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A Paired Kidney Analysis of Simultaneous Heart-Kidney Transplantation and Kidney Transplantation After Heart Transplantation

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Objective: To assess the outcomes of a pair of kidneys from a single donor used for simultaneous heart-kidney transplantation (SHKT) or kidney after heart transplantation (KAH).

Background: An Increase in kidney dysfunction among heart transplant candidates has led to an increased need for SHKT and KAH. The risk of early kidney graft loss and mortality is higher in SHKT compared with kidney-alone recipients.

Methods: Among adult kidney transplant recipients from Oct 2014 to Oct 2022, outcomes were compared between paired kidney-alone *vs* SHKT and kidney-alone *vs* KAH. Paired kidney models were used to mitigate differences among donor risk factors. Differential graft years were calculated using restricted mean survival analysis.

Results: A total of 1220 pairs of kidney-alone and SHKT recipients and 441 pairs of kidney-alone and KAH recipients were identified. Among the paired donor kidneys, graft survival was significantly lower in SHKT recipients compared with kidney-alone recipients at 1-year post-transplant (96.1% *vs* 89.3%; $P < 0.001$) and at 3-year post-transplant (83.9% *vs* 78.8%; $P < 0.001$). This resulted in lower mean graft years [SHKT (3.98 years, standard error = 0.06) *vs* kidney-alone (4.55 years, standard error = 0.04); $P < 0.001$] and an additional loss of 57 kidney graft years per 100 transplants ($P < 0.01$) during the study period. There was no difference in graft survival of paired kidneys in kidney-alone *vs* KAH recipients with additional loss of 17 kidney graft years per 100 transplants ($P = 0.20$).

Conclusions: Optimal recipient selection for kidney after heart transplant under the new safety-net policy may help mitigate the significant risk of kidney graft failure among SHKT recipients.

Keywords: outcomes, Kidney Transplant, heart transplant, simultaneous heart kidney transplant

INTRODUCTION

Kidney dysfunction is a common sequela of end-stage heart disease, and it may be associated with worse graft and overall survival after heart transplantation (HT).[1–6] The prevalence of kidney dysfunction in HT candidates with advanced heart failure has increased over the last decade from 3.9% in 2009 to 7.5% in 2019,[7] leading to an increase in simultaneous heart and kidney transplantation (SHKT) in the United States.[7–13]

While SHKT was shown to improve survival in HT recipients with end-stage renal dysfunction,[10,14] it is unclear if similar benefit extends to HT recipients with mild to moderate kidney dysfunction.[6,10,11,14–16] SHKT is more complex than heart-alone or kidney-alone transplantation due to the risks of an additional complex surgery and associated medical and surgical challenges.[12,13,17,18] Likely driven by hemodynamic instability during the pre-, peri-, and postoperative periods, kidney allograft outcomes are worse in SHKT recipients compared with kidney-alone transplant recipients.[12,13,18,19] During the period of 2002 to 2010, paired kidney graft survival was comparable between SHKT and kidney-alone.[8] Since then, the SHKT candidates are older and with more medical comorbidities.[12,20] This change in recipient characteristics, along with hemodynamic challenges introduced by the new heart allocation policy, which prioritizes transplanting acutely ill patients with the highest waitlist mortality,[9] is associated with poor kidney allograft and patient survival in recent SHKT recipients.[13,20,21] Safety-net policy of utilizing kidney transplant after HT (KAH) was implemented on June 29, 2023[22] to mitigate such risks. While the kidney graft survival benefit in kidney after liver transplant has been shown in liver transplant recipients,[23] data regarding potential benefits of KAH for HT recipients remains limited.

To assess kidney graft survival in SHKT and KAH, we conducted a nationwide cohort analysis comparing outcomes of using the kidney allograft pairs from a single donor where one kidney was used in SHKT or KAH and the second was used for kidney-alone transplant. Using paired analysis allowed for addressing the donor-related confounding noted in previous studies that reported kidney graft outcomes in SHKT recipients.

METHODS

Data Source and Study Group

The adult (aged ≥18 years) deceased donor kidney transplant recipients between October 2014 and October 2022 were

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The data that support the findings of this study are available on request from the corresponding author. The data is not publicly available due to privacy or ethical restrictions.

SDC Supplemental digital content is available for this article. Direct URL citations appear in the printed text and are provided in the HTML and PDF versions of this article on the journal's Web site (www.annalsofsurgery.com).

