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ORIGINAL SCIENTIFIC REPORT

Hospital Utilization of Nationally Shared Liver Allografts from 2007 to 2012

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Abstract

Background Due to the current geographic disparities in liver allocation a policy, which endorses broader sharing of allografts, has been proposed. We performed a retrospective cohort study to identify how nationally shared allografts, under the current policy, affect perioperative outcomes and resource utilization following liver transplantation (LT).

Methods Univariate and multivariate analysis identified how patient characteristics and hospital outcomes were associated with national sharing. This analysis was based on 12,282 deceased donor liver transplants performed between 2007 and 2012 using the scientific registry of transplant recipients linked to the University HealthSystem Consortium database.

Results Compared to locally distributed livers, nationally shared livers are more likely to have a donor risk index >1.8 (64.3 vs. 11.6 %), to be classified as expanded criteria donors (44.6 vs. 24.8 %), and transplanted into healthier recipients. Nationally shared LTs were more likely to be performed at high-volume centers (49.1 vs. 30.6 %), resulted in longer length of stay (11 vs. 9 days), and had higher in-hospital mortality (6.6 vs. 3.3 %). Additionally, nationally shared allografts were independent predictors of in-hospital mortality (OR 1.64, 95 % CI 1.13–2.39) and length of stay (OR 1.12, 95 % CI 1.02–1.21).

Conclusion These data suggest that increased national sharing of livers may result in inferior patient outcomes and increased resource utilization.

Introduction

Since the advent of an organized system of organ allocation, waitlist mortality has been a highly publicized topic within the field of liver transplantation (LT). Arguably, the most influential change in liver allocation came in 2002 when the model for end-stage liver disease (MELD) score was introduced as a means of prioritizing waitlist patients based on mortality risk. With a more standardized method of organ allocation in place, focus was shifted to the geographic disparities in access to LT that existed within the United States. Efforts to reduce regional variation were introduced with the "Regional Share 15" and "Regional Share 35" policies, which were implemented in 2005 and 2013, respectively. While available data have shown an improvement in waitlist mortality, [1, 2] significant geographic variability in liver allograft allocation still exists at the national level. [3–6]

Under the current allocation policy, differences in MELD score at transplant may vary by more than 7 points

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depending upon the region in which the candidate resides. In addition, waitlist mortality varies up to twofold between the 11 United Network for Organ Sharing (UNOS) regions. [4] To address this issue, the Organ Procurement and Transplantation Network (OPTN) has proposed a redistricting plan to improve waitlist time and mortality in those regions most severely affected. [7] The application of such a policy change would significantly broaden the sharing of donor organs across large distances and have potentially significant effects on patient outcomes and resource utilization.

Currently, no research has been done to assess the impact broader sharing and therefore increased travel and cold ischemia times may have on clinical outcomes of the recipients. We aimed to identify those organs that are nationally shared under the current allocation policy to identify trends in hospital utilization and perioperative outcomes.

Methods

Study population

A retrospective cohort study was performed for all LT recipients transplanted in the U.S. between January 1, 2007 and December 31, 2012. Data for this analysis were acquired from two separate sources. First, clinical data for recipient and donor characteristics were obtained from the scientific registry of transplant recipients (SRTR) Standard Analysis File. These data were then linked to recipient clinical and hospital encounter-specific data obtained from the University HealthSystem Consortium (UHC) Clinical Data Base/Resource Manager (CDB/RM). UHC is an alliance of 118 academic medical centers and 298 of their affiliated hospitals representing approximately 95 % of the nation's major not-for-profit academic medical centers. The CDB/RM is an administrative database wherein patient demographic, financial, ICD-9 diagnosis, and procedure data are provided by the member medical centers. Hospital charges are reported for each patient encounter and are converted to cost estimates using institution-specific Medicare cost-to-charge ratios, and federally reported area wage indexes are utilized to normalize regional variation in labor cost. [8–10] All costs were adjusted to 2012 dollars using the overall Consumer Price Index to account for inflation, as previously described. [11].

