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Predictors of Length of Stay and Mortality During Simultaneous Liver-Kidney Transplant Index Admission: Results From the US-Multicenter SLKT Consortium

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Background. Length of stay (LOS) during index solid organ transplant impacts morbidity and healthcare costs. To date, there are no studies evaluating characteristics and outcomes of simultaneous liver-kidney transplant (SLKT) index hospitalization. We examined factors associated with LOS and mortality during index SLKT admission. **Methods.** Adult SLKT recipients between 2002 and 2017 at 6 transplant centers across 6 UNOS regions were retrospectively enrolled in the US-Multicenter SLKT Consortium. Multivariable regression analyses assessed predictors of SLKT LOS and death during index admission. **Results.** Median age of cohort (N = 570) was 58 y (interquartile range: 51–64); 63% male, 75% White, 32.3% hepatitis C, 23.3% alcohol-related, 20.1% nonalcoholic steatohepatitis with median MELD-Na at SLKT 28 (23–34). Seventy-one percent were hospitalized at the time of SLKT with median LOS pretransplant of 10 d. Majority of patients were discharged alive (N = 549; 96%), and 36% were discharged to subacute rehab facility. LOS for index SLKT was 19 d (Q1: 10, Q3: 34 d). Female sex ($P = 0.003$), Black race ($P = 0.02$), advanced age ($P = 0.007$), ICU admission at time of SLKT ($P = 0.03$), high MELD-Na ($P = 0.003$), on cyclosporine during index hospitalization ($P = 0.03$), pre-SLKT dialysis ($P < 0.001$), and kidney delayed graft function ($P < 0.001$) were the recipient factors associated with prolonged LOS during index SLKT hospitalization. Prolonged LOS also contributed to overall mortality (HR = 1.007; $P = 0.03$). **Conclusions.** Despite excellent survival, index SLKT admission was associated with high-resource utilization with more than half the patients with LOS >2 wk and affected overall patient survival. Further investigation is needed to optimize healthcare resources for these patients in a financially strained healthcare landscape.

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INTRODUCTION

Simultaneous liver-kidney transplantation (SLKT) is a critical life-saving treatment for liver transplant (LT) candidates with certain forms of acute kidney injury deemed irreversible, advanced chronic kidney disease, or specific metabolic disorders.[1] The prevalence of chronic kidney disease among liver transplant candidates has increased significantly, largely as a consequence of evaluating older patients and those with nonalcoholic steatohepatitis (NASH) and metabolic syndrome.[2] This rise in NAFLD, diabetes, and associated chronic kidney disease in these liver transplant candidates has resulted in a notable rise in the incidence of SLKTs performed in the United States.[2]

Length of stay (LOS) of index solid organ transplantation has been associated with increased morbidity and mortality. In kidney-alone transplant, both donor and recipient factors have been associated with increased LOS and cost, as measured by Medicare payments.[3,4] LOS in liver transplant recipients has been previously validated as a surrogate marker for resource utilization, associated with increased costs and readmission rates.[5,6] Moreover, increased LOS of index lung transplant was associated with increased mortality at both 1 y and 5 y after lung transplant.[7] Hence, it is logical to think that dual-organ transplant may further increase the resource utilization and affect the index transplant LOS.

One recent study examined the burden of early hospitalization among SLKT recipients.[8] To our knowledge, there are no studies that have examined the outcomes of index SLKT admission. Therefore, we aimed to examine the factors associated with LOS and mortality during index SLKT admission using the data from the US-multicenter SLKT consortium.[2,8,9]

MATERIALS AND METHODS

As described previously,[2,8,9] the US-multicenter SLKT consortium includes candidate, donor, and recipient data on all adult (≥18 y) recipients of SLKT performed at 6 large US centers (Columbia University Irving Medical Center; Duke University; Northwestern University; University of California, San Francisco; Michigan Medicine, University of Michigan; University of Washington) in 6 different United Network of Organ Sharing (UNOS) regions between February 2002 to June 2017. The study was approved by each participating center's institutional review boards, and the data use agreements were established. Deidentified coded data were uploaded in the Research Electronic Data Capture (REDCap) at the University of Michigan, the data coordinating center for this consortium.

