Differential Impact of the UNOS Simultaneous Liver-kidney Transplant Policy Change Among Patients With Sustained Acute Kidney Injury

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Background. Simultaneous liver-kidney transplant (SLK) allocation policy in the United States was revised in August 2017, reducing access for liver transplant candidates with sustained acute kidney injury (sAKI) and potentially adversely impacting vulnerable populations whose true renal function is overestimated by commonly used estimation equations. **Methods.** We examined national transplant registry data containing information for all liver transplant recipients from June 2013 to December 2021 to assess the impact of this policy change using instrumental variable estimation based on date of listing. **Results.** Posttransplant survival was compared for propensity-matched patients with sAKI who were only eligible for liver transplant alone (LTA_post; n = 638) after the policy change but would have been SLK-eligible before August 2017, with similar patients who were previously able to receive an SLK (SLK; n = 319). Overall posttransplant patient survival was similar at 3 y (81% versus 80%; $P = 0.9$). However, receiving an SLK versus LTA increased survival among African Americans (87% versus 61% at 3 y; $P = 0.029$). A trend toward survival benefit from SLK versus LTA, especially later in the follow-up period, was observed in recipients ≥ age 60 (3-y survival: 84% versus 76%; $P = 0.2$) and women (86% versus 80%; $P = 0.2$). **Conclusions.** The 2017 United Network for Organ Sharing SLK Allocation Policy was associated with reduced survival of African Americans with end-stage liver disease and sAKI and, potentially, older patients and women. Our study suggested the use of race-neutral estimation of renal function would ameliorate racial disparities in the SLK arena; however, further studies are needed to reduce disparity in posttransplant outcomes among patients with liver and kidney failure.

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INTRODUCTION

The adoption of the Model of End-Stage Liver Disease (MELD) score to guide the Organ Procurement and Transplantation Network (OPTN) liver allocation policy in 2002 led to a significant increase in the number of simultaneous liver-kidney transplants (SLKs), as the inclusion of serum creatinine in the MELD score results in prioritization of liver transplant (LT) candidates with acute and chronic kidney injury.[1] The rapid increase in the SLK rate generated controversy, as a significant proportion of SLK recipients were believed to have potentially reversible hepatorenal syndrome (HRS) or acute tubular necrosis (ATN). Thus, combined transplant may result in the unnecessary transplant of a high-quality kidney in a multiorgan recipient, despite the ever-growing waiting list for kidney transplant (KT) alone (KTA).[2,3] This allocation practice was asserted by some transplant professionals to be contrary to the OPTN Final Rule[4] due to concerns about the potentially unwarranted priority for dual organ transplants for kidney allografts. In response, the OPTN adopted revised criteria for SLK allocation in August 2017, which limited access to KT for certain LT

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candidates with sustained acute kidney injury (sAKI) and chronic kidney disease (CKD). The policy also allowed patients who underwent LT alone (LTA) with sustained kidney dysfunction after LTA to qualify for a "Safety Net" kidney, which prioritized access to KT for LTA recipients with continued dialysis dependency or kidney dysfunction in the first year (provided they are registered on the KTA waiting list within 365 d).[5] The primary goals of the policy change were to preserve access to KT without compromising LT patient and graft survival.[6]

Recent analyses of OPTN registry data[7] support the early success of the revised SLK policy. After the implementation of this policy, the proportion of LTs that were SLK decreased from 9.7% to 8.7%, and registration for kidney after LT (KALT) increased from 1.8 to 7.6 candidates per month nationally. Ninety-four percent of KALTs were "Safety Net" eligible, and the posttransplant patient and graft survival of KALT and KTA recipients were comparable.

These data supported the inference that the 2017 SLK policy change did not impact patient survival and may support more equitable distribution of organs for those awaiting KTA. Importantly, the impact of this policy on survival among subgroups of patients with sAKI who are now precluded from SLK is understudied.[8] If the proportion of patients with sAKI who are now ineligible for SLK is increasing and posttransplant survival is impaired for at-risk populations, revision of the policy to ensure equivalent access may be warranted. To rigorously assess the impact of the 2017 SLK policy on posttransplant outcomes of patients with liver failure and sAKI, we compared patients who are no longer eligible for SLK under the current policy versus similar patients who received SLK before August 2017. Using this analytic framework, we assessed the specific implication of the policy in potentially vulnerable subgroups, including an assessment of differential outcomes by race, age, and sex.

