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Single-center Outcomes After Liver Transplantation With SARS-CoV-2–Positive Donors: An Argument for Increased Utilization

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Background. The COVID-19 pandemic has led to an increase in SARS-CoV-2–test positive potential organ donors. The benefits of life-saving liver transplantation (LT) must be balanced against the potential risk of donor-derived viral transmission. Although emerging evidence suggests that the use of COVID-19–positive donor organs may be safe, granular series thoroughly evaluating safety are still needed. Results of 29 consecutive LTs from COVID-19–positive donors at a single center are presented here. **Methods.** A retrospective cohort study of LT recipients between April 2020 and December 2022 was conducted. Differences between recipients of COVID-19–positive (n = 29 total; 25 index, 4 redo) and COVID-19–negative (n = 472 total; 454 index, 18 redo) deceased donor liver grafts were compared. **Results.** COVID-19–positive donors were significantly younger ($P = 0.04$) and had lower kidney donor profile indices ($P = 0.04$) than COVID-19–negative donors. Recipients of COVID-19–positive donor grafts were older ($P = 0.04$) but otherwise similar to recipients of negative donors. Donor SARS-CoV-2 infection status was not associated with a overall survival of recipients (hazard ratio, 1.11; 95% confidence interval, 0.24-5.04; $P = 0.89$). There were 3 deaths among recipients of liver grafts from COVID-19–positive donors. No death seemed virally mediated because there was no qualitative association with peri-LT antispike antibody titers, post-LT prophylaxis, or SARS-CoV-2 variants. **Conclusions.** The utilization of liver grafts from COVID-19–positive donors was not associated with a decreased overall survival of recipients. There was no suggestion of viral transmission from donor to recipient. The results from this large single-center study suggest that COVID-19–positive donors may be used safely to expand the deceased donor pool.

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The COVID-19 pandemic posed a particular risk to patients needing and receiving solid organ transplantation. Initially reported morbidity and mortality rates from SARS-CoV-2 viral infections were greater in transplant recipients than in the general population,[1,2] although this gap improved as experience in diagnosing and treating the virus accrued.[3] Over the course of the pandemic, the burden of acute liver failure and end-stage liver disease attributable to alcohol increased. Despite this increasing need for liver transplantation (LT), concerns about potential donor transmission of COVID-19 limited the utilization of COVID-19–positive deceased donor livers.[4]

Despite some recommendations against using grafts from deceased donors with active SARS-CoV-2 infection,[5,6] donor scarcity has encouraged some transplant centers to cautiously use these organs.[7-9] This practice theoretically allows for potential donor-derived viral infection after LT. Autopsy studies of nontransplant patients who died from severe COVID-19 revealed predominantly pulmonary and renal organotropisms, although some viral expression was detected in the liver by reverse transcription-polymerase chain reaction (RT-PCR), immunohistochemistry, ribonucleic acid sequencing, and spatial transcriptomics.[10,11] This concern of viral transmission and even occult hepatic injury resulted in lower recovery rates of organs from COVID-19–positive donors (CPDs) than from COVID-19–negative donors (CNDs), and hence significantly higher organ discard.[8] However, small clinical series and larger national registry studies have not identified significant short-term differences in transplant outcomes between recipients of kidney, liver, or heart organs from CPDs versus CNDs,[7,8,12] leading to changes in recommendations for high mortality risk LT candidates.[9,13]

Given the ongoing COVID-19 pandemic, understanding the short- and long-term safety of using liver grafts from CPDs is necessary. This study examines a large, granular single-center case series of LTs using CPD livers. We compare LTs using CPD livers to CND livers from the start of the COVID-19 pandemic to the end of 2022. Our primary aim was to determine whether LTs from CPDs confer a risk of decreased recipient survival, with a secondary aim of scrutinizing donor-to-recipient viral transmission risk.

MATERIALS AND METHODS

The records of all LTs performed at our single center between April 1, 2020, and December 31, 2022, were retrospectively reviewed. All research was conducted in accordance with the Declaration of Helsinki and the Declaration of Istanbul under Houston Methodist Research Institute Institutional Review Board protocol PRO00000587. SARS-CoV-2 testing data for all deceased liver allograft donors accepted by our center during the study period were obtained from the United Network for Organ Sharing data services based on data as of January 6, 2023. Donor SARS-CoV-2 status was considered positive based on nucleic acid or antigen tests performed on upper or lower respiratory tract specimens within 14 d of the organ donation date. A donor with any positive test in the 14 d before procurement was interpreted as a CPD, irrespective of the number and sequence of negative tests, as described elsewhere in the literature and at the recommendation of our Transplant Infectious Disease consultants.[14] All donors were asymptomatic at the time of testing. During the study period, our institution did not accept allografts from donors with symptomatic SARS-CoV-2 infections or donors who died from complications of COVID-19.