The data collection sheets included recipients' demographic information, listing, transplant, donor, and posttransplant characteristics as well as donor characteristics as described previously.[2,8,9]

Immunosuppression

The immunosuppression protocols among all 6 centers were similar. All the centers use tacrolimus-based immunosuppression with mycophenolic acid and corticosteroids. Northwestern University revised their immunosuppression protocol in April 2015 and included induction with basiliximab on day 0 and 2 in addition to solumedrol, and a maintenance phase with tacrolimus, mycophenolic acid, with a corticosteroid taper to 5 mg indefinitely. In all other centers, immunosuppression protocols for SKLT were like the kidney transplant alone immunosuppression protocol. Induction with thymoglobulin, basiliximab, and dacluzimab was based on the presence of panel reactive antibodies and sensitization. The therapeutic tacrolimus trough levels in all the centers were similar and based on days after SLKT. The levels were maintained between 8 and 12 ng/mL in the first 90 d among all the centers.

Analytic Approach

The primary outcome was the LOS of index SKLT admission defined as number of days in the hospital from the day of transplant to the day of discharge. The secondary outcomes were (1) KDGF, (2) death during SLKT admission, and (3) discharge to the subacute rehabilitation facility (SAR).

The continuous variables were expressed as median (interquartile range), and the categorical variables were expressed as percentages. Patients were classified into SLKT era based on the date of SLKT (2002–2008 = Era 1, 2009–2012 = Era 2, 2012–2017 = Era 3) based on changes in SLKT practices.[2,9] MELD-Na score was calculated using OPTN MELD calculator, and renal risk index (RRI) was calculated based on recipients' characteristics using RRI calculator (https://rri.med.umich.edu). The RRI score combines 14 recipient factors at the time of transplant to summarize the post-LT ESRD risk into a single number.[10] The RRI score expresses the relative risk of incident ESRD for a given LT recipient compared with the reference LT recipient with a RRI of 1; values exceeding 1 have higher than expected ESRD risk than the reference LT recipient, and vice versa. SLKT LOS was calculated from the transplant date to the discharge or death during the transplant admission. For patients who were in-patient at the time of SLKT, their LOS was divided into pre-SLKT LOS and SLKT LOS. All the models were adjusted a priori for covariates as clinically indicated.

Linear regression was used to assess the predictors of SLKT LOS. The LOS was skewed and had a long tail. Therefore, we performed the logarithmic transformation of the LOS, which resulted in normal distribution of LOS. This model was a priori adjusted for recipient age, race, sex, etiology of liver disease, hospitalized or ambulatory at SLKT, SLKT era, pre-LT dialysis, body mass index (BMI), hypertension, diabetes (DM), MELD-Na, RRI, induction, kidney delayed graft function (KDGF), cold ischemia time (CIT), warm ischemia time (WIT), donor age, and center. All the components of Kidney Donor Profile Index were not available on all the patients. Therefore, we used the kidney donor age as a covariate for donor quality in the models as described previously.[2,8,9]

To interpret the effect of beta coefficients on LOS from the logarithmic transformation, we exponentiate the coefficient, subtract 1 from this number, and multiply by 100. This gives the percent increase (or decrease) in the response for every 1-unit increase in the independent variable (eg 1, the coefficient is 0.0088 in age (continuous variable) above. Hence, the (exp(0.0088) – 1) * 100 ≅ 0.9. For every 1-unit increase in the age, our LOS increases by about 0.9%. Example 2: the coefficient is 0.21 in Black (race) (categorical variable) above. Hence, the (exp (0.21) – 1) * 100 ≅ 23.4, Black or African American is significantly associated with an increase in LOS increases by about 23.4% compared with White (https://data.library.virginia.edu/interpreting-log-transformations-in-a-linear-model/).

Cox model was used to explore the effect of LOS on overall survival among those who were discharged alive after index SLKT admission. This model was stratified by center and "a priori" adjusted for age, race, gender, etiology of liver disease, status at SLKT (ICU/ambulatory/Floor), era, dialysis at SLKT, KDGF, BMI, hypertension, DM, induction therapy, immunosuppression, MELD-Na, donor age, CIT, WIT, and RRI.