MATERIALS AND METHODS

Dataset

This study is a retrospective cohort study using the Organ Procurement Transplant Network (OPTN)/United Network for Organ Sharing (UNOS) Standard Transplant Analysis and Research file. The content of the analysis is the responsibility of the authors alone and does not necessarily reflect the views or policies of the Department of Health and Human Services. Mention of trade names, commercial products, or organizations does not imply endorsement by the US Government. This study was approved by the University of Iowa Institutional Review Board (No. 202203636).

The cohort included adult (age ≥18 y), first-time deceased donor LT recipients who were listed for LTA or SLK between June 18, 2013, and, January 31, 2020, with follow-up through December 31, 2021. Baseline characteristics of the recipients while on the waitlist and posttransplant were obtained through the "LIVER_DATA" file. The trajectory of the estimated glomerular filtration rate (eGFR) was calculated based on the "LIVER_WLHISTORY" file, which contains all recorded serum creatinine levels with dates for all the candidates. We used the 2009 Chronic Kidney Disease Epidemiology Collaboration (CKD-EPI) equation, widely used for UNOS kidney allocation[9] until June 2022. Candidate renal function was assessed to determine if they had sufficient waitlist time with an eGFR ≤30 or dialysis dependance to qualify for SLK under current allocation policy. We subsequently conducted a simulation analysis calculating eGFR of LT candidates using the race-neutral 2021 CKD-EPI equation to assess the impact on candidacy for SLK.[10]

We included all LT candidates who were listed after June 18, 2013. This date was chosen taking the 2 major LT-related events into account: (1) the implementation of the Share 35 policy on June 18, 2013,[11] and (2) the development of novel direct-acting antivirals for hepatitis C infection[12] (sofosbuvir was approved by U.S. Food and Drug Administration in December 2013). Patients were followed from the date of LT/SLK to posttransplant death, loss to follow-up, or end of the study period. Retransplants and combined organ recipients, except for SLK, were excluded.

Study Design

To determine the impact of the allocation policy on posttransplant survival, we compared posttransplant survival of recipients of SLKs with matched recipients of LT alone. An instrumental variable (IV) estimation method was used to control for confounding and measurement errors.[13] An IV is a factor associated with the exposure (organ allocation) but not with the outcomes (posttransplant patient survival) except through its impact on the exposure; in this study, the listing date (before or after August 10, 2017) was used. Although calendar time can be confounded with a variety of patient and practice-related factors, its selection as an IV here is consistent with recommendations that it be restricted to contexts in which dramatic changes in practice occur over a small interval of time.[14] The SLK group was composed of all SLK recipients with sAKI listed for SLK before August 10, 2017, who would not meet the new OPTN SLK criteria. That is, those who (i) received SLK and were listed between June 18, 2013 and August 9, 2017; (ii) were diagnosed as acute kidney injury (AKI) (defined as those whose etiology for kidney listing being ATN or HRS); and (iii) the duration of having end-stage kidney disease (defined by [a] on hemodialysis and/or [b] eGFR ≤25 mL/min per 1.73 m^2) was <6 wk, which would exclude them from SLK under the new policy. The LTA group was composed of LTA recipients with sAKI who were listed between August 10, 2017, and January 31, 2020, and would have been eligible for SLK if they had been listed before August 10, 2017, namely, those who meet the same inclusion criteria of (ii) and (iii) and labeled as LTA_post. Those who were listed after February 1, 2020, were excluded to avoid the impact of the COVID-19 pandemic[15] and the Acuity Circle policy.[16] Patients who received LT alone before August 10, 2017, but could have qualified for SLK under the prior criteria were labeled as the LTA_pre-group. The decision to perform LT alone during this period reflects clinical judgment and practice guidelines.[17] It is important to note that before the new allocation system, a KT safety net was not available for patient who did not recover kidney function, leading some clinicians to choose SLK in this population. To account for differences in patient characteristics among patients who eligible for both (SLK and LTA_pre), a propensity score was calculated to assess the

likelihood of listing for SLK.[18] Each patient's propensity score to receive an SLK was calculated as a probability from a logistic regression model. Covariates used in the model in the propensity score include (1) age; (2) sex; (3) race; (4) UNOS region; (5) etiology of liver disease; (6) hospitalization status at LT (home versus hospitalized versus intensive care unit [ICU]); (7) days between listing to transplant; and (8) hemodialysis at LT (**Table S1, SDC**, http://links.lww.com/TP/C867).[19] The magnitude of missing data in the propensity score-matched cohort was minimal (<1% among covariates). The propensity score was then used to match SLK (pre-policy) with LTA_post (post-policy) at a 1:2 ratio using nearest neighborhood matching.

