhibit a significantly steeper slope in eGFR changes compared to normotensive donors (unstandardized β , -1.39; 95% CI, -1.93 to 0.03; $p = 0.06$). However, hypertensive donors had a significantly higher risk of proteinuria than normotensive donors (HR, 2.28; 95% CI, 1.05–4.94; $p = 0.04$).

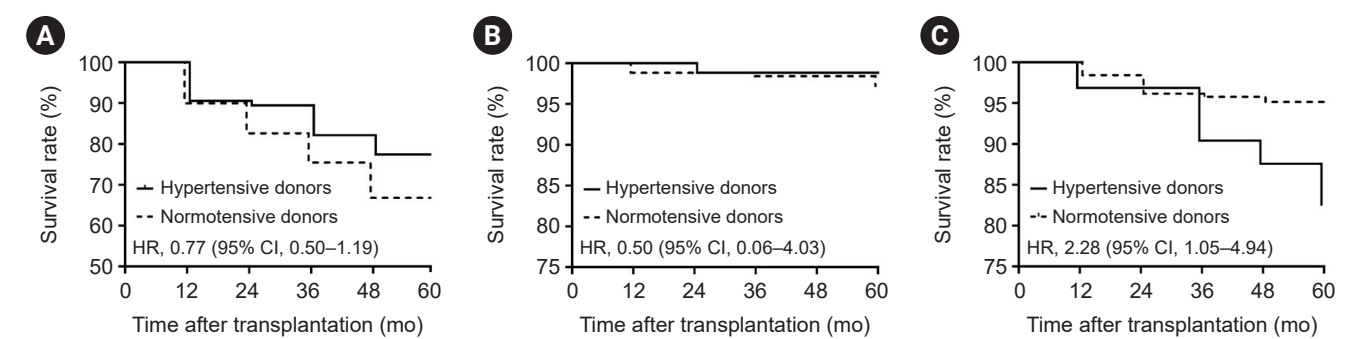


Figure 2. Cumulative event rates between hypertensive and normotensive donors in the propensity score-matched cohort. (A) Mild decrease in renal function. (B) Moderate decrease in renal function. (C) Proteinuria. CI, confidence interval; HR, hazard ratio.

Table 2. Incidence rate and HR of lower renal function and proteinuria in hypertensive and normotensive donors after transplantation of propensity score-matched study population

Variable	No. of events (%)	Person-year	Incidence rate ^a	Unadjusted HR (95% CI)	p-value
Mild decrease in renal function					
Normotensive donors	133 (26.2)	16,044	9.3	Reference	
Hypertensive donors	25 (19.7)	3,900	6.4	0.77 (0.50–1.19)	0.24
Moderate decrease in renal function					
Normotensive donors	8 (1.8)	15,912	0.5	Reference	
Hypertensive donors	1 (0.8)	3,888	0.3	0.50 (0.06–4.03)	0.52
Proteinuria					
Normotensive donors	18 (3.5)	15,792	1.1	Reference	
Hypertensive donors	10 (7.9)	3,828	2.6	2.28 (1.05–4.94)	0.04

CI, confidence interval; HR, hazard ratio.
^aEvents per 1,000 person-year.

Subgroup analyses of the risk of proteinuria in the propensity score-matched cohort

We divided the study participants into subgroups to assess the risk of proteinuria based on the predefined criteria (Table 3). The risk of proteinuria in donors with hypertension was significantly increased in those with BMI <25 kg/m² (HR, 4.73; 95% CI, 1.78–12.61; *p* = 0.002), in comparison to the normotensive donors. Donor hypertension was also associated with an increased risk of proteinuria in patients with fasting glucose level <110 mg/dL (HR, 2.47; 95% CI, 1.05–5.84; *p* = 0.04). There was no significant interaction in terms of risk of proteinuria between donor hypertension and the predefined criteria.

Comparison of renal function, proteinuria, and complications between hypertensive and normotensive donors in the entire cohort

Multivariable Cox regression analysis revealed that hypertensive donors did not exhibit a significantly higher risk of mildly decreased renal function donors (adjusted HR, 0.87; 95% CI, 0.70–1.09; *p* = 0.22) compared to normotensive donors (Supplementary Table 2, available online). Furthermore, this pattern was observed even in cases of moderately decreased renal function (adjusted HR, 1.52; 95% CI, 0.79–2.94; *p* = 0.21). The eGFR slopes of hypertensive and normotensive donors were found to be similar (adjusted

unstandardized β , -0.19; 95% CI, -1.15 to 0.76; *p* = 0.69). Donors with hypertension had a significantly higher risk of proteinuria than normotensive donors (adjusted HR, 1.77; 95% CI, 1.10–2.85; *p* = 0.02).

CV events and end-stage renal disease after transplantation did not occur in normotensive or donors with hypertension. New-onset DM was identified more frequently in donors with hypertension than in normotensive donors (19 cases, 3.0% vs. 45 cases, 0.9 %; *p* < 0.001).