Logistic regression was used to examine the probability of developing KDGF (N = 570), death during index SLKT hospitalization and discharged being alive. Patients who died during the SLKT hospital admission were excluded from discharge to SAR model. Models were "a priori" adjusted for age, race, sex, etiology of liver disease, hospitalized, or ambulatory at SLKT, SLKT era, pre-LT dialysis, body mass index (BMI), hypertension, DM, MELD-Na, RRI, induction, KDGF, CIT, WIT, donor age, and center.

All analyses were performed in SAS 9.4.

RESULTS

Clinical Characteristics

The clinical characteristics of the cohort (n = 570) are displayed in Table 1. The median age was 58 y, with 63% of the cohort being male and 75% being White. At the time of transplant, 58% of the cohort were hospitalized in the ICU, and 39% required renal replacement therapy at SLKT. Hypertension and diabetes, traditional risk factors for chronic kidney disease, were present in 54% and 42%, respectively. Median BMI was 27 kg/m^2, median RRI score was 7.57, and median MELD-Na at transplant was 28. Seventy-one percent of the candidates were inpatient at the time of SLKT. The mean pre-SLKT inpatient LOS was 10 d.

Donor characteristics are also summarized in Table 1, with 56% of donors being male and median donor age being 36 y old. Only 4% were donation after circulatory death (DCD) donors. KDPI scores available in 184 cases with mean risk index of 32%. Median liver CIT was 360 min, and median WIT was 37.5 min.

Almost all the recipients were on tacrolimus (95%), 82% were on triple immunosuppression (calcineurin inhibitor, mycophenolate, and corticosteroids), and only 3% were on calcineurin inhibitor monotherapy at the time of discharge from the index SLKT admission. One fourth (24%) of the patients received induction therapy after SLKT: 74% received basiliximab, 18% received thymoglobulin, and 7% received dacluzimab as induction therapy.

Predictors of LOS of SLKT Index Admission

Table 2 shows the outcomes of SLKT index hospitalization. Of the 570 patients in the cohort, 549 were discharged alive from the hospital. The mean SLKT admission LOS was 19 d. Among those who were discharged alive (N = 549), 64% of patients were discharged home, whereas 36% were discharged to a SAR.

Table 3 shows the independent associations of prolonged LOS of SLKT admission. Female sex ($P = 0.003$) and Black race ($P = 0.02$) were associated with significantly longer LOS compared with male sex and White race, respectively. The median LOS was significantly longer for females than males (14 d [q1:9, q3:24] versus 12 d [q1:7, q3:18]; $P = 0.001$). Every year increase in age ($P = 0.007$) and unit increase in MELD-Na ($P = 0.003$) was associated with increase in LOS. LOS was increased by 24.6% for those who were in ICU at the time of SLKT compared those who were ambulatory and by 43% for those who developed KDGF compared with those who did not.

We further tested the interaction between KDGF and hospitalization status (ICU or floor) at the time of SLKT on LOS. The interaction between KDGF*ICU ($P = 0.77$) and KDGF*floor ($P = 0.72$) was nonsignificant.

TABLE 1.

Baseline characteristics at SLKT

Variables at LT (N = 570)	Median (IQR) or N (%)
Recipient characteristics	
Age at transplant	58 (51–64)
Male	361 (63%)
Race	
White	432 (75%)
Black	71 (12%)
Other	67 (12%)
Etiology of liver disease	
Hepatitis C	189 (33%)
Alcohol	131 (23%)
NASH/cryptogenic cirrhosis	112 (20%)
Other	138 (24%)
Status at transplant	
ICU	329 (58%)
Ambulatory	166 (29%)
Hospital floor	74 (13%)
Renal replacement therapy at liver transplant	220 (39%)
Medical comorbidities at transplant	
Hypertension	306 (54%)
Diabetes	237 (42%)
Body mass index	27 (24–32)
Renal risk index	7.57 (5.2–12.2)
MELD-Na	28 (23–34)
Donor and transplant characteristics	
Donor age (y)	36 (23–48)
Donation after circulatory death	24 (4%)
Donor sex (male gender)	318 (56%)
Cause of death: cerebrovascular	382 (67%)
KDPI (N = 184)	32% (15%–66%)
Cold ischemia time (min)	360 (300–465)
Warm ischemia time (min)	37.5 (25–60)
Immunosuppression	
Induction	138 (24%)
Tacrolimus	541 (95%)
Cyclosporine	29 (5%)

ICU, intensive care unit; IQR, interquartile range; KDPI, Kidney Donor Profile Index; LT, liver transplant; MELD-Na, model for end stage liver disease-sodium; NASH, nonalcoholic steatohepatitis.