The same procedure including the propensity score matching was performed for each stratum of the study population based on race (White, African American, Hispanic, Asian, and others), age (below and above 60 y), and sex to consider the impact of the policy changes on potentially vulnerable subgroups who may be at particular risk for overestimation of true GFR by the 2009 CKD-EPI equation.

Statistical Analysis

The matched patient populations were analyzed to confirm comparability and determine survival outcome. Continuous data were reported as mean and SD and categorical data by counts and percentages. Comparison of groups was with a 2-sided Student's *t* test for continuous data and χ^2 test as appropriate for categorical data. Posttransplant patient survival rates in each group of recipients were analyzed using Kaplan–Meier curves and compared using the log-rank test. All reported *P* were 2-sided, and $P < 0.05$ were considered to be statistically significant. Statistical analyses were performed with R software packages (version 4.2.0 [R Foundation for Statistical Computing, Vienna, Austria]).

RESULTS

Study Sample

Among 109 626 LT candidates registered on the waitlist between June 18, 2013, and January 31, 2020, 63 904 received deceased-donor LT, including 319 patients classified as SLK group who were transplanted before the new allocation system and would not meet current listing criteria, 8669 patients who were listed for LTA alone despite having evidence of sAKI and potentially eligible for SLK (LTA_pre), and 5965 in the LTA_post-group transplanted after the new allocation policy reduced access. The analytic cohort matched the 319 SLK recipients eligible before policy shift to 638 LTA_post were who demographically similar but precluded from SLK after the policy shift (Figure 1).

Recipient Characteristics and Propensity Score Matching

Demographic and recipient characteristics among patients with who were listed for LTA and SLK differed significantly (Table 1). Among the past_SLK group, there were significantly higher numbers of patients with hemodialysis at LT, alcoholic liver disease, and fewer patients with hepatitis C virus, ascites at LT, and ICU stay at LT, than those in LTA_pre-group. The distribution of race/ethnicity (White/non-Hispanic, Hispanic, African American, Asian, and others), and UNOS regions were significantly different. Among LT candidates with sAKI, older age, hepatitis C, and longer time on the waiting list were associated with listing for LTA. Conversely, LT candidates with AKI who were African American, diagnosed with alcoholic liver disease or nonalcoholic steatohepatitis, and who were in the ICU were more likely to be listed for SLK. Regional differences were also noted as patients outside of UNOS regions 1 and 5 were more likely to be listed for SLK.

After propensity score matching, the demographics differences between the populations were attenuated and population demographics were similar. Standardized mean differences (SMDs) for each covariate after propensity score matching were within 0.2, suggesting comparable populations (**Figure S1, SDC**, http://links.lww.com/TP/C867).[20] In the subgroup analysis, the SMDs for the covariates in the matched cohort were also within 0.2.

Patient Outcomes

Patient survival following transplantation was similar between the matched SLK and LTA_post-groups (1-y survival: 87% versus 89%; 3-y survival: 81% versus 80%; $P = 0.9$; Figure 2A). Among 638 matched LTA_post-recipients, 499 patients who were alive at 1-y posttransplant, 76 (15.2%) were on KT waitlist, and 49 (9.8%) received subsequent (KT) at the end of the follow-up. Out of the 76 KT candidates, 59 (78%) were listed within 1-y post-LTA. The majority of the KT recipients (n = 45) received KTA within 1 y of LTA and 5 KT candidates were on waitlist for <12 mo at the end of the follow-up, suggesting the use of the "Safety Net" KT priority. Among the other listed patients, 3 died on KT waitlist, 2 experienced improved kidney function and were removed, 2 received living-donor KT, and 2 were on KT waitlist >12 mo. This "Safety Net" KT group (n = 50) included 29 (58%) White, 8 (16%) African American, 11 (22%) Hispanic non-White, and 2 (4%) Asian, 16 (32%) patients with age ≥ 60 y and 17 (34%) women.