From January 2007 to December 2012, 34,611 LTs from 135 centers were identified from the SRTR database. Over the same time period, 21,868 LTs from 67 centers were identified from the UHC CDB/RM database. [12, 13] A linkage of patients within the 2 datasets was performed using recipient age, procedure date, gender, and transplant center, if patients did not match on all 4 variables they were excluded. Recipient age <18 years ($n = 1433$) and repeat-LT within the same hospitalization ($n = 396$) were also excluded from this dataset prior to linkage. The final matched cohort consisted of 14,997 deceased donor LT recipients from 63 transplant centers representing 43.3 % of the LTs performed nationally over the six-year period. After the linkage, living donor transplants ($n = 715$) were excluded due to the scope of the study at hand resulting in our final cohort of 14,282 representing 41.3 % of all LTs. This dataset was found to be similar to the overall SRTR LT cohort with regard to donor and recipient characteristics as well as liver disease etiology, severity of disease, and survival following LT. From these parameters, we identified 10,690 locally distributed, 2790 regionally distributed, and 802 nationally shared liver allografts. Nationally shared allografts are defined as those livers that cross regional boundaries and will be referred to as "shared" livers for the remainder of this manuscript. Through the linkage of these 2 independent datasets, we were able to assess transplant-specific outcomes including patient and graft survival, as well as hospital-level outcomes including 30-day readmission, discharge disposition, length of stay (LOS), and cost.

Study variables

Allograft distribution categories (local, regional, and national) were defined according to the OPTN definitions based upon geographic relationship between the hospital where the organ is recovered and the transplant hospital where the candidate is listed. [7]

Recipient and donor race were categorized into 4 groups: white, Black, Hispanic, and other. Pre-transplant Model for End-Stage Liver Disease (MELD) score was calculated for each recipient as previously described. [14] MELD exception scores were not used. Donor type was categorized as standard criteria donor (SCD), expanded criteria donor (ECD), or donation after cardiac death (DCD). Expanded criteria donation was based on the UNOS kidney definition in regards to kidney donors. Donor risk index (DRI) was calculated as previously described [15, 16] and was stratified into quartiles. Centers were ranked based on annual case volume and stratified into tertiles, representing low-volume centers (lower third of centers based on annual case volume ranging from 5 to 56 ± 4 transplantations/year), medium-volume centers (middle third of centers based on case volume of 62 ± 6 to 99 ± 10 transplantations/year), and high-volume centers (upper third of centers based on case volume of 102 ± 9 to 172 transplantations/year). [9, 17, 18] Centers performing fewer than five procedures per year were excluded from the center volume analysis.

Table 1 Demographic and clinical characteristics of liver allograft donors

Characteristic	Local (n = 10,690)	Regional (n = 2790)	Shared (n = 802)	p value
Sex				0.005
Male	6450 (60.3 %)	1606 (57.6 %)	452 (56.4 %)	
Female	4240 (39.7 %)	1184 (42.4 %)	350 (43.6 %)	
Age of donor (years)	42 (28)	43 (28)	50 (26)	<0.001
Race				0.003
White	7042 (65.9 %)	1864 (66.8 %)	553 (69 %)	
Black	2017 (18.9 %)	549 (19.7 %)	155 (19.3 %)	
Hispanic	1260 (11.8 %)	298 (10.7 %)	60 (7.5 %)	
Other	371 (3.5 %)	79 (2.8 %)	34 (4.2 %)	
Donor type				<0.001
SCD	7542 (70.6 %)	1857 (66.6 %)	380 (47.4 %)	
ECD	2652 (24.8 %)	760 (27.2 %)	358 (44.6 %)	
DCD	496 (4.6 %)	173 (6.2 %)	64 (5.0 %)	
Donor history of hepatitis C	284 (2.7 %)	135 (4.8 %)	106 (13.2 %)	<0.001
Cause of death				<0.001
Trauma	3796 (35.5 %)	933 (33.4 %)	180 (22.4 %)	
Anoxia	2435 (22.8 %)	622 (22.3 %)	207 (25.8 %)	
CVA	4193 (39.2 %)	1144 (41.0 %)	392 (48.9 %)	
Other	266 (2.5 %)	91 (3.3 %)	23 (2.9 %)	
Donor risk index				<0.001
<1.2	4063 (38.0 %)	540 (19.4 %)	15 (1.9 %)	
1.2–1.49	3068 (28.7 %)	792(28.4 %)	112 (14.0 %)	
1.5–1.79	2317 (21.7 %)	666 (23.9 %)	159 (19.8 %)	
>1.8	1242 (11.6 %)	792 (28.4 %)	516 (64.3 %)	
BMI	26.29758 (7.2)	26.30804 (7.4)	27.08352 (8.5)	<0.001
Cold ischemia time (hours)	6.17 (3)	7.26 (3)	9 (3)	<0.001
Warm ischemia time (minutes)	40 (20)	39 (17)	39 (18)	<0.001