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retrospectively analyzed using the de-identified United Network for Organ Sharing (UNOS) Standard Transplant Analysis and Research file. The adult donors in which one kidney was transplanted to a kidney-alone recipient and the paired kidney transplanted to either an SHKT or KAH recipient were included. SHKT was defined based on a transplant date within 2 days for each organ type for the same recipient. KAH was defined based on the follow-up information of an HT recipient as a kidney transplant recipient. Recipients with re-transplants, other multi-organ transplants, and living donations were excluded. This study was approved by the Institutional Review Board (No. 14680). Informed consent was waived due to secondary data usage.

Outcomes and Definitions

The primary endpoint was kidney graft survival, which was defined as the composite endpoint of patient death and kidney graft failure: (1) removal of kidney graft; (2) requirements of any chronic dialysis; or (3) a creatinine clearance or estimated glomerular filtration rate (eGFR) of 20 mL/min/1.73 m^2 or less.

Secondary endpoints were mortality, kidney delayed graft function (DGF) (requirement of dialysis within 7 days after kidney transplant),[24] kidney allograft rejection episodes, and serum creatinine in the initial admission, 6 months, and one year. Kidney Donor Profile Index (KDPI) was using 2020 mapping conversion.

Statistics

Nonparametric analysis was used to compare continuous variables between groups (Mann–Whitney *U* test), and the chi-square test or Fisher exact test was used for categorical data. The overall survival (OS) and graft survival (GS) were calculated from the date of transplant to the date of event using the Kaplan–Meier method. The log-rank test was used to compare survival curves.

Cox proportional-hazard regression analysis was applied to identify the factors that were associated with OS and GS during the follow-up period. We generated models censored at 90 days and 1 year post-transplantation and evaluated conditional overall kidney graft and patient survival among recipients with at least 1-year survival. Results were presented as hazard ratios (HR) and reported with 95% confidence intervals (CI). All variables with a value of $P < 0.2$ in the univariable model were entered into the multivariable model. The stepwise backward model selection method was used to build the most parsimonious multivariable model. Adjusted HR (aHR) was shown in multivariable models. Restricted mean survival estimates to calculate cumulative within 5-year post-transplantation. These estimates indicated the area under the survival curve for the fixed duration and were compared with *t* tests. All survival models were censored administratively on October 1, 2023. Missing data was shown in Supplemental Table 1, https://links.lww.com/AOSO/A507. For all statistical analyses, $P < 0.05$ was considered as statistically significant. All statistical analyses were performed using R-Studio using R version 4.1.1 (R-Studio, Boston, MA).

RESULTS

During the study period, 1220 donors led to 2440 kidney transplants, where 1 donor kidney was used for SHKT and the other for kidney-alone transplant, and 441 donors led to 882 kidney transplants, where 1 donor kidney was used for KAH transplant and the other for kidney-alone transplant. Donor characteristics are shown in Table 1.

The median (IQR) donor age in the kidney-alone and SHKT cohort was 33 (26–42) years, and in the kidney-alone and KAH cohort was 38 (29–49) years. Donors after brain death were utilized for 95% of transplants for kidney-alone and SHKT recipients, and in 84% of transplants for kidney-alone and KAH recipients. The median (IQR) KDPI for kidney-alone and SHKT was 21% (10–37), and for kidney-alone and KAH was 32% (18–54).

TABLE 1.

Deceased Donor Characteristics of Paired Kidney Donors to Kidney alone, Simultaneous Heart-Kidney and Kidney After Heart Transplant Recipients

	Simultaneous Heart-Kidney Transplant (SHKT)	Kidney after Heart Transplant (KAH)
Donor Characteristics	**N = 1220**	**N = 246**
Age	33.0 (26.0–42.0)	38.0 (29.0–49.0)
Male	925 (76%)	294 (67%)
Race		
White	776 (64%)	313 (71%)
Black	143 (12%)	57 (13%)
Hispanic	264 (22%)	60 (14%)
Asian	22 (1.8%)	7 (1.6%)
Others	15 (1.2%)	4 (0.9%)
Blood type		
A	385 (32%)	178 (40%)
AB	29 (2.4%)	24 (5.4%)
B	135 (11%)	49 (11%)
O	671 (55%)	190 (43%)
Body mass index	27.8 (24.0–31.6)	27.8 (24.1–32.0)
HCV NAT positive	97 (8.0%)	32 (7.3%)
HCV Ab positive	133 (11%)	47 (11%)
Serum creatinine at donation, mg/dl	0.92 (0.70–1.20)	0.90 (0.70–1.26)
Donation type		
Donation after brain death	1163 (95%)	372 (84%)
Donation after circulatory death	57 (4.7%)	69 (16%)
Donor cause of death		
Anoxia	502 (41%)	202 (46%)
Cerebral vascular disease	191 (16%)	89 (20%)
Trauma	497 (41%)	142 (32%)
Others	30 (2.4%)	8 (1.8%)
KDPI, %	21 (10–37)	32 (18–54)

Ab indicates antibody; HCV, hepatitis C virus; NAT, nucleic acid test.