African Americans who received SLK had better survival than comparable patients who underwent LTA (1-y: 89% versus 83%; 3-y: 87% versus 61%; $P = 0.03$; Figure 2B). Asian patients showed a trend toward better survival with SLK (1-y: 100% versus 100%; 3-y: 100% versus 84%; $P = 0.07$). Patients ≥ 60 y showed a trend toward benefit from SLK compared with LTA at 3 y (1-y: 89% versus 89%; 3-y: 84% versus 76%; $P = 0.20$; Figure 2C), although the sample size was limited. Procedure type did not significantly impact survival among women (1-y: 91% versus 90%; 3-y 86% versus 80%; $P = 0.24$; Figure 2D). Note that all the matched cohort of the subgroups (African American, Asian, patients with age ≥ 60 and women) had similar demographic and clinical variables ($P > 0.05$) and decently small SMDs (<0.2).

Potential Outcomes of Using 2021 CKD-EPI

In a simulation analysis evaluating the impact of policy changes using the race-neutral 2021 CKD-EPI for eGFR, in total, 66 more out of all 417 African Americans in the LTA_post-group (and 14 more out of the initially matched 80 subjects) would have been eligible for SLK before the SLK policy change, but they were excluded based on eGFR

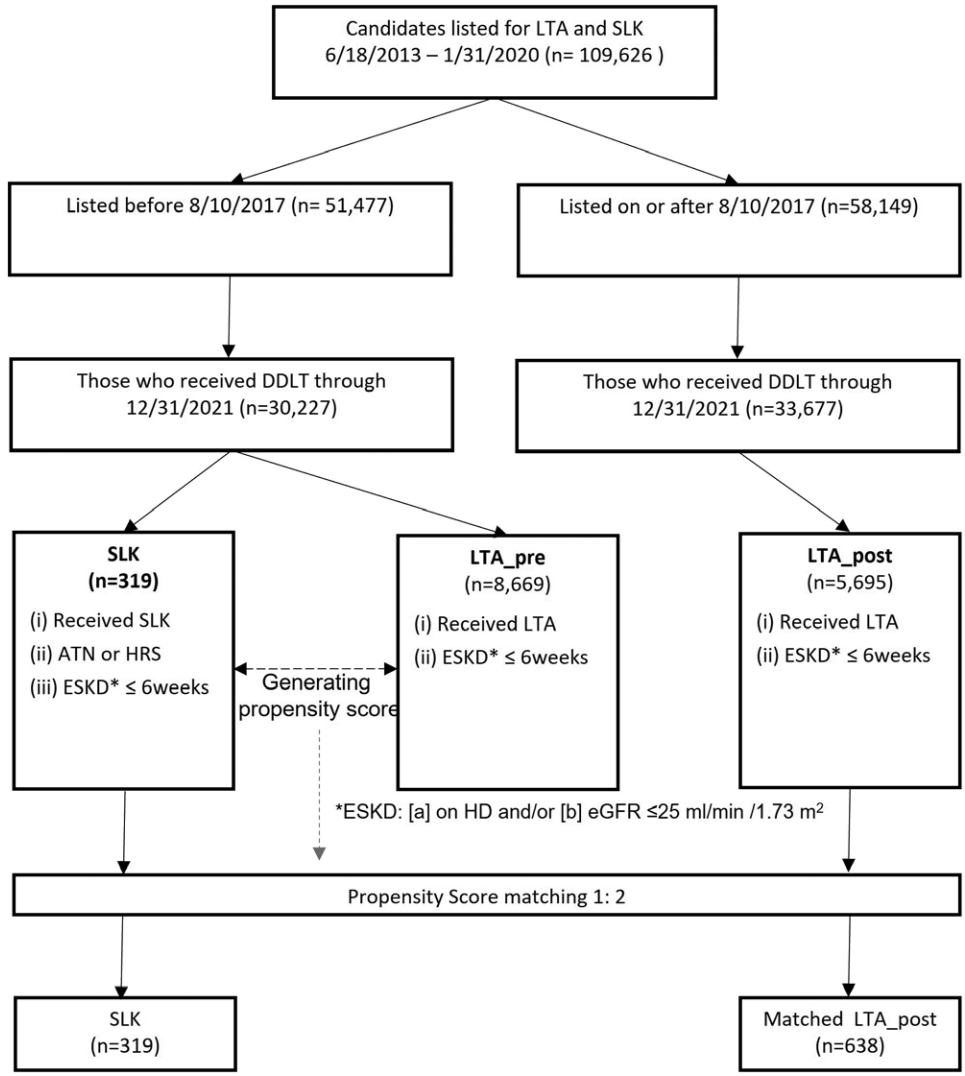

FIGURE 1. Patient selection flowchart. ATN, acute tubular necrosis; DDLT, deceased donor liver trasnsplantation; eGFR, estimated glomerular filtration rate; ESKD, end-stage kidney disease; HD, hemodialysis; HRS, hepatorenal syndrome; LTA, liver transplant alone; SLK, simultaneous liver-kidney transplant.

that exceeded current policy thresholds. Had these patients received SLK, differences in posttransplant survival would have been ameliorated (**Figure S2B, SDC,** http://links.lww.com/TP/C867). Thus, the African Americans with sAKI would have had similar survival with and without SLK (P = 0.17) once the race disparity in eGFR estimate was eliminated.