SCD standard criteria donor, *ECD* extended criteria donor, *DCD* donation after cardiac death, *CVA* cerebrovascular accident

Statistical analysis

Statistical analysis was performed using SAS 9.4 statistical software (SAS Institute, Cary, NC). Univariate analysis was performed using the Pearson's Chi-squared test for categorical variables and Wilcoxon rank-sum test for continuous variables. Statistical significance was determined by a p value less than 0.05. Multivariable analysis was performed by analyzing total length of stay and discharge status. Variables that were found to be significant in univariate analysis were included in the covariate selection process in the multivariable analysis.

Odds ratio (OR) of mortality and discharge status after LT were estimated using logistic regression techniques, while Poisson regression techniques were used for overall length of stay. Models were adjusted for donor, recipient, and center variables as noted in Tables 3, 4, and 5. Graft and patient survival were estimated using Kaplan–Meier survival curves. Log-rank test was used to determine significant differences ($p < 0.05$) between cohorts.

The University of Cincinnati's Institutional Review Board approved this study. The linkage of these two databases was approved by the University HealthSystems Consortium, the SRTR, and the HRSA. The SRTR data system includes data on all donor, wait-listed candidates, and transplant recipients in the US, submitted by the members of the OPTN, and has been described elsewhere. The HRSA, U.S. Department of Health and Human Services, provides oversight to the activities of the OPTN and SRTR contractors.

Results

Donor characteristics are outlined in Table 1. Shared donors aged 50 years versus 42 and 43 for local and regional donors, respectively. Shared donors were also more likely to be classified as ECD (44.6 %) as compared to locally and regionally placed donors (24.8 and 27.2 %) and were more likely to be positive for HCV antibody.