SARS-CoV-2 testing in recipients was universally negative immediately before LT. SARS-CoV-2 testing in recipients was not protocolized but was frequently performed as indicated by clinical judgment in the first 14 d post-LT, either by nasal swab RT-PCR or by peripheral blood antispike IgG antibodies. Semiquantitative antispike IgG antibody titers were measured pre- and post-LT in 8 patients. At the discretion of the Infectious Disease consultant, patients who received liver allografts from CPDs were administered either remdesivir (200 mg initial dose followed by 100 mg daily for 2 d) or monoclonal antibodies (one-time dose), starting on postoperative day 0 or 1. SARS-CoV-2 variants dominant at the state level at the dates of organ procurement were obtained from the Global Initiative on Sharing Avian Influenza Data database.[15] Kidney Donor Profile Index (KDPI) was calculated on the basis of the formula described by the US Organ Procurement and Transplantation Network.[16]

Patient characteristics were reported as frequencies and proportions for categorical variables and as median and interquartile range for continuous variables. Differences in groups by donors' SARS-CoV-2 status were determined by the chi-square or Fisher exact tests for categorical variables and Wilcoxon rank-sum tests for continuous variables as appropriate. Because patients undergoing index and retransplantation had multiple donors, in some cases both CNDs and CPDs, all recipient-level analyses were restricted to index LTs, including survival.

Cox proportional hazard regression was used to determine factors associated with all-cause mortality. Variables for the multivariable models were selected on the basis of their clinical importance and also by the least absolute shrinkage and selection operator method with the cross-validation selection option.[17,18] All analyses were performed on Stata version 17.0 (StataCorp LLC, College Station, TX). A P value of <0.05 was considered statistically significant.

RESULTS

Donor Characteristics

During the study period from April 20, 2020, to December 29, 2022, 485 patients received LT from 501 donors (Table 1). A total of 1319 SARS-CoV-2 tests were performed on donors, and 34 donors had at least 1 positive test result (**Table S1, SDC**, http://links.lww.com/TXD/A633; **Figures S1** and **S2, SDC**, http://links.lww.com/TXD/A633). Of those donors, 29 met our inclusion criteria of test positivity for SARS-CoV-2 within 14 d of donation. Causes of death in the CPD and CND groups were not significantly different (Table 1), and only 1 donor passed of "respiratory" causes in the CND group.

CPDs were significantly younger than CNDs ($P = 0.04$; Table 1). The gender ($P = 0.57$) and racial/ethnic ($P = 0.21$) makeup of both donor groups was similar. CPDs were less likely to test positive for Epstein-Barr virus ($P = 0.01$), but they tested positive for hepatitis C ($P = 0.26$) and hepatitis B ($P = 1.00$) infections (past or present) at similar rates as CNDs. CPD grafts were more likely to be shared regionally than CND grafts ($P = 0.01$). Overall donor quality, estimated by the KDPI, was superior in CPDs ($P = 0.04$). CPD grafts were more likely to be used in liver retransplantation than were CND grafts

TABLE 1.

Donor features stratified by SARS-CoV-2 positivity within 14 d of transplant date