Discussion

We compared the clinical outcomes of hypertensive and normotensive donors in this nationwide prospective study to evaluate the clinical safety of donors after nephrectomy. We found that the risk of decreased renal function was not significantly increased in donors with hypertension and that there was no difference between hypertensive and normotensive donors in terms of eGFR slope. However, the incidence of proteinuria was significantly higher in donors with hypertension. Moreover, their risk for proteinuria was independently increased compared to that of normotensive donors in both the entire and propensity score-matched cohorts. These findings suggest that the risk of kidney injury after donation increased in donors with hypertension, while it did not translate into a significant decline in renal function.

We found that donors with hypertension had a lower

Table 3. Subgroup analysis on the risk of proteinuria in hypertensive donors of propensity score-matched study population

Variable	Normotensive donors		Hypertensive donors		HR (95% CI)	p-value
	No. of patients (%)	Incidence rate ^a	No. of patients (%)	Incidence rate ^a		
Age (yr)						
<65	493 (77.6)	1.2	120 (18.9)	2.5	2.13 (0.96–4.74)	0.06
≥65	14 (2.2)	0	8 (1.3)	4.6	NA	
Sex						
Male	212 (33.4)	0.9	51 (8.0)	2.0	2.17 (0.54–3.79)	0.28
Female	295 (46.5)	1.3	77 (12.1)	3.0	2.32 (0.91–5.89)	0.08
Body mass index (kg/m ²)						
<25	298 (46.9)	0.9	66 (10.4)	4.1	4.73 (1.78–12.61)	0.002
≥25	209 (32.9)	1.5	62 (9.8)	1.1	0.69 (0.15–3.16)	0.64
Fasting blood glucose (mg/dL) ^b						
<110	387 (69.7)	1.3	85 (15.3)	3.1	2.47 (1.05–5.84)	0.04
≥110	94 (16.9)	1.0	32 (5.8)	2.3	2.16 (0.36–12.96)	0.40

CI, confidence interval; HR, hazard ratio; NA, not available.

^aEvents per 1,000 person-year. ^bData unavailable in 37 patients (5.9%).

baseline eGFR before transplantation in comparison to the normotensive donors. Several clinical studies and experimental results support that hypertension is a significant cause of kidney damage. Moreover, several pathophysiological mechanisms of renal injury have also been suggested [15–19]. Therefore, a lower baseline eGFR in donors with hypertension could be associated with hypertensive renal injury to some extent. In addition, hypertensive donors exhibit multiple factors that may contribute to a decreased eGFR. The presence of obesity, metabolic syndrome, DM, and a history of CV disease is more commonly observed in hypertensive patients. Nevertheless, we found that donors with hypertension did not demonstrate a significant increase in the risk for a mild decrease in renal function during the follow-up period. These findings indicate that the risk of critical eGFR reduction after donor nephrectomy is not substantial in donors with hypertension, despite a lower baseline eGFR.

Kidney donors undergo renal compensation after nephrectomy. The function of the remaining kidney increases and is completed within approximately 36 months [20]. In this study, we found a modest increase in the eGFR of donors with hypertension after discharge. Furthermore, we also found that the eGFR slope per year of donors with hypertension was not different from that of normotensive donors. These findings indicate that the magnitude of eGFR compensation in the residual kidney was similar between hypertensive and normotensive donors. A previous study on older donors with hypertension was consistent with our findings and showed that hyperfiltration capacity and compensatory renocortical hypertrophy were not impaired in donors with hypertension [21]. Nevertheless, the marginally lower slope of eGFR in the propensity score-matched hypertensive donors prompts concerns about the risk of decreased renal function. We suggest that long-term follow-up data is necessary to ensure the stable safety of hypertensive donors.

Proteinuria is evidence of glomerular injury and a major risk factor for renal disease progression. It has been shown that proteinuria is associated with a risk of more rapid eGFR decline [22]. In this study, we observed that proteinuria occurred more frequently in donors with hypertension and that the risk of proteinuria was significantly increased in such donors. These findings suggest that donors with hypertension are potentially exposed to a greater risk of

renal function decline over the long term. We suggest that regular monitoring of proteinuria is important to establish the safety of donors with hypertension, and that early management of proteinuria is critical to prevent renal function decline.

It is well-known that obesity and hyperglycemia are important metabolic risk factors for kidney injury and proteinuria, often coexisting with hypertension [23]. Nevertheless, our subgroup analysis revealed that hypertension was significantly associated with an increased risk of proteinuria in donors with BMI <25 kg/m² and donors with FBG <110 mg/dL. While the reasons for these findings remain unclear, we speculate that hypertensive donors with higher BMI or higher FBG levels are associated with metabolic risk factors. In such cases, lifestyle modification after donation can easily control blood pressure and reduce the risk of organ injury. However, hypertensive donors with lower BMI or lower FBG are considered to have hypertension less related to metabolic risk, and it was thought that non-modifiable factors, including genetic susceptibility or other underlying secondary causes of hypertension, may be relevant [24,25]. These factors might be challenging to correct after donation, potentially exacerbating renal damage postdonation [26,27].