Table 2 Demographic and clinical characteristics of liver transplant recipients

Characteristic	Local (n = 10,690)	Regional (n = 2790)	Shared (n = 802)	p value
Sex				<0.001
Male	7404 (69.2 %)	1812 (65.0 %)	536 (66.8 %)	
Female	3286 (30.7 %)	978 (35.0 %)	266 (33.2 %)	
Recipient age (years)	56 (11)	56 (12)	57 (11)	<0.001
Race				0.221
White	7681 (71.9 %)	2043 (73.2 %)	584 (72.8 %)	
Black	1078 (10.0 %)	298 (10.7 %)	75 (9.4 %)	
Hispanic	1225 (11.5 %)	272 (9.8 %)	91 (11.4 %)	
Other	706 (6.6 %)	177 (6.3 %)	52 (6.5 %)	
Cause of liver disease				<0.001
Alcohol	1432 (13.4 %)	333 (11.9 %)	131 (16.3 %)	
HBV	349 (3.3 %)	90 (3.2 %)	22 (2.7 %)	
HCC	1330 (12.4 %)	279 (10.0 %)	84 (10.5 %)	
HCV	3750 (35.1 %)	931 (33.4 %)	289 (36.0 %)	
HCVHBV	47 (0.4 %)	11 (0.4 %)	4 (0.5 %)	
NASH	1370 (12.8 %)	363 (13.0 %)	105 (13.1 %)	
Other	2410 (22.6 %)	782 (28.0 %)	167 (20.8 %)	
Functional status				<0.001
Independent	5112 (47.8 %)	1127 (40.4 %)	430 (53.6 %)	
Dependent	3335 (31.2 %)	887 (31.8 %)	258 (32.2 %)	
Severely Ill	1710 (16 %)	653 (23.4 %)	105 (13.1 %)	
Unknown	533 (5.0 %)	123 (4.4 %)	9 (1.1 %)	
Severity of illness				<0.001
Minor	845 (8.8 %)	209 (8.3 %)	65 (9.6 %)	
Moderate	3805 (39.8 %)	864 (34.3 %)	288 (42.7 %)	
Major	3382 (35.4 %)	962 (38.1 %)	240 (35.6 %)	
Extreme	1530 (16.0 %)	487 (19.3 %)	81 (12.0 %)	
Physical capacity				<0.001
Hospitalized or severely limited	2254 (27.7 %)	812 (34.7 %)	136 (19.3 %)	
Limited	1404 (17.3 %)	308 (13.2 %)	151 (21.4 %)	
No limitations	4483 (55.1 %)	1219 (52.1 %)	419 (59.4 %)	
Admission status				<0.001
ICU	729 (6.8 %)	335 (12 %)	48 (5.9 %)	
Hospital ward	1423 (13.3 %)	458 (16.5 %)	80 (9.9 %)	
Not hospitalized	8508 (79.8 %)	1992 (71.5 %)	674 (84 %)	
MELD	19 (13)	21 (16)	16 (8)	<0.001
BMI	27.5652 (7.7)	27.56585 (7.7)	27.3362 (7.7)	<0.001
Pre-transplant lab values				
ALT	43 (45)	46 (56)	38 (37)	<0.001
Bilirubin	3.3 (6.5)	4.1 (9.3)	2.5 (3.3)	<0.001
Albumin	2.9 (0.9)	3 (1)	3 (0.9)	<0.001
INR	1.5 (0.7)	1.6 (1)	1.4 (0.6)	<0.001
Cr	1.1 (0.8)	1.1 (0.9)	1 (0.5)	<0.001
Na	136 (6)	136 (6)	136 (6)	<0.001
Recipient on HD	890 (8.3 %)	212 (7.6 %)	35 (4.4 %)	<0.001
Recipient on ventilator	328 (3.1 %)	167 (5.9 %)	27 (3.4 %)	<0.001
Center volume				<0.001
LV-C	3840 (36.0 %)	769 (27.6 %)	203 (25.3 %)	

Table 2 continued

Characteristic	Local ($n = 10,690$)	Regional ($n = 2790$)	Shared ($n = 802$)	p value
MV-C	35.97 (33.4 %)	1003 (36.0 %)	205 (25.6 %)	
HV-C	3269 (30.6 %)	1018 (36.5 %)	393 (49.1 %)	
Length of stay	9 (8)	10 (9)	11 (9)	<0.001
Direct cost	104,527 (64,953)	97,830 (57,200)	102,299 (67,292)	<0.001
Mortality	385 (3.6 %)	129 (4.6 %)	53 (6.6 %)	<0.001
Routine D/C home	8784 (85.2 %)	2292 (86.1 %)	611 (81.5 %)	0.008
Readmission (30 days)	3820 (37.1 %)	967 (36.3 %)	297 (39.7 %)	0.253

MELD model for end-stage liver disease, *HD* hemodialysis, *LV-C* low-volume center, *MV-C* medium-volume center, *HV-C* high-volume center, *D/C* discharge

Shared donors' cause of death was more often due to cerebrovascular accidents, that they had a longer cold ischemia times, and that they were more likely to have DRIs >1.8.