	SARS-CoV-2–negative donors (N = 472)	SARS-CoV-2–positive donors (N = 29)	*P*
Donor age, y, median (IQR)	34.0 (24.0–46.0)	27.0 (23.0–36.0)	**0.04**
Donor male gender, n (%)	292 (61.9)	20 (69.0)	0.44
Race/ethnicity, n (%)			0.18
White	239 (50.6)	16 (55.2)	
Black	109 (23.1)	3 (10.3)	
Hispanic	113 (23.9)	9 (31.0)	
Asian	8 (1.7)	0 (0.0)	
Other	3 (0.6)	1 (3.4)	
Donor history of diabetes, n (%)	48 (10.3)	5 (17.9)	0.21
Donor history of hypertension, n (%)	114 (24.6)	7 (25.0)	0.96
Donor creatinine, mg/dL, median (IQR)	1.1 (0.7–1.9)	0.9 (0.7–1.4)	0.19
Donor bilirubin, mg/dL, median (IQR)	0.7 (0.5–1.0)	0.6 (0.5–0.8)	0.15
Donor hepatitis C positive, n (%)	4 (0.8)	1 (3.4)	0.26
Donor hepatitis B positive, n (%)	6 (1.3)	0 (0.0)	1.00
Donor EBV positive, n (%)	440 (93.2)	23 (79.3)	**0.01**
Allocation type, n (%)			**0.01**
Local	168 (35.6%)	8 (27.6%)	
Regional	136 (28.8%)	16 (55.2%)	
National	168 (35.6)	5 (17.20)	
Donor after cardiac death, n (%)	32 (6.8)	4 (13.8)	0.15
KDPI, median (IQR)	30.0 (13.0–55.5)	18.0 (7.0–42.0)	**0.04**
Donor cause of death, n (%)			0.096
Anoxia	176 (37.3)	14 (48.3)	
Head trauma	174 (36.9)	12 (41.4)	
Cerebrovascular/stroke	115 (24.4)	2 (6.9)	
Gunshot wound	3 (0.6)	0 (0)	
Cardiac	1 (0.2)	0 (0)	
Congestive heart failure	1 (0.2)	0 (0)	
Overdose	1 (0.2)	1 (3.4)	
Respiratory	1 (0.2)	0 (0)	
SARS-CoV-2 positive test method, n (%)			**<0.001**
Antigen	1 (0.2)[a]	1 (3.4)	
Antigen and nucleic acid test	0 (0)	1 (3.4)	
Nucleic acid test	4 (0.8)[a]	27 (93.1)	
None	467 (98.9)	0 (0)	
Dominant SARS-CoV-2 variants, n (%)			NA
Omicron 21K		10 (34.5)	
Omicron 21L		5 (17.2)	
Omicron 22B		8 (27.6)	
Omicron 22C		2 (6.8)	
Omicron 22E		3 (10.2)	
Liver graft recipient setting, n (%)			**0.03**
Index transplant	454 (96.2)	25 (86.2)	
Redo transplant	18 (3.8)	4 (13.8)	

Bold values denote $P < 0.05$.
[a]Positive SARS-CoV-2 test was >14 d before donation.
EBV, Epstein-Barr virus; IQR, interquartile range; KDPI, kidney donor profile index; NA, not applicable.

($P = 0.03$). As recipients undergoing multiple LTs during the study period may have had both CND and CPD grafts, subsequent analyses focused on index LT (479 index recipients, 25 recipients of CPDs, and 454 recipients of CNDs).

Recipient Characteristics

Recipients of liver allografts from CPDs were significantly older than CND allograft recipients ($P = 0.04$; Table 2). Otherwise, the clinical characteristics of CPD and CND recipients were statistically similar. The frequencies of end-stage liver disease diagnoses were similar in both groups ($P = 0.75$), as were Model for End-stage Liver Disease scores and the times patients spent on the waiting list ($P = 0.61$, 0.61, respectively).

CPD recipients were considered for postexposure prophylaxis post-LT at the discretion of the infectious disease specialist. This consisted of remdesivir (Veklury, Gilead Sciences, Foster City, CA) for 14 recipients, antibody-based regimen for 2, and no prophylaxis for 9. Antibody-based regimens consisted of a combination of tixagevimab and cilgavimab (Evusheld AstraZeneca, Cambridge, United Kingdom) in 1 patient and sotrovimab alone (GlaxoSmithKline, Durham,

TABLE 2.

Recipient features stratified by donor SARS-CoV-2 status at index liver transplantation