Recipient Characteristics

Kidney-Alone vs SHKT

Table 2 shows the characteristics of paired kidney recipients in the kidney-alone and SHKT cohort. SHKT recipients were older (median age: 59 *vs* 48 years, $P < 0.001$), more male (81% *vs* 56%, $P < 0.001$), and of more white race (47% *vs* 33%, $P < 0.001$). SHKT recipients had a higher incidence of diabetes (48% *vs* 28%, $P < 0.001$) and peripheral vascular disease (14% *vs* 8.8%, $P < 0.001$). SHKT recipients had lower pretransplant serum creatinine (2.5 *vs* 8.3 mg/dL, $P < 0.001$) and a lower rate of dialysis before transplant (27% *vs* 86%, $P < 0.001$). The waiting time for kidney transplant was significantly shorter in SHKT (median: 37 *vs* 586 days, $P < 0.001$). Kidney allocation was wider in SHKT (national: 37% *vs* 24%, $P < 0.001$).

Kidney-Alone vs KAH

KAH recipients compared with kidney-alone recipients were older (median age: 61 *vs* 57 years, $P = 0.013$), more male (74% *vs* 64%, $P = 0.020$), of more white race (60% *vs* 41%), less Hispanic (5.7% *vs* 16%), and had lower BMI (26.6 *vs* 29.0, $P < 0.001$), lower serum creatinine level (6.5 *vs* 8.0 mg/dL,

TABLE 2.

Recipient Characteristics of Paired Donor Kidney-Alone and Simultaneous Heart-Kidney and Paired Donor Kidney-Alone and Kidney After Heart Transplant Recipients

	Paired Kidney-Alone vs Simultaneous Heart-Kidney transplant (SHKT)			Paired Kidney-Alone vs Kidney after Heart transplant (KAH)		
Recipient Characteristics	**Kidney-Alone N = 1220**	**SHKT N = 1220**	***P***	**Kidney-Alone N = 246**	**KAH N = 246**	***P***
Age	48.0 (38.0–59.0)	59.0 (51.0–64.0)	<0.001	57.0 (48.0–65.0)	61.0 (51.0–67.0)	0.013
Male	684 (56%)	990 (81%)	<0.001	157 (64%)	181 (74%)	0.020
Race			<0.001			<0.001
White	406 (33%)	573 (47%)		100 (41%)	148 (60%)	
Black	419 (34%)	426 (35%)		88 (36%)	73 (30%)	
Hispanic	287 (24%)	134 (11%)		40 (16%)	14 (5.7%)	
Asian	83 (6.8%)	61 (5.0%)		16 (6.5%)	9 (3.7%)	
Others	25 (2.0%)	26 (2.1%)		2 (0.8%)	2 (0.8%)	
Body mass index	27.8 (24.2–32.1)	27.5 (24.2–31.1)	0.043	29.0 (25.5–32.9)	26.6 (23.7–29.6)	<0.001
Blood type			<0.001			0.93
A	370 (30%)	435 (36%)		109 (44%)	105 (43%)	
AB	49 (4.0%)	73 (6.0%)		20 (8.1%)	23 (9.3%)	
B	170 (14%)	195 (16%)		35 (14%)	38 (15%)	
O	631 (52%)	517 (42%)		82 (33%)	80 (33%)	
Hepatitis C positive serostatus	43 (3.5%)	35 (2.9%)	0.36	17 (6.9%)	9 (3.7%)	0.11
Diabetes	341 (28%)	584 (48%)	<0.001	106 (43%)	110 (45%)	0.72
Serum creatinine at transplant, mg/dL	8.3 (6.0–11.1)	2.5 (1.9–3.7)	<0.001	8.0 (5.9–10.9)	6.5 (3.9–8.4)	<0.001
Dialysis at transplant	1051 (86%)	324 (27%)	<0.001	206 (84%)	178 (72%)	0.002
Peripheral vascular disease	107 (8.8%)	171 (14%)	<0.001	31 (13%)	39 (16%)	0.30
Kidney waitlist time, days	586 (136–1557)	37 (11–137)	<0.001	682 (160–1404)	548 (155–1199)	0.21
Donor share type			<0.001			0.33
Local	716 (59%)	472 (39%)		159 (65%)	152 (62%)	
Regional	210 (17%)	293 (24%)		34 (14%)	46 (19%)	
National	294 (24%)	455 (37%)		53 (22%)	48 (20%)	
Cold ischemia time (hours)	16 (11–21)	16 (9–22)	0.060	18 (12–23)	18 (12–24)	0.60
Kidney on pump	417 (34%)	531 (44%)	<0.001	135 (55%)	141 (57%)	0.59

TABLE 3.