Table 2 demonstrates recipient characteristics from the overall cohort. Recipients of local, regional, and shared liver allografts were similarly more often male, white, and did not differ clinically in age. With regard to their health and pre-transplant status, recipients of shared liver allografts were more likely to be independent (53.6 %) as compared to recipients of locally and regionally placed liver allografts, less likely to be severely limited, on hemodialysis prior to transplant, or in the ICU. They also tended to have a lower MELD score (16 vs. 19 and 21, $p < 0.001$) and were less likely to qualify for MELD exception points.

Liver transplantations for shared allografts were more likely performed at high-volume centers, had higher in-hospital mortality (6.6 %), longer total LOS, and were less likely to be discharged to home. Thirty-day readmissions were no different across the 3 groups, and direct cost was found to be statistically significantly higher for locally distributed organs as compared to regional and shared organs. Our unadjusted analysis of patient and graft survival is consistent with the literature [19] demonstrating that shared livers had lower patient ($p = 0.003$) and graft survival ($p < 0.001$) according to the Kaplan–Meier analysis.

Results of the final logistic regression model are shown in Table 3. After adjusting for recipient, donor, and center characteristics, shared allografts remained independent predictors of in-hospital mortality (Table 3) and length of stay (Table 4). Patients receiving shared livers were also less likely to be discharged to home (Table 5). Additional factors that were independently associated with increased in-hospital mortality included recipient factors such as age, extreme severity of illness, and use of DCD allografts. Undergoing transplantation at medium- and high-volume centers was protective against in-hospital mortality. An interaction term was introduced to this model to assess the association between organ location and pertinent donor variables on the aforementioned outcome measures. Organ location had no significant interaction with donor type (ECD vs. DCD), donor history of HCV, donor age, or cause of death in regards to in-hospital mortality, length of stay, or discharge status (p value all > 0.05).

Discussion

This study provides analysis of shared liver allografts, under the current UNOS allocation system, to highlight the effects we may see should the proposed policies for broader sharing be implemented. Compared with locally and regionally distributed liver allografts, shared donor livers were of poorer quality as they were more often from elderly donors, positive for HCV antibody, and had higher DRIs. In addition, shared liver allografts were transplanted into healthier recipients more likely to be classified as independent, with lower MELD scores, and less likely to be hospitalized or in the ICU prior to transplant. After controlling for donor- and recipient-specific characteristics, shared allografts were independent predictors of in-hospital mortality, total length of stay, and failure to discharge patient to home. Additionally, further analysis confirmed that organ location had no significant interaction with donor type (ECD vs. DCD), donor history of HCV, donor age, or cause of death in regards to all outcome measures.

While cost was not significantly higher for shared livers in our analysis, the $2228 difference suggests that as liver allografts are increasingly shared, they will incur the costs associated with increasing recipient MELD scores, donor risk index, and transportation. After adjusting for donor, recipient, and center characteristics, Lai et al. demonstrated no increased risk of long-term patient and/or graft loss with nationally shared livers as compared to locally placed livers. However, in that study, only six of 113 transplant

Table 3 Multivariate analysis of predictors of in-hospital mortality for OLT recipients

Variable	Odds ratio	95 % CI	*p* value
Organ location			
Local	1.00		
Regional	1.09	0.85–1.39	0.515
Shared	1.64	1.13–2.39	0.01
Physical capacity			
Limited	1.19	0.87–1.64	0.262
Severely limited	3.13	1.63–6.02	0.001
Recipient on ventilator	2.14	1.44–3.18	<0.001
Severity of Illness			
Minor	1.00		
Moderate	0.81	0.50–1.31	0.39
Major	1.20	0.76–1.91	0.440
Extreme	1.89	1.16–3.07	0.011
Center volume			
LV-C	1.00		
MV-C	0.66	0.52–0.85	0.001
HV-C	0.69	0.54–0.87	0.002
Recipient albumin	0.83	0.72–0.95	0.009
Donor type			
SCD	1.00		
ECD	0.86	0.66–1.11	0.251
DCD	2.02	1.39–2.92	<0.001
Recipient age (years)	1.01	1.00–1.02	0.009
Recipient MED condition			
ICU	0.72	0.36–1.45	0.357
Hospital ward	0.49	0.26–0.97	0.041
Not hospitalized	1.00		
Cause of death			
Trauma	1.00		
Anoxia	1.27	0.96–1.67	0.090
Cerebrovascular accident	1.49	1.15–1.94	0.003
Other	0.59	0.26–1.38	0.227