TABLE 2.

Outcomes of SLKT index admission

Outcome variable (N = 570)	Median (IQR) or N (%)
Discharge status	
Home	366 (64%)
SAR	172 (30%)
Death	21 (4%)
Length of stay (d)	19 (10–34)
KDGF	133 (23.3%)

IQR, interquartile range; KDGF, kidney delayed graft function; SAR, subacute rehabilitation facility; SLKT, simultaneous liver-kidney transplant.

TABLE 3.

Factors affecting LOS of index SLKT admission

Variables	Beta[a] (95% CI)	*P*	LOS change per unit (%)
Intercept	1.78 (1.15-2.41)	<0.001	
Age (per y)	**0.009 (0.003-0.014)**	**0.002**	**0.9%**
Race (vs White)			
Black	**0.21 (0.039-0.38)**	**0.02**	**23.5%**
Others	**0.062 (–0.12 to 0.24)**	**0.50**	**6.4%**
Female (vs male)	**0.20 (0.092-0.31)**	**<0.001**	**22.5%**
Etiology (vs others)			
Alcohol	–0.02 (–0.17 to 0.14)	0.83	–1.7%
Hepatitis C	0.05 (–0.10 to 0.20)	0.53	4.9%
NASH	0.10 (–0.07 to 0.27)	0.25	10.7%
Status at SLKT (vs ambulatory)			
Admitted to floor	**0.13 (–0.067 to 0.32)**	**0.19**	**13.6%**
Admitted to ICU	**0.22 (0.016-0.42)**	**0.03**	**24.5%**
Dialysis pre-SLKT (ref = No)	**0.21 (0.087-0.33)**	**<0.001**	**23.3%**
BMI (vs <18.5 kg/m^2-underweight)			
18.5–25 kg/m^2	–0.11 (–0.54-0.33)	0.63	–10.1%
26–29 kg/m^2	–0.18 (–0.61-0.26)	0.42	–16.1%
≥30 kg/m^2	–0.19 (–0.62-0.25)	0.40	–17.2%
Era (<2008–Era 1)			
2008–2012 (Era 2)	0.05 (–0.09-0.19)	0.48	5.4%
>2012 (Era 3)	(0.04 (–0.10-0.19)	0.55	4.5%
Pre-LT hypertension (vs no)	–0.11 (–0.23-0.01)	0.06	–10.5%
Pre-LT DM (vs no)	0.11 (–0.02-0.24)	0.10	11.4%
Cyclosporine (vs tacrolimus)	**0.28 (0.027-0.54)**	**0.03**	**32.6%**
MELD-Na at SLKT	**0.011 (0.004-0.018)**	**0.003**	**1.1%**
KDGF (ref = No)	**0.36 (0.22-0.51)**	**<0.001**	**30.5%**
RRI	**–0.018 (–0.028 to –0.008)**	**<0.001**	**–1.8%**
Donor age (per y)	0.002 (–0.002-0.006)	0.29	0.2%
CIT (per min)	0.0002(–0.0002-0.0005)	0.32	0.02%
WIT (per min)	–0.001 (–0.002-0.001)	0.48	–0.06%

[a]This model was also adjusted for the centers.

BMI, body mass index; CI, confidence intervals; CIT, cold ischemia time; DM, diabetes; ICU, intensive care unit; LOS, length of stay; LT, liver transplant; SLKT, simultaneous liver-kidney transplant; WIT, warm ischemia time.

Factors Associated With KDGF

One hundred thirty-three patients (23%) developed KDGF, requiring renal replacement therapy during the index SLKT admission, for a median of 13 d (interquartile range 4–40). The median LOS was significantly longer for those who developed KDGF compared with who did not (18 d versus 11 d; $P < 0.001$).