Outcomes of Paired Donor Kidney-Alone and Simultaneous Heart-Kidney and Paired Donor Kidney-Alone and Kidney After Heart Transplant Recipients

	Paired Kidney-Alone *vs* Simultaneous Heart-Kidney transplant (SHKT)			Paired Kidney-Alone *vs* Kidney after Heart transplant (KAH)		
Outcomes	**Kidney-Alone N = 1220**	**SHKT N = 1220**	***P***	**Kidney-Alone N = 246**	**KAH N = 246**	***P***
Length of stay, days	4 (3–6)	20 (14–32)	<0.001	5 (4–7)	5 (4–9)	0.001
				7 (8)	10 (16)	
Delayed kidney graft function	245 (20%)	363 (30%)	<0.001	82 (33%)	82 (33%)	0.99
Serum creatinine at discharge, mg/dL	2.40 (1.46–4.92)	1.29 (0.93–1.80)	<0.001	3.71 (2.17–6.47)	3.36 (1.48–5.67)	0.004
Serum creatinine at 6 months, mg/dL	1.21 (1.00–1.50)	1.31 (1.10–1.70)	<0.001	1.39 (1.10–1.80)	1.41 (1.11–1.83)	0.26
Serum creatinine at 1 year, mg/dL	1.20 (1.00–1.48)	1.30 (1.10–1.60)	<0.001	1.31 (1.08–1.70)	1.37 (1.10–1.73)	0.21
Rejection before discharge	11 (0.9%)	21 (1.7%)	0.11	2 (0.8%)	2 (0.8%)	0.99
Rejection (treated) 6 months	52 (4.3%)	18 (1.5%)	<0.001	12 (4.9%)	7 (2.8%)	0.34
Rejection (treated) 1 year	65 (5.3%)	27 (2.2%)	<0.001	12 (4.9%)	9 (3.7%)	0.67
Patient death 30 days	4 (0.3%)	51 (4.2%)	<0.001	2 (0.8%)	6 (2.4%)	0.29
Kidney survival 1-year rate	96.1%	83.9%	<0.001	89.6%	92.4%	0.75
Kidney survival 3-year rate	89.3%	78.8%		77.2%	75.3%	

$P < 0.001$) as well as lower rate of dialysis at time of transplant (72% *vs* 84%, $P = 0.002$) (Table 2). The transplant waiting time and cold ischemia time were comparable between the 2 groups. In the KAH recipients, the median time from initial HT to subsequent kidney transplant after was 3002 days.

Outcomes of Paired Kidney-Alone and SHKT

The median (IQR) follow-up period was 1.99 (0.74–3.97) years. Compared with kidney-alone, the median length of post-transplant hospital stay was longer in SHKT recipients (20 *vs* 4 days, $P < 0.001$) (Table 3). The incidence of kidney DGF was higher in SHKT (30% *vs* 20%, $P < 0.001$), but median serum creatinine at discharge was lower (1.29 *vs* 2.40 mg/dL, $P < 0.001$). Compared to kidney-alone, SHKT recipients had significantly higher 30-day mortality (4.2% *vs* 0.3%, $P < 0.001$), higher incidence of kidney graft rejection before discharge (1.7% *vs* 0.9%, $P = 0.011$), but lower incidence of kidney graft rejection requiring treatment at 6-months (1.5% *vs* 4.3%, $P < 0.001$) and at 1-year (2.2% *vs* 5.3%, $P < 0.001$) post-transplant.

Kidney GS between the 2 groups is shown in Figure 1A. Kidney GS among recipients of SHKT was significantly worse at 1-year (SHKT 83.9% *vs* kidney-alone 96.1%), and 3-year post-transplant (SHKT 78.8% *vs* kidney-alone 89.3%) (P<0.001).