LV-C low-volume center, *MV-C* medium-volume center, *HV-C* high-volume center, *SCD* standard criteria donor, *ECD* extended criteria donor, *DCD* donation after cardiac death, *ICU* intensive care unit

Table 4 Multivariate analysis of predictors of total length of stay for OLT recipients

Variable	Odds ratio	95 % CI	*p* value
Organ location			
Local	1.00		
Regional	0.97	0.93–1.02	0.307
Shared	1.12	1.02–1.21	0.012
Physical capacity			
Limited	1.19	1.13–1.27	<0.001
Severely limited	1.57	1.34–1.84	<0.001
Recipient on ventilator	0.75	0.63–0.89	0.001
Recipient on life support	1.75	1.48–2.07	<0.001
Severity of illness			
Minor	1.00		
Moderate	1.12	1.01–1.23	0.025
Major	1.47	1.33–1.62	<0.001
Extreme	1.92	1.73–2.13	<0.001
Center volume			
LV-C	1.00		
MV-C	0.89	0.85–0.94	<0.001
HV-C	0.96	0.91–1.01	0.105
Recipient bilirubin	1.01	1.00–1.01	0.017
Recipient albumin	0.96	0.93–0.99	0.006
Recipient on dialysis	1.08	1.01–1.15	0.025
Recipient age (years)	1.01	1.00–1.01	<0.001
Recipient MED condition			
ICU	0.83	0.70–0.99	0.042
Hospital ward	0.76	0.65–0.89	0.001
Not hospitalized	1.00		

LV-C low-volume center, *MV-C* medium-volume center, *HV-C* high-volume center, *SCD* standard criteria donor, *ECD* extended criteria donor, *DCD* donation after cardiac death, *ICU* intensive care unit

centers (all classified as high-volume) utilized 64 % of nationally shared allografts. [19].

Interestingly, cost was found to be higher for recipients of locally distributed liver allografts as compared to recipients of shared livers. This finding may be attributed to several factors. As noted above, the strongest predictor of increased hospital costs is higher MELD score at transplantation. In this analysis, the average MELD score at transplant for recipients of shared livers was 16, which was significantly lower than that of recipients of local organs. In addition, recipients of shared organs were more likely to have their transplant procedures performed at high-volume, high-efficiency hospitals. Lai et al. demonstrate that over 60 % of all nationally shared liver allografts are utilized by just six transplant centers, all of which were classified as high-volume centers. Although not within the immediate scope of this analysis, as liver allocation is heavily biased toward high MELD score recipients nationwide, smaller transplant centers lacking the infrastructure and efficiency seen at the high-volume centers will be asked to perform LTs on severely debilitated patients. As a result, we will likely observe a significant increase in cost and resource utilization per LT. Lastly, there are many extraneous costs such as transportation that are not captured in this analysis. Thus, the overall cost of shared liver allograft transplantations is likely underestimated in the current analysis.

Measures of potential success of the current redistricting proposals have been based upon regional median MELD

Table 5 Multivariate analysis of predictors of discharge disposition for OLT recipients