In this study, we found that donors with hypertension had an increased baseline BMI, higher levels of FBG and uric acid, and a greater proportion of DM than normotensive donors. These metabolic components have been reported to be frequently clustered and increase the burden of CV complications [28,29]. New-onset DM was also identified more frequently among donors with hypertension during follow-up. These findings suggest that donors with hypertension have multiple risk factors for CV disease, and that the development of new-onset DM could further increase the risk of CV complications. Indeed, a recent study supported the fact that donors with hypertension incurred a higher rate of CV disease than those with normotension after donation [8]. Therefore, it is advisable for donors with hypertension to receive preventive management for CV complications to promote post-donor nephrectomy health.

This study had a few limitations which need to be considered. The donors with hypertension included in this study had a relatively short follow-up period. Long-term follow-up is necessary to monitor hypertensive renal injuries and CV complications [30,31]. Therefore, it might be

insufficient to derive significant results based on eGFR decline, despite the increased risk of proteinuria. Moreover, the study did not include information on antihypertensive medications. The types and numbers of antihypertensive medications and the use of angiotensin receptor blockers and angiotensin-converting enzyme inhibitors could affect the risk of proteinuria and renal function. Finally, proteinuria quantification data was not consistently collected during pretransplant screening, and definitive exclusion of proteinuria proved challenging in some patients.

In conclusion, our study demonstrated that the risk of proteinuria after donation was significantly increased in hypertensive donors. While no substantial deterioration of renal function was observed in this study, long-term follow-up data would be necessary to thoroughly evaluate potential declines in renal function. Our study underscores the importance of regular proteinuria monitoring for the safety of hypertensive donors, which would provide critical information in the prevention of hypertensive complications following kidney donation.

Additional information

The Korean Organ Transplantation Registry (KOTRY) was established in 2014 and has managed nationwide cohorts of kidney, liver, pancreas, heart, and lung transplants. The kidney subcommittee consisted of 41 researchers from 39 transplant centers. The names of the KOTRY participating hospitals and principal investigators of the kidney subcommittee are as follows: BHS Hanseo Hospital (Jin Min Kong), Hanyang University Hospital (Oh Jung Kwon), Korea University Anam Hospital (Myung-Gyu Kim, Cheol-Woong Jung), Wonju Severance Christian Hospital (Sung Hoon Kim), Inje University Busan Paik Hospital (YeongHoon Kim), Bongseng Memorial Hospital (Joong Kyung Kim), Kyungpook National University Hospital (Chan-Duck Kim), The Catholic University of Korea, Bucheon St. Mary's Hospital (Ji Won Min), Chonbuk National University Hospital (Sung Kwang Park), Gachon University Gil Medical Center (Yeon Ho Park), Ajou University Hospital (Inwhae Park), Samsung Medical Center (Jae Berm Park), Konkuk University Medical Center (Jung Hwan Park), Yeungnam University Hospital (Jong-Won Park), The Catholic University of Korea, Eunpyeong St. Mary's Hospital (Tae Hyun Ban), Pusan National University Hospital (Sang Heon Song),

Ewha Womans University Medical Center (Seung Hwan Song), Kosin University Gaspel Hospital (Ho Sik Shin), The Catholic University of Korea, Seoul St. Mary's Hospital (Chul Woo Yang), The Catholic University of Korea, Incheon St. Mary's Hospital (HyeEun Yoon), Chungnam National University Hospital (Kang Wook Lee), Maryknoll Medical Center (Dong Ryeol Lee), Pusan National University Yangsan Hospital (Dong Won Lee), Kangdong Sacred Heart Hospital (Samuel Lee), Kyung Hee University Hospital at Gangdong (Sang-Ho Lee), CHA Bundang Medical Center (Yu Ho Lee), SMG-SNU Boramae Medical Center (Jung Pyo Lee), Myongji Hospital (Jeong-Hoon Lee), Soonchunhyang University Seoul Hospital (JinSeok Jeon), Inje University Ilsan Paik Hospital (Heungman Jun), Kyung Hee University Hospital (Kyunghwan Jeong), Ewha Womans University Mokdong Hospital (Ku Yong Chung), Ulsan University Hospital (Hong Rae Cho), Gangnam Severance Hospital (Man Ki Ju), Seoul National University Bundang Hospital (Dong-Wan Chae), Chonnam National University Hospital (Soo Jin Na Choi), Asan Medical Center (Duck Jong Han), Keimyung University School of Medicine (Seungyeup Han), Severance Hospital (Jaeseok Yang, Kyu Ha Huh), and Seoul National University Hospital (Curie Ahn).

Conflicts of interest

All authors have no conflicts of interest to declare.

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Data sharing statement

The data presented in this study are available from the corresponding author upon reasonable request.

Authors' contributions

Conceptualization, Funding acquisition: HSH

Data curation, Investigation: KYC, JCJ, SJNC, JY, MSK; and the Korean Organ Transplantation Registry Study Group
 Formal analysis: JHK, YHL, HSH
 Methodology: DKK, JSK, KHJ, JHK, YHL, HSH
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