DISCUSSION

The current study demonstrates that the 2017 eligibility policy for SLK was not associated with a significant overall decrease in posttransplant survival among the majority patients with liver failure and sAKI. Furthermore, < 10% of patients with sAKI who underwent LTA under the new policy required a KT within 1 y. However, African Americans who were no longer eligible for SLK given eGFR cutoffs were found to have significantly diminished survival. There were nonstatistically significant trends toward survival decrements for women and older adults (age ≥ 60 y) who were only eligible for LTA under the new criteria, with power limited by the sample size of the matched cohort.

Before the 2017 allocation policy, many centers followed recommendations by the consensus conference sponsored by relevant societies and refrained from listing patients with AKI who had relatively short periods of renal dysfunction.[17] This practice is supported by our data (Figure 1), which demonstrated that among 8669 patients with should term renal impairment received only a liver allograft (29% of all liver recipients before 2017). Conversely, 319 recipients received an SLK who would not have qualified after 2017, constituting only approximately 1% of pre-2017 liver recipients. However, there were data demonstrating a rapid increase in utilization of SLK given MELD based allocation systems, which led to the need for a policy revision.[8]

Before the revised SLK policy was implemented in 2017, retrospective cohort studies reported comparable patient outcomes between LTA and SLK in patients with reversible kidney injury.[8] Studies that evaluated the impact of the revised SLK policy using a cohort waitlisted after August 2017 are mixed in terms of the overall survival benefit of SLK posttransplant, presumably given the heterogeneity of inclusion criteria in the LTA reference groups.[21–23]

TABLE 1.

Patient characteristics of SLK and matched LTA_post-group as well as LTA_post (nonmatched) and LTA_pre

	SLK	LTA_post (matched)	P[a]	LTA_post (nonmatched)	P[a]	LTA_pre	P[a]
n	319	638		5965		8669	
Age[b]	55.34 (10.66)	54.09 (11.33)	0.101	52.56 (11.90)	<0.001	53.89 (10.59)	0.011
Men = Y (%)	196 (61.4)	370 (58.0)	0.34	3347 (56.1)	0.07	4851 (56.0)	0.006
Race (%)			0.456		0.013		0.264
White	214 (67.4)	425 (66.6)		4127 (69.2)		6077 (70.1)	
African American	40 (12.3)	61 (9.6)		417 (7.0)		702 (8.1)	
Hispanic	50 (15.7)	110 (17.2)		1070 (17.9)		1484 (17.1)	
Asian	9 (2.8)	19 (3.0)		213 (3.6)		266 (3.1)	
Native American	5 (1.6)	14 (2.2)		79 (1.3)		78 (0.9)	
Other	1 (0.3)	9 (1.3)		59 (1.0)		62 (0.7)	
Etiology (%)			0.325		<0.001		0.001
Alcoholic	91 (28.6)	198 (31.1)		2716 (45.5)		2013 (23.2)	
NASH	69 (21.6)	130 (20.4)		1158 (19.4)		1268 (14.6)	
HCV	73 (22.9)	114 (17.9)		358 (6.0)		2084 (24.0)	
Other	86 (27.0)	196 (30.7)		1733 (29.1)		3304 (38.1)	
BMI at LT[b]	29.68 (6.90)	30.38 (6.90)	0.139	30.24 (6.87)	0.157	29.86 (6.48)	0.458
HD at LT = Y (%)	224 (70.2)	402 (63.0)	0.032	3394 (56.9)	<0.001	4074 (47.0)	<0.001
MELD score at LT[b]	34.88 (7.16)	36.01 (7.44)	0.026	36.35 (7.58)	0.001	35.68 (8.08)	0.089
HE at LT= Y (%)	255 (79.9)	508 (79.6)	0.977	4811 (80.7)	0.808	6947 (80.1)	0.862
Ascites at LT = Y (%)	293 (91.8)	577 (90.4)	0.551	5322 (89.2)	0.164	7681 (88.6)	0.066
Days on waitlist[b]	104.61 (182.06)	77.72 (150.58)	0.015	54.11 (129.23)	<0.001	140.59 (315.94)	0.232
UNOS region (%)			0.686		<0.001		<0.001
1	10 (3.1)	33 (5.2)		260 (4.4)		344 (4.0)	
2	28 (8.8)	61 (9.6)		776 (13.0)		989 (11.4)	
3	49 (15.4)	91 (14.3)		817 (13.7)		1243 (14.3)	
4	24 (7.5)	51 (8.0)		664 (11.1)		852 (9.8)	
5	59 (18.5)	117 (18.3)		1272 (21.3)		2026 (23.4)	
6	4 (1.3)	19 (3.0)		164 (2.7)		254 (2.9)	
7	62 (19.4)	113 (17.7)		528 (8.9)		830 (9.6)	
8	19 (6.0)	29 (4.5)		252 (4.2)		501 (5.8)	
9	21 (6.6)	38 (6.0)		363 (6.1)		397 (4.6)	
10	17 (5.3)	26 (4.1)		383 (6.4)		573 (6.6)	
11	26 (8.2)	60 (9.4)		486 (8.1)		660 (7.6)	
Location at LT (%)			0.783		<0.001		<0.001
ICU	111 (34.8)	228 (35.7)		2873 (48.2)		3972 (45.8)	
Hospitalized	128 (40.1)	263 (41.2)		2258 (37.9)		3272 (37.7)	
Nonhospitalized	80 (25.1)	147 (23.0)		834 (14.0)		1425 (16.4)	
Cold ischemic time ≥ 300 min = Y (%)	227 (71.2)	453 (71.0)	1	4057 (68.0)	0.265	6131 (70.7)	0.518
Donor age ≥ 60 (%)	22 (7.0)	60 (9.4)	0.16	594 (10.0)	0.06	815 (9.4)	0.10