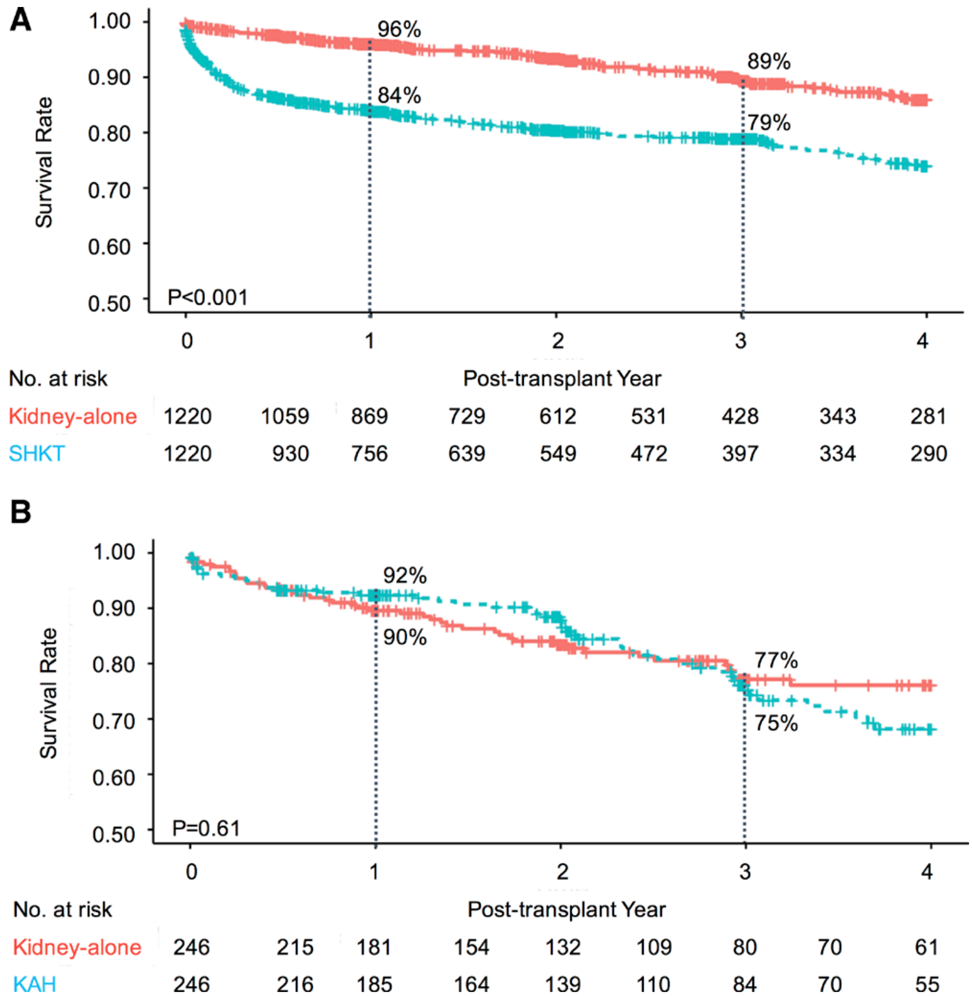

FIGURE 1. A, Kidney graft survival for kidney alone and simultaneous heart-kidney transplantation with paired donor kidneys. B, Kidney graft survival for kidney alone and kidney after heart transplant with paired donor kidneys.

Multivariable Cox proportional-hazard regression analysis showed that SHKT was associated with increased risk of kidney graft failure (aHR = 1.97; 95% CI = 1.56–2.47; P < 0.001) compared with kidney-alone transplant (Table 4). For SHKT recipients, the adjusted hazard for kidney graft failure was highest within the first 90-days post-transplant (aHR = 8.45; 95% CI = 5.02–14.2; P < 0.001), but no significant difference in conditional kidney graft on 1-year survival (aHR = 1.07; 95% CI = 0.78–1.46; P = 0.68) was seen.

Kidney Graft Failure in SHKT Recipients

In subgroup analysis of SHKT recipients (Supplemental Table 2, https://links.lww.com/AOSO/A507), multivariable Cox proportional-hazard regression analysis for 90-day kidney graft failure was associated with female (aHR = 1.79; P = 0.006), prior left ventricular assist device (LVAD) (aHR = 1.87; P < 0.001), Extracorporeal membrane oxygenation (ECMO) at time of HT (aHR = 2.22; P = 0.011), prolonged kidney cold ischemia time (aHR = 1.03; P = 0.007), and higher KDPI (aHR = 2.69; P = 0.038).

Multivariable Cox proportional-hazard regression analysis for 1-year kidney graft failure was associated with female (aHR = 1.63; P = 0.008), prior LVAD (aHR = 1.49; P = 0.013), ECMO at time of HT (aHR = 2.11; P = 0.005), prolonged kidney cold ischemia time (aHR = 1.03; P = 0.001), infection treatment before transplant (aHR = 1.73; P = 0.004), and younger donor age (aHR = 1.01; P = 0.043).

Outcomes of Kidney-Alone and KAH

The median (IQR) follow-up period was 2.07 (1.00–3.99) years. Compared to kidney-alone, the median length of post-transplant hospital stay was longer in KAH (10 *vs*. 7 days; P = 0.001) (Table 3). The incidence of kidney DGF was same between the 2 groups (33%). The median serum creatinine at discharge was lower in KAH (3.36 *vs* 3.71 mg/dL, P = 0.004), but there was no difference in serum creatinine at 6-month and 1-year follow-up.