Variable	Odds ratio	95 % CI		*p* value
Organ location				
Local	1.00			
Regional	1.21	1.025	1.416	0.024
Shared	0.61	0.481	0.777	<0.001
Cause of liver disease				
Alcohol	0.74	0.615	0.901	0.003
HCC	0.89	0.697	1.145	0.373
NASH	0.72	0.593	0.87	<0.001
Other	1.03	0.855	1.231	0.779
Gender				
Male	1.00			
Female	0.80	0.69–0.92		0.002
Race				
White	1.00			
Black	0.91	0.74–1.12		0.367
Hispanic	1.41	1.15–1.73		0.001
Other	1.39	1.02–1.91		0.038
MELD	0.97	0.96–0.99		<0.001
Recipient angina	0.62	0.46–0.84		0.002
Recipient on hemodialysis	0.75	0.60–0.92		0.006
Recipient TIPPS	0.73	0.58–0.94		0.013
Functional status				
Independent	1.00			
Dependent	0.95	0.79–1.13		0.572
Severely Ill	0.65	0.49–0.86		0.002
Unknown	0.66	0.36–1.23		0.191
Physical capacity				
Hospitalized or severely limited	0.22	0.14–0.35		<0.001
Limited	0.67	0.57–0.83		<0.001
No limitations	1.00			
Recipient MELD condition				
Not hospitalized	1.00			
Hospital ward	2.49	1.55–3.98		<0.001
ICU	2.19	1.31–3.68		0.003
Recipient on ventilator	0.34	0.24–0.48		<0.001
Severity of illness				
Minor	1.00			
Moderate	0.87	0.63–1.19		0.370
Major	0.46	0.34–0.63		<0.001
Extreme	0.32	0.23–0.44		<0.001
Center volume				
LV-C	1.00			
MV-C	1.17	1.00–1.37		0.046
HV-C	1.38	1.18–1.60		<0.001
Recipient age (years)	0.96	0.95–0.96		<0.001
Recipient bilirubin	1.01	1.00–1.02		0.011
Recipient albumin	1.36	1.24–1.49		<0.001

Table 5 continued

Variable	Odds ratio	95 % CI	*p* value
Donor type			
SCD	1.00		
ECD	0.90	0.78–1.04	0.168
DCD	0.63	0.49–0.82	<0.001

HCC hepatocellular carcinoma, *NASH* non-alcoholic steatohepatitis, *ICU* intensive care unit, *LV-C* low-volume center, *MV-C* medium-volume center, *HV-C* high-volume center, *SCD* standard criteria donor, *ECD* extended criteria donor, *DCD* donation after cardiac death

score equalization and reductions in waitlist mortality. [20] This is the first analysis to assess the potential effects of such a policy change on perioperative outcomes and immediate hospital resource utilization following transplant. In our study, in-hospital mortality was twice as high for recipients of shared allografts as compared to those who received locally distributed livers despite a significantly healthier recipient pool. Additionally, shared allografts remained independent predictors of increased in-hospital mortality, total length of stay, and decreased routine discharge to home on multivariate analysis. Inferior perioperative outcomes were seen with shared allografts despite their being transplanted into healthier recipients. Should the proposed policies be implemented it is likely that similar donors will be prioritized and transplanted into severely debilitated recipients who lack the reserve of those patients encountered in this analysis. As more severely ill patients with higher MELD scores receive broadly shared livers, we may experience worse immediate outcomes and increased financial strain on transplant centers.

This retrospective study of a large, national cohort of deceased donor LT recipients is not without its limitations, specifically those that come with the use of a large administrative database. Due to the nature of liver allocation, we do not know the overall number of shared allografts that were accepted but not utilized for transplantation. Additionally, the UHC database reports cost estimates but is lacking the granularity that is necessary for a more thorough analysis to identifying what accounts for cost differences. It is unlikely that many of the extraneous costs, including graft transport, have been accounted for in this model and may underestimate the overall cost of transplantations with shared liver allografts. We were also unable to determine which livers were obtained via DonorNet versus an expedited allocation. Lastly, this linkage only represents 43 % of all liver transplants during this time period and, as a result, there may be some unavoidable selection bias.

In conclusion, it is necessary for us to recognize the potential ramifications of the proposed redistricting policies on perioperative outcomes. This analysis demonstrates that as broader sharing becomes the routine method of liver allocation, immediate perioperative outcomes and hospital resource utilization will likely be affected.

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Compliance with ethical standards

Conflicts of interest The authors report no financial disclosures or conflicts of interest.

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