[a]*P* values are as compared with the SLK group.
[b]Mean (SD).
BMI, body mass index; HCV, hepatitis C virus; HD, hemodialysis; HE, hepatic encephalopathy; ICU, intensive care unit; LT, liver transplant; LTA, liver transplant alone; MELD, Model of End-Stage Liver Disease; NASH, nonalcoholic steatohepatitis; SLK, simultaneous liver-kidney transplant; UNOS, United Network for Organ Sharing.

Wilk et al[7] reported that the implementation of the revised 2017 OPTN SLK policy led to a significant decrease in the number of SLK procedures. Our study corroborates the finding by Wilk et al[7] and further demonstrates that the new criteria substantially reduced the number of unnecessary SLK procedures for patients with LT candidates and sAKI (accounting for >90% of all SLK cases) while maintaining good patient outcomes for most individuals. These findings suggest that the revised criteria could have a positive impact on overall transplant outcomes for LT and KT candidates on a societal level, by preserving access to kidney allografts for KT candidates. Importantly, although infrequently used, the "Safety Net" kidney allocation provided an important protection for patients who did not recover sufficient native kidney function after LTA.[24-26] Our findings suggest that the "Safety Net" kidney allocation adequately rescued non-Black patients who lost the SLK eligibility after the 2017 policy change.

Despite the largely beneficial outcome of the new allocation system, this analysis demonstrated that Black patients who were now ineligible for SLK experienced worse post-transplant outcome. The outcome disparity among Black