Pre-SLKT dialysis or renal replacement therapy, advanced donor age, and cold ischemia time were independently associated with the increase odds of DGF, whereas Black and White race compared with other races had lower odds of DGF after SLKT (Table 4). This model was adjusted for age, race, sex, etiology of liver disease, hospitalized or ambulatory at SLKT, SLKT era, pre-LT dialysis, body mass index (BMI), hypertension, DM, MELD-Na, RRI, induction, immunosuppression, CIT, WIT, donor age, and center.

Factors Associated With Death During SLKT Admission

Twenty-one patients died after index SLKT (Table 5). As seen in Table 5, patients with hepatitis C ($P = 0.0069$), lower BMI ($P = 0.02$), and prolonged liver CIT ($P = 0.0186$) were independently associated with death during SLKT index admission. This model was adjusted for age, race, sex, etiology of liver disease, hospitalized or ambulatory at SLKT, SLKT era, pre-LT dialysis, BMI, hypertension, DM, MELD-Na, RRI, induction, immunosuppression, KDGF, CIT, WIT, donor age, and center.

TABLE 4.

Factors associated with KDGF

Variables	Odds ratio (95% CI)	*P*
Intercept	0.000	0.09
SLKT year	1.05 (0.99-1.11)	0.09
Age (per y)	0.98 (0.96-1.00)	0.07
Female vs male	1.34 (0.84-2.14)	0.2
Black vs other race	**0.33 (0.14-0.79)**	**0.013**
White vs other race	**0.35 (0.19-0.67)**	**0.001**
Etiology (vs others)		
NASH	1.32 (0.37-1.55)	0.4
Alcohol	0.84 (0.43-1.64)	0.6
Hepatitis C	0.94 (0.50-1.77)	0.9
Hypertension vs not	0.99 (0.61-1.62)	0.9
Diabetes vs not	1.13 (0.64-1.99)	0.7
MELD-Na	1.0 (0.97-1.03)	0.9
BMI	1.01 (0.99-1.04)	0.3
Tacrolimus vs cyclosporine	0.44 (0.18-1.07)	0.07
Donor age (per y)	**1.03 (1.01-1.05)**	**<0.001**
Cold ischemia time (per min)	**1.002 (1.000-1.003)**	**0.03**

BMI, body mass index; CI, confidence intervals; KDGF, kidney delayed graft function; MELD-Na, model for end stage liver disease-sodium; NASH, nonalcoholic steatohepatitis; SLKT, simultaneous liver-kidney transplant.

TABLE 5.

Factors associated with mortality during index SLKT admission

Variable	Odds ratio (95% CI)	*P*
Hepatitis C etiology	3.84 (1.02-14.39)	0.007
Body mass index	0.895 (0.811-0.988)	0.028
Cold ischemia time	1.004 (1.001-1.007)	0.019

CI, confidence intervals; SLKT, simultaneous liver-kidney transplant.

Factors Associated With Discharge to Subacute Rehab Facility

Of 549 patients discharged alive following SLKT index admission, 172 (36%) patients were discharged to a SAR. The independent predictors of being discharged to SAR included older age ($P = 0.013$), era of SLKT ($P = 0.011$), dialysis at transplant ($P = 0.022$), and KDGF ($P = 0.003$) (Table 6). Pre-LT hospitalization did not predict the discharge to SAR. This model was also adjusted for centers.

Effect of LOS on Overall Survival of Those Discharged Alive After Index SLKT Admission

In a Cox model (N = 549) stratified by centers and adjusted for age, race, gender, etiology of liver disease, status of SLKT(ICU/ambulatory/Floor), era, dialysis at SLKT, BMI, hypertension, diabetes, induction, immunosuppression, MELD-Na, donor age, CIT, WIT, and RRI, everyday increase in LOS of index SLKT was associated with increased hazard of death after discharge (HR = 1.007; 95% CI, 1.000-1.014; $P = 0.04$).

TABLE 6.