KAH and kidney-alone recipients had comparable 30-day mortality (2.4% *vs* 0.8%; P = 0.29). KAH recipients had comparable episodes of kidney graft rejection at initial discharge, at 6-month and at 1-year post-transplant compared with kidney-alone recipients. Kidney graft survival between the 2 groups is shown in Figure 1B. Kidney graft survival at 1-year (KAH 92.4% *vs* kidney-alone 89.6%) and 3-years post-transplant (KAH 75.3% *vs* kidney-alone 77.2%) was comparable between the 2 groups (P = 0.75).

Multivariable Cox proportional-hazard regression analysis showed that KAH was not associated with an increased risk of kidney graft failure (aHR = 0.93; 95% CI = 0.63–1.36; P = 0.70) compared to kidney-alone (Table 4).

Difference in Kidney Graft Survival Between Paired SHKT or KAH and Kidney-Alone Transplantation

During the study period, restricted mean graft years for kidney-alone recipients was 4.55 years (standard error = 0.04)

TABLE 4.

Adjusted Hazard Ratio of Overall Kidney Graft Loss by Transplant Type

	Transplant Type	N	Events	Adjusted Hazard Ratio (95% CI)
90-day kidney graft loss	Kidney-alone	1220	18	1 (Reference)
	Simultaneous heart-kidney	1220	132	8.45 (5.02–14.2)
1-year kidney graft loss	Kidney-alone	1220	43	1 (Reference)
	Simultaneous heart-kidney	1220	183	4.36 (3.04–6.23)
Kidney graft loss conditioned on 1-year survival	Kidney-alone	872	2	1 (Reference)
	Simultaneous heart-kidney	775	18	1.07 (0.78–1.46)
Kidney graft loss	Kidney-alone	1220	137	1 (Reference)
	Simultaneous heart-kidney	1220	273	1.97 (1.56–2.47)
90-day kidney graft loss	Kidney-alone	246	9	1 (Reference)
	Kidney after heart transplant	246	11	1.33 (0.51–3.42)
1-year kidney graft loss	Kidney-alone	246	24	1 (Reference)
	Kidney after heart transplant	246	18	0.77 (0.40–1.48)
Kidney graft loss conditioned on 1-year survival	Kidney-alone	186	36	1 (Reference)
	Kidney after heart transplant	189	46	1.04 (0.66–1.65)
Kidney graft loss	Kidney-alone	246	56	1 (Reference)
	Kidney after heart transplant	246	60	0.93 (0.63–1.36)

Adjusted with age, gender, race, body mass index, diabetes.

compared with 3.98 years (standard error = 0.06) for SHKT within 5-year post-transplantation (P < 0.001) (Figure 2A). This difference of 0.57 kidney graft years lost over the 5-year period in SHKT recipients equates to 695 kidney graft year difference among 1220 paired transplants. Meanwhile, there was no significant difference in restricted mean graft years between KAH recipients (4.10 years, standard error = 0.12) and kidney-alone recipients (4.04 years, standard error = 0.12) (P = 0.72) (Figure 2B).

DISCUSSION

Using a paired donor model, our study shows that the kidney allograft outcomes in SHKT recipients are inferior to that of kidney-alone recipients, with a statistically significant loss of 57 kidney allograft years per 100 transplants in SHKT compared with kidney-alone.

Under the multiorgan allocation policy, transplant programs receive priority allocation of kidney along with other organ and the ability to choose the side of the kidney based on anatomy or other findings. Previous studies had shown potential benefits of SHKT, including improved survival of HT recipients with associated kidney dysfunction.[25,26] But similar benefits are less obvious in recent studies, and best practices for allocation and utilization of organs in simultaneous organ transplant are still being defined. An ideal allocation should ensure equitable access of these organs to kidney-alone transplant candidates for whom kidney transplantation offers a promising long-term survival and improved quality of life with a comparatively lower postoperative risk.[27] Therefore, current results of worse organ and patient survival during SHKT can help adjust the current paradigm of simultaneous transplants, especially with the protection offered under the new safety-net policy.

SHKT recipients had worse short-term outcomes than kidney-alone recipients for both patient survival.[12] This is likely associated with the complexities and complications associated with 2 major surgeries (eg, use of cardiopulmonary bypass, the fluctuations in the perioperative hemodynamics, fluid imbalance, and need for hemodynamic support[25,28–31]). Of these risk factors, mechanical circulatory support before HT, including ECMO, intra-aortic balloon pump, or percutaneous LVAD, is shown to be associated with increased mortality and kidney graft failure in the immediate postoperative period.[31] The risk of hemodynamic instability in the pre-, peri-, and postoperative periods creates a "kidney hostile milieu" that leads to higher rates of kidney primary nonfunction, graft failure, and mortality in the early post-transplant period.[12] Our previous study also confirms that utilization of ECMO or LVAD in SHKT recipients is associated with early kidney graft failure.[12] Under the current heart allocation policy, more candidates are on temporary mechanical circulatory support at the time of transplant,[20,32–34] thereby increasing the risk of hemodynamic instability that may further predict the risk of renal failure during the post-transplant period.