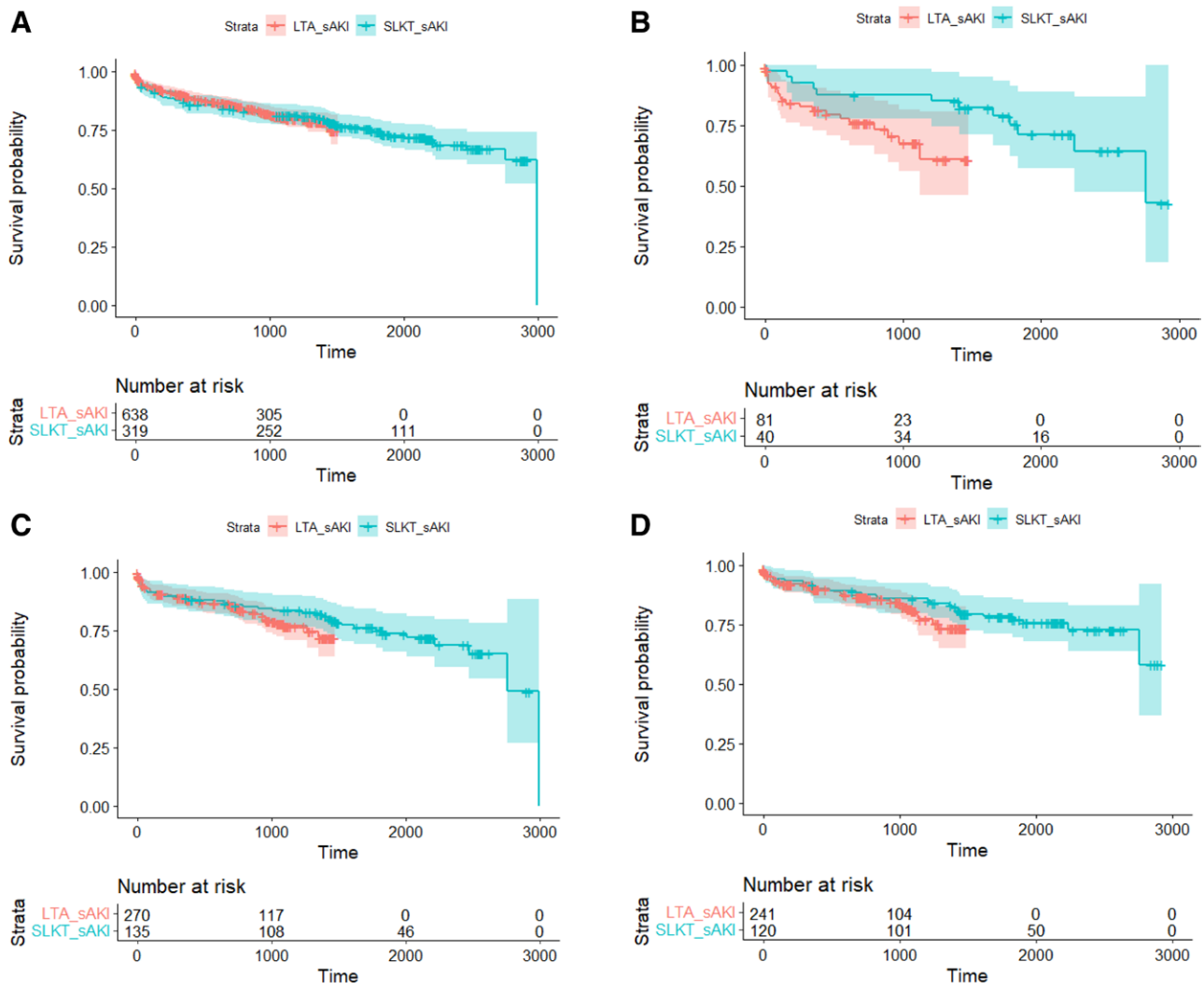

FIGURE 2. Kaplan–Meier analysis comparing the patient survival between SLK and LTA_post-groups, with results of log-rank tests for (A) the entire group ($P = 0.9$), (B) a stratified group of African Americans ($P = 0.029$), (C) a stratified group of patients ≥ 60 y ($P = 0.20$), and (D) a stratified group of women ($P = 0.24$). LTA, liver transplant alone; sAKI, sustained acute kidney injury; SLK, simultaneous liver-kidney transplant.

patients appeared to reflect the use of the 2009 CKD-EPI equation to calculate estimated GFR. This equation has been shown to systematically overestimate renal function in Black patients, thereby reducing access to SLK for Black patients with advanced liver disease and sAKI, as patients with eGFRs >30 mL/min/1.73 m^2 for CKD or >25 mL/min/1.73 m^2 for sAKI no longer qualified for SLK.[27,28] To address this issue, the transplant community recommended the implementation of a refit CKD-EPI eGFR creatinine formula, which excludes racial variables in all laboratories.[10,29] On June 27, 2022, OPTN adopted a new policy requiring this race-neutral calculation (2021 CKD-EPI) for GFR estimation for kidney allocation, which may ameliorate the survival differences demonstrated here.[9] Using this equation, we estimated that 66 additional African American candidates would have been eligible for SLK, which, in turn, would have eliminated the difference in posttransplant survival. Impaired posttransplant survival in Black LTA recipients may also indirectly support that the "Safety Net" did not function to rescue those with sustained renal injury following LTA, again, partly due to the use of prior 2007 CKD-EPI equation.[30,31] These data suggest that all patients listed for LT should have renal function reestimated using the race-neutral 2021 CKD-EPI equation, and candidacy for SLK reconsidered accordingly and further evaluation is need to ensure that the use of the 2021 CKD-EPI equation results in equitable access to SLK or kidney safety net transplant for all patients regardless of their race.