Predictors of discharge to SAR following SLKT

Variables	OR* (95% CI)	*P*
Intercept	0.032 (0.002-0.387)	0.008
Age (per y)	1.027 (1.005-1.051)	0.02
Race		
Black (vs White)	1.20 (0.59-2.41)	0.61
Others (vs White)	1.11 (0.48-2.48)	0.81
Female (vs male)	1.24 (0.80-1.90)	0.34
Etiology		
Alcohol (vs others)	1.27 (0.69-2.36)	0.45
Hepatitis C (vs others)	1.43 (0.77-2.68)	0.26
NASH/crypto (vs others)	1.72 (0.87-3.39)	0.12
SKLT status		
Floor (vs ambulatory)	2.38 (0.97-5.90)	0.06
ICU (vs ambulatory)	5.05 (1.95-13.57)	0.001
Era		
Era 2 2008–2012 (vs <2008–Era 1)	1.22 (0.69-2.17)	0.49
Era 3 >2012 (vs ≤2008)	1.95 (1.11-3.43)	0.02
Pre-SLKT dialysis (ref = No)	2.45 (1.49-4.09)	<0.001
BMI (Ref: <18.5 mg/m^2–underweight)		
18.5–25 kg/m^2	1.09 (0.22-6.03)	0.92
26–29 kg/m^2	1.06 (0.22-5.86)	0.94
≥30 kg/m^2	1.02 (0.21-5.71)	0.98
Hypertension (ref = No)	0.81 (0.51-1.30)	0.39
Diabetes (ref = No)	1.29 (0.78-2.13)	0.33
Induction (ref = No)	1.38 (0.65-3.00)	0.40
Cyclosporine (vs Tarco)	0.90 (0.29-2.60)	0.84
MELD-NA at SLKT	1.00 (0.97-1.03)	0.99
Donor age	0.990 (0.976-1.004)	0.16
CIT (per min)	1.001 (0.999-1.002)	0.23
WIT (per min)	1.004 (0.997-1.011)	0.19
KDGF (ref = No)	2.28 (1.24-4.27)	0.009

BMI, body mass index; CI, confidence intervals; CIT, cold ischemia time; ICU, intensive care unit; KDGF, kidney delayed graft function; MELD-Na, model for end stage liver disease-sodium; NASH, nonalcoholic steatohepatitis; OR, odds ratio; SAR, subacute rehabilitation facility; SLKT, simultaneous liver-kidney transplant; WIT, warm ischemia time.

DISCUSSION

This is the first study to examine the outcomes of index SLKT admission. In this large multicenter retrospective analysis of SLK transplants, we have shown survival during SLKT index hospitalization is excellent; however, resource utilization is higher as demonstrated by prolonged LOS after SLKT. To put these results in perspective, we reviewed the literature and found average LOS is approximately 6 d for kidney-alone transplant[4] and 11 d for liver-alone transplant.[11] In our study, female sex, Black race, ICU admission at the time of SLKT, KDGF, MELD-Na, and cyclosporine use during the index SLKT hospitalization predicted prolonged LOS of SLKT index admission.

Kidney transplant candidates are usually ambulatory and not acutely sick at the time of kidney transplant. Our study showed that more than half of our SLKT candidates were in the ICU at the time of SLKT. It further demonstrated that being very sick (in the ICU at the time of SLKT) was associated with prolonged LOS, similar to what is shown in liver transplantation alone literature.[12,13]

One key finding of our study was that female SLKT recipients had longer LOS compared with males, after adjusting for MELD-Na. This finding is comparable to a recent analysis[11] that demonstrated female sex was independently associated with posttransplant LOS in liver transplant alone. MELD-Na underestimates the urgency and therefore mortality risk for females. Therefore, typically a MELD-Na 28 female who undergoes SLKT is sicker than a MELD 28 male. SLKT recipients who were on cyclosporine (5% of the entire cohort) also had prolonged LOS in our study.

This may suggest that patents discharged on cyclosporine may have initiated on a tacrolimus-based regimen, underwent a switch in immunosuppression because of tacrolimus-related toxicity, and experienced a delay in discharge until adequate levels were achieved. Finally, prolonged LOS was also associated with increased mortality after being discharged alive from the index SLKT admission.

We did not identify an era effect on LOS of SLKT index admission. This may suggest that despite changes in the policies and practice patterns for SLKT over time, LOS over the study period did not change. There has been an increase in DCD donor utilization over time; however, use of DCD donor utilization in our cohort was only 5% and did not significantly affect the LOS.