	SARS-CoV-2–negative donor recipients (N = 454)	SARS-CoV-2–positive donor recipients (N = 25)[a]	*P*
Age, y, median (IQR)	57.0 (46.0–65.0)	62.0 (52.0–68.0)	**0.04**
Male gender, n (%)	279 (61.5)	11 (44.0)	0.08
Race/ethnicity, n (%)			0.38
White	269 (59.3)	18 (72.0)	
Black	38 (8.4)	3 (12.0)	
Hispanic	122 (26.9)	3 (12.0)	
Asian	23 (5.1)	1 (4.0)	
Other	2 (0.4)	0 (0.0)	
Body mass index, kg/m^2, at transplant, median (IQR)	28.9 (24.8–33.9)	29.7 (27.8–35.2)	0.27
Laboratory MELD score, median (IQR)	30.0 (21.0–37.0)	27.0 (19.0–35.0)	0.61
Time on waiting list, d, median (IQR)	33.0 (6.0–284.0)	16.0 (8.0–329.0)	0.61
Diabetes, n (%)	144 (31.7)	10 (40.0)	0.40
Medical condition at transplant, n (%)			0.62
Home	171 (40.7)	9 (40.9)	
Hospital	65 (15.5)	5 (22.7)	
ICU	184 (43.8)	8 (36.4)	
Primary diagnosis at transplant, n (%)			0.75
Alcohol-associated liver disease	183 (44.0)	10 (45.5)	
Nonalcoholic steatohepatitis	89 (21.4)	5 (22.7)	
Hepatitis B or C	52 (12.5)	4 (18.2)	
Other	92 (22.1)	3 (13.6)	
Organs transplanted, n (%)			1.00
Liver only	374 (82.4)	22 (88)	
Liver-heart	13 (2.9)	0 (0)	
Liver-heart-kidney	4 (0.9)	0 (0)	
Liver-kidney	58 (12.8)	3 (12)	
Liver-lung	5 (1.1)	0 (0)	
Cold ischemia time, h, median (IQR)	6.0 (4.9–8.2)	6.7 (5.2–11.0)	0.13
Hospital length of stay, d, median (IQR)	17.0 (12.0–26.0)	17.0 (11.0–37.0)	0.92
SARS-CoV-2 test method and result,[b] n (%)			0.77
Negative	444 (97.8)	24 (96)	
Nucleic acid test, nasal swab, positive	4 (0.9)	0 (0)	
Antibody, peripheral blood, positive	5 (1.1)	1 (4)	
No testing available	1 (0.2)	0 (0)	
Posttransplant SARS-CoV-2 prophylaxis, n (%)			
Remdesivir		14 (56.0)	
Antibody-based		2 (8.0)	
No prophylaxis		9 (36.0)	
Patient status, n (%)			1.00
Alive	402 (88.5)	23 (92.0)	
Dead	36 (7.9)	2 (8.0)	
Retransplanted	16 (3.5)	0 (0.0)	

Bold values denote $P < 0.05$.

[a]Recipients were stratified by donor features at index liver transplant, excluding redo liver transplantation (n = 4 SARS-CoV-2–positive donors).

[b]SARS-CoV-2 testing was performed routinely on postoperative d 5 and 7 and as needed clinically for all liver transplant recipients.

ICU, intensive care unit; MELD, Model for End-stage Liver Disease.

NC) in another patient. Of the 4 CPD retransplantation recipients, 2 received remdesivir, 1 tixagevimab and cilgavimab, and 1 casirivimab and imdevimab (REGEN-COV, Regeneron Pharmaceuticals Inc, Tarrytown, NY; **Figure S3, SDC,** http://links.lww.com/TXD/A633). Immunosuppression regimen did not vary with the COVID-19 status of donors and consisted of a corticosteroid taper, mycophenolate, and tacrolimus, with a tacrolimus target level of 4 to 6 ng/mL.

Of the 25 CPD recipients, only 1 (4%) recipient tested positive within 14 d of index LT, by antispike IgG on postoperative day 1. The patient then tested negative twice subsequently by nasal swab RT-PCR on postoperative days 26 and 35, before passing away on postoperative day 44 of venothromboembolic disease. He was asymptomatic for COVID-19 throughout. Of 454 CND recipients, 9 (2%) recipients tested positive within 14 d of index LT, of whom only 1 passed away 66 d after a positive test for bacterial sepsis. Frequencies of COVID-19 test positivity within 14 d of index LT were not significantly different ($P = 0.77$) between the 2 groups.

We compared semiquantitative antispike IgG antibody titers pre- and post-LT in 8 patients (Figure 1). Post-LT