Commonly used eGFR equations, including 2021 CKD-EPI, may also overestimate actual renal function in older adults[32,33] and Asian persons[34,35] who have lower total muscle mass. Women may face an additional burden as their degree of liver disease is frequently underestimated with the MELD-Na score, whereas renal function is overestimated, potentially limiting access to SLK when needed.[36,37] These factors might have been related to the trend toward a worse long-term prognosis for those these subpopulations of candidates with sAKI who did not receive SLK. This analysis was limited in power to confirm this observation, but further study is needed.

Our current study has several limitations. First, there might have been potential misclassification of sAKI. The transplant registry contains creatinine values, which are only recorded during MELD updates or MELD score increases, resulting in potential misclassification of sAKI. However, requirements to frequently update patients with MELD scores > 35 should reduce the risk of error as patients in the study have an average MELD score > 36. Furthermore, the definition of sAKI in the SLK group was based on the diagnosis of ATN or HRS registered in OPTN reporting forms, and this variable was not available for LTA_pre- and LTA_post-groups. Although they could have included some patients with CKD, there is no evidence that this misclassification would occur more commonly in the LTA versus SLK groups. We believe our inclusion criteria, which included end-stage kidney disease duration, should have accurately excluded the majority of patients with preexisting CKD. Second, given the nature of this retrospective design using a registry-based dataset, standard patient level variables, such as comorbidities, which are known to be associated with the risk of sAKI, perioperative and posttransplant mortality, are not available in the Standard Transplant Analysis and Research file. Likewise, we do not have clear explanations for why those in LTA_pre did not receive or were not listed for SLK. Also, the sample size in the subgroup analysis (older patients, women) may be insufficient, potentially leading to a lack of statistical power. However, it is worth noting that these analyses included the entire target population in the United States in which women[38] and older patients[39] tend to be less commonly listed and transplanted. Despite the current results being from limited sample size, it is imperative to provide equal treatment to all vulnerable populations (especially given their limited access to transplantation[40]). These issues are likely to be exacerbated by the shift to acuity circles, which results in higher median MELD scores at transplant in many regions and a higher incidence of patients with compromised kidney function. Third, other unmeasured changes in organ availability or practice may confound causal inference analysis (ie, potential violation of the assumptions for the application of IV[41]) from time series data. Although some differences may reflect the improvement in transplant practice over time; however, we believe the combined application of IV method and propensity score matching resulted comparable populations. The finding of similar outcomes overall but highly significant differences in the Black patients suggests that observed effect is not the result of confounding due to practice. The study period of our analysis (from June 2013 to January 2020) also eliminated major confounding factors including the introduction of Share 35,[11] widespread access to direct-acting antivirals for hepatitis C virus (especially sofosbuvir),[12] implementation of Acuity Circles, and the changes in practice resulting from the COVID-19 pandemic. Indeed, the Scientific Registry of Transplant Recipients annual report shows, for example, comparable 1-y patient death rates of 6.4% in 2019 and 8.1% in 2013,[42] which supports this statement. Fourth, the propensity score was LT center specific, and therefore, center-specific effects may be present. This was done to avoid violating the positivity assumption that each eligible patient had a positive probably of receiving SLK or LTA,[43] because 52 centers did not perform SLK and 22 performed only 1 case of SLK for LT candidates with sAKI (based on our inclusion criteria). We used UNOS region as a covariate as a proxy for organ availability supply differences.

In conclusion, the 2017 UNOS SLK policy for candidates with sAKI did not adversely impact posttransplant survival in the majority of recipients. However, the policy appears to have adversely affected African Americans, and potentially, older candidates and women. Recent modifications to the equation to calculate eGFR may have ameliorated some race-based disparities, but these findings demonstrate the need for ongoing assessment to assess of posttransplant outcomes to ensure equity. Further studies, by potentially including more granular data on patient and center level variables with electronic health record-based or claim-based dataset, evaluating other LT-related outcomes including patient quality of life and readmission rate, which are improved with early KT, should be considered to comprehensively assess the impact reduced access to KT among LT candidates with impaired renal function.

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