Current data is clear that SHKT recipients not only lose kidney grafts at a higher rate, but they are also at higher risk of mortality post-transplant.[12,13] So, the potential survival benefit described in earlier studies in a different cohort of SHKT candidates is not seen under the current allocation policy.[19] The criteria for SHKT remain nonstandardized and are very diverse across transplant centers, which also takes away the opportunity to study the impact of HT on renal recovery in SHKT recipients who were previously not on hemodialysis.

Presumed quality of donor kidneys used for SHKT is notably better than for those for kidney-alone recipients.[12] Therefore, a significant loss of these good-quality kidneys in SHKT recipients is creating an inequity of resources,[13] especially among KT candidates with many years of wait time, while also widening the preexistent gender and racial disparities in prelisted KT candidates.

A potential solution to maximize the kidney graft function and longevity is offered through the implementation of a "safety-net" policy for KAH.[22] The safety-net policy was originally developed for liver transplant recipients with nonreversible kidney dysfunction to increase their access to kidney transplant and to mitigate the worst outcomes of simultaneous liver-kidney transplant. Safety-net policy for liver-kidney transplants successfully increased access to all kidney transplants and improved transplant outcomes of kidney after liver transplant.[35,36] Under the safety-net policy, Schold et al[23] showed that there is a persistent difference in kidney graft survival between simultaneous liver-kidney and kidney-alone transplantation, which was mainly driven by early graft loss associated with recipient mortality. Not only kidney after liver transplant recipients have additional 21 graft years/100 transplants, but the resource utilization were lower as measured by adjusted kidney DGF and length of post-transplant hospital stay. A similar phenomenon is seen between SHKT and kidney-alone in our study, where the loss of additional kidney graft years is even higher at 57 graft years/100 transplants. Even though SHKT recipients received kidneys with the lowest KDPI (median 21%), which was better than KAH recipients (median KDPI 32%), the outcome of KAH was not inferior to kidney-alone.

KAH also had the added benefit of increased utilization of donation after cardiac death (DCD) donors. This could help to increase the overall utilization of organs since kidney survival in KAH is comparable to kidney-alone transplant and is better than SHKT. In the new era of machine perfusion, utilization of DCD donors for SHKT is also increasing.[37] Compared to donation after brain death donors, SHKT recipients from DCD donors have similar survival and freedom from graft failure and have significantly shorter waitlist time.[37] So, in the current period of safety-net and increased availability of DCD donors, our results can help guide transplant centers to improve the future candidate selection for SHKT *vs* KAH. While KAH has a selection