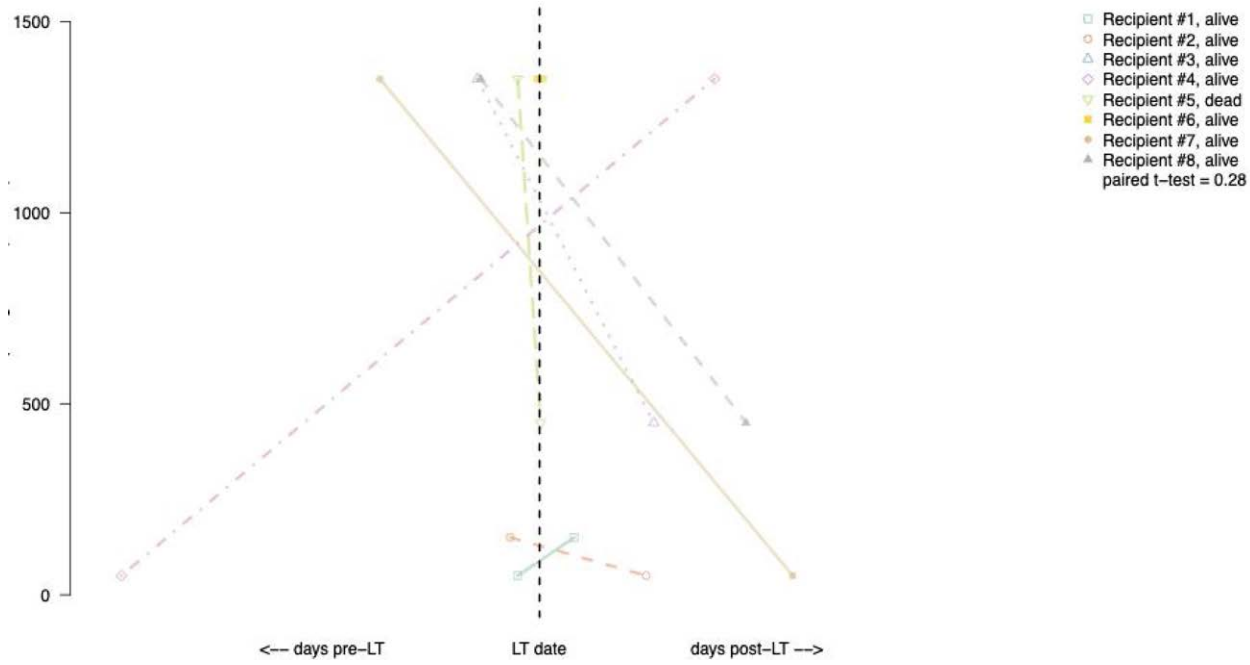

FIGURE 1. The point-and-segment plot of SARS-CoV-2 antispike immunoglobulin G antibody titers pre– and post–liver transplant in recipients of SARS-CoV-2–positive donors. Each of 8 cases is denoted in a separate color.

titers were lower in 5 recipients, unchanged in 1, and higher in 2.

Recipient Outcomes

No liver graft failures occurred in recipients of CPDs, and hence, no subsequent retransplantations occurred. Sixteen (3.5%) recipients of CNDs at index LT required retransplantation ($P = 1.0$; Table 2). To avoid the potentially confounding factor of needing liver retransplantation, outcomes analyses focused on recipients of a single index liver allograft from 25 CPDs and 438 CNDs whose outcomes were either alive or death at time of last follow-up.

Overall survival (OS) post-LT of CPD and CND recipients was not significantly different (hazard ratio, 1.61; 95% confidence interval, 0.38-6.76; $P = 0.52$; Figure 2). OS for CPD recipients were 100%, 100%, 91.3%, 91.3%, and 91.3% at 30 d, 60 d, 90 d, 6 mo, and 1 y after transplant, respectively. CND recipients had OS of 98.9%, 98.5%, 97.1%, 94.5%, and 92.1% at 30 d, 60 d, 90 d, 6 mo, and 1 y after transplant, respectively.

Three recipients of CPD liver grafts died, 1 after an index CND transplant followed by CPD retransplant. All 3 deaths occurred in patients who received grafts from a donor in a hospital where Omicron 21 variants were predominant (2 Omicron 21K, 1 Omicron 21L; **Figure S4, SDC,** http://links.lww.com/TXD/A633). The deceased recipients did not have a documented history of SARS-CoV-2 infection pretransplant (**Figure S5, SDC,** http://links.lww.com/TXD/A633). However, all recipients did have high (1:1350) antispike antibody titers against SARS-CoV-2 pre-LT (**Figure S6, SDC,** http://links.lww.com/TXD/A633) and had documented RNA-based SARS-CoV-2 vaccination (**Figure S7, SDC,** http://links.lww.com/TXD/A633) pre-LT. These patients died before 180 d posttransplant: 1 due to venothromboembolic disease in a skilled nursing facility (day 44), 1 due to sepsis in intensive care unit (day 54), and 1 due to prolonged debility and withdrawal of life-sustaining therapies at the hospice (day 154).

Other Features Affecting OS

Univariable Cox proportional hazards analysis identified several factors associated with OS in the pooled cohort of 463 index LT recipients (Table 3). Receiving a graft from a CPD was not associated with a higher mortality risk (hazard ratio, 1.11; 95% confidence interval, 0.24-5.04; $P = 0.89$). Multivariable analysis identified status 1a recipient, donor serum creatinine, donor cytomegalovirus and Epstein-Barr virus positivity, and donor urinary tract infections as independent predictors of mortality after LT (Table 3).

DISCUSSION

With 29 LTs using CPD grafts and a median follow- up time of 376 d (interquartile range, 183–605), we present what we think is the largest single-center series to date. This series demonstrates that donor SARS-CoV-2 positivity is neither associated with recipient outcomes nor with evidence of viral transmission. The former finding is concordant with 3 recent national-level studies.[7,8,12] The latter finding is an important corroboration based on recipient SARS-CoV-2 infection history, serial antispike antibody titers, and medication regimens afforded by our granular data set.

The number of CPDs has increased from the start of the pandemic to now.[7] To inform LT in the COVID-19 era, factors affecting the use of CPDs must be better elaborated. We found that organ allocation patterns differed between CPD and CND, with a greater proportion of regional allocations for the former. This may either reflect a greater incidence of SARS-CoV-2 positivity in our region, a greater willingness of organ procurement organizations (OPOs) in our region to

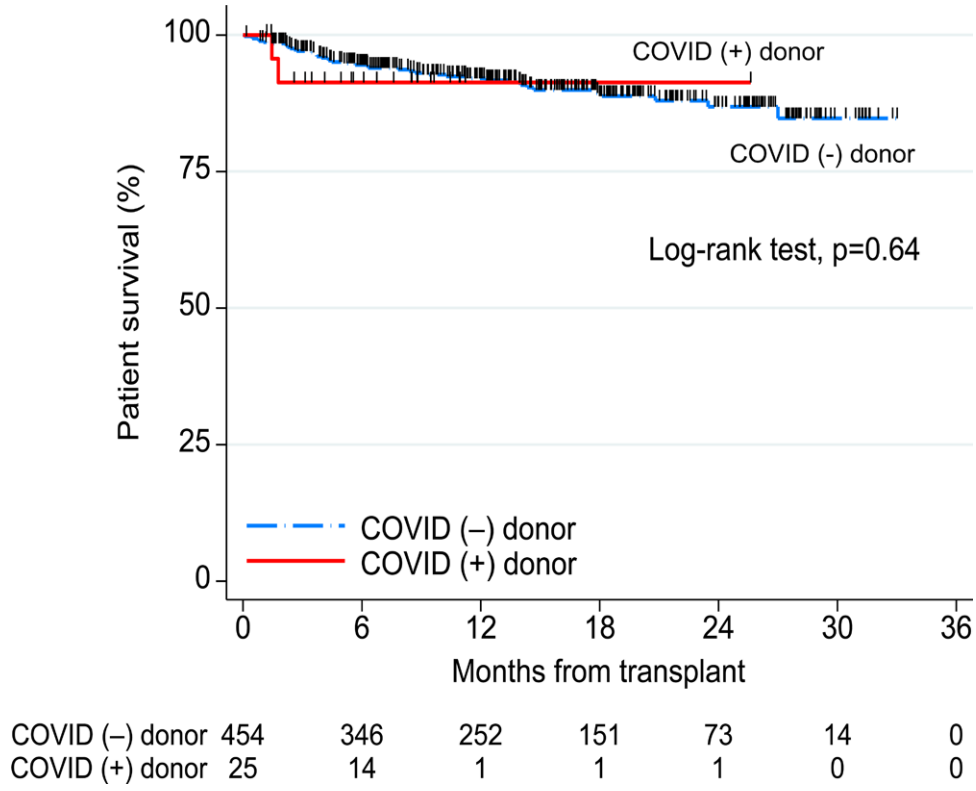

FIGURE 2. Recipient survival from index liver transplant stratified by donor SARS-CoV-2 status.

consider CPDs, or a lesser willingness of other regional centers to accept CPD liver allografts. Wide variations in OPO utilization of CPDs have been reported.[8] Although we cannot ascertain the causes with the data available at this time, our results should offer greater confidence to both OPOs and transplant centers in using these donors.

The increased use of liver allografts from CPDs for redo LTs implies that these were otherwise standard-to-high-quality donors. In the current cohort, CPDs had a lower KDPI, indicating CPDs were of higher quality overall. KDPI is a marker of donor health correlated with both kidney and liver allograft survival that closely approximates the liver donor risk index.[19] Larger registry data have also shown that CNDs and CPDs have similar KDPI scores.[8] Combined with increased regional sharing, similar donor quality implies that CPDs are underused