Incidence of KDGF in our cohort was lower than 1 single-center study of SLKT[14] as well as KDGF incidence reported in kidney transplant alone literature.[15] The recipient and donor factors associated with KDGF were similar to what was reported in these studies as well. Importantly, KDGF in kidney transplant alone is associated with higher odds of LOS exceeding >2 wks.[16] In our study, KDGF was an intermediary outcome, which affected the LOS adversely among SLKT recipients. Patients with KDGF stay in the hospital for dialysis and are monitored carefully until the renal allografts start functioning. It is important to note that there may be opportunity to mitigate the risk of KDGF in SLKT recipients and

therefore potentially improve LOS. A strategy of hypothermic pulsatile machine perfusion and delayed renal graft implantation (>48 h) after liver graft implantation may reduce risk of KDGF and lead to improved longer-term outcomes such as graft and patient survival.[17] Our consortium's data on renal outcomes have been reported previously,[9] and in this study, we further demonstrated that KDGF is one of the strongest predictors of LOS.

The mortality during the SLKT index admission over 15 y remained low, but these patients have higher resource utilization. Hepatitis C, BMI, and prolonged liver CIT were identified as predictors of increased mortality during the index hospitalization. Hepatitis C was previously identified to be associated with reduced survival in SLKT recipients in a UNOS database study, spanning 2003–2012 (eras 1 and 2 in this study).[18] This may be related to high burden of hepatitis C–induced viral injury to renal allograft and lack of available treatment for hepatitis C because of interferon-associated renal allograft rejection[18] before direct acting antiviral agents. Finally, cold ischemia time is a well-documented risk factor for both graft dysfunction and increased mortality in both the liver- and kidney-alone transplant recipients and extends to the dual-organ transplant population as well.[4,19]

Over the last 2 decades, transplantation for both kidney and liver alone in older, sicker patients has increased significantly; however, despite the increase in the acuity and burden of comorbidities, outcomes in these transplant recipients have improved over time.[2] Our study demonstrated that advanced age and dialysis at SLKT and KDGF were associated with discharge to SAR. These factors may be the surrogate of frailty and reflective of poor functional status, hence, may benefit from SAR. The era effect on discharge to SAR was more profound in recent era (2012–2017) because of older, sicker (more frail, higher MELD) SLKT candidate on dialysis, hence the need for additional rehabilitation after a dual-organ transplant. We suggest identifying patients at high risk for discharge to SAR to guide patient and caregiver education and discharge planning similar to the preoperative nomogram created by Kelly et al to predict discharge to rehabilitation facility after liver transplantation.[20]

Our study has limitations that include the retrospective design, heterogeneity, and variability in practices during the long study period across the 6 centers, resulting in potential bias because of unmeasured characteristics and patient selection. Furthermore, we do not have data on reoperations or return to operation room events, which may have independently led to longer hospital stays. The lack of a comparison arm makes it difficult to put these results in perspective. There are very few dual-organ studies (heart-kidney, lung-kidney), and these studies only examined the survival after dual-organ transplant.[21,22] Comparing dual-organ transplant to single organ transplant is not a valid comparison either. Therefore, we used the LOS for kidney transplant alone and liver transplant alone from the literature to gauge the burden of resource utilization during index SLKT admission. Despite these shortcomings, this is the first and the largest study to comprehensively examine the predictors of length of stay and discharge outcomes after SLKT. Given the granular data from 6 different sites, the heterogeneity across in 6 different UNOS regions provides the real-life experience, which is an additional strength to the study.

Despite excellent survival, index SLKT admission was associated with high resource utilization with >2 wks of LOS and discharge to SAR. Prolonged LOS also affected the overall survival. This highlights the need to risk stratify SLKT candidates who are at higher risk for prolonged LOS so that strategies can be developed to educate the patients, as well as caregivers, with targeted discharge planning. Efforts should be focused on minimizing CIT and KDGF to mitigate resource utilization. Ultimately, further investigation is needed to optimize healthcare resources for these patients in a financially strained healthcare landscape and future work includes examining costs associated with specific risk factors identified here and longer-term resource utilization metrics.

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