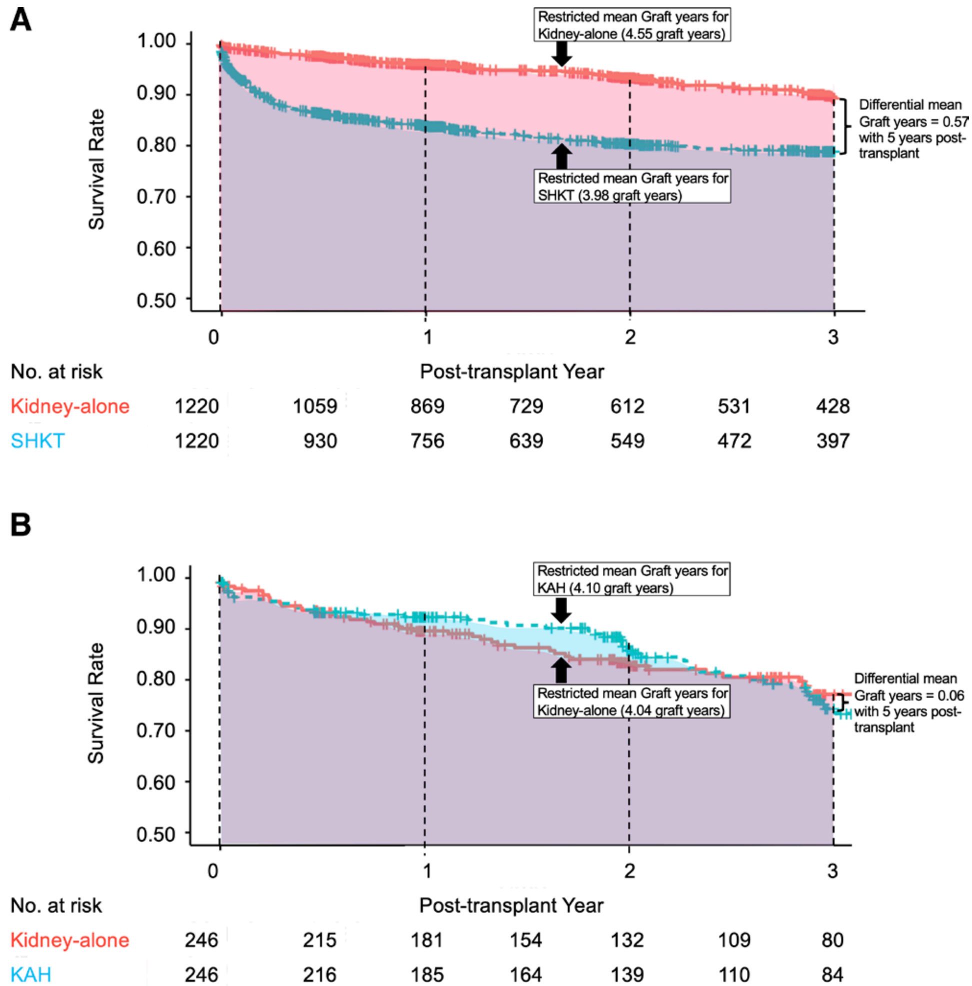

FIGURE 2. A, Differential in kidney graft years between kidney alone and simultaneous heart-kidney transplantation (follow-up 5 years post-transplantation). B, Differential in kidney graft years between kidney alone and kidney after heart transplantation (follow-up 5 years post-transplantation).

survival bias, in selected candidates, the strategy for KAH may offer a favorable approach to avoid kidney graft failure seen in early hostile conditions of SHKT.

In the present study, the recipient factors, such as the requirement of ECMO and LVAD[12] were also found to be associated with early kidney graft failure in SHKT recipients. Wayda et al[15] previously demonstrated that SHKT would have greater benefit in younger (18–49 years) HT candidates with renal dysfunction whose probability of renal recovery was less than 35%.[14] Using these data, we can try to define a prospective candidate who would benefit from survival advantage offered by SHKT *vs* candidates who would be at higher risk of immediate death and kidney graft failure post-SHKT. Future studies using paired donors to assess the impact of the safety-net in KAH recipients can further help the transplant centers to optimize patient selection in SHKT.

Overall, KAH transplant under safety-net policy offers many benefits: more graft years, early access to kidney transplant (within 6 months) for suitable candidates, lower risk of DGF, lower resource utilization, all while attempting to decrease the inequities created by SHKT.

We should also remain vigilant about the fact that a kidney transplant outcome in any high-risk group should not be based on absolute survival but on relative survival benefit. Therefore, any future prospective analysis, when evaluating outcomes after the introduction of safety-net, would also benefit from an additional relative survival benefit approach to ensure that the scarce resource, like kidney grafts, is utilized optimally.

Limitations of this study include a retrospective design using the UNOS database, inability to evaluate the detailed information regarding the causes of patient's death and graft failure, and the post-transplant complications, especially in acute kidney injury, and the duration of kidney DGF was not available in the database. The diagnosis of the causes of kidney graft failures was relied upon in the report to UNOS, and the diagnosis would vary in each transplant program and was not universally defined in this study. In addition to these, the perioperative hemodynamic instability, including the mechanical support and utilization of vasopressors, bleeding complications, including blood transfusions and postoperative duration of hemodialysis or renal insufficiency, and renal recovery were not available. Only KAH recipients were analyzed, so the outcomes remain unclear in HT recipients who were listed for KAH but never received a subsequent kidney transplant.

CONCLUSIONS

SHKT compared with paired kidney-alone transplants was associated with significantly lower kidney graft survival, while KAH compared with paired kidney-alone transplant had comparable kidney graft survival. Potential benefits of KAH in the safety-net era include an increase in duration of preserved kidney graft function, access to kidney transplant within 6 months of HT, lower risk of kidney DGF and graft loss, lower resource utilization, and decrease in inequities associated with SHKT.

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AUTHOR CONTRIBUTIONS

Concept/design: K.O., S.O., and A.D. Data analysis/interpretation: K.O., S.O., and A.D. Drafting article: K.O., S.O., and A.D. Critical revision of article: K.O., S.O., R.M., S.N., S.L., and A.D. Statistical analysis: K.O., S.O., and A.D. Approval of article: All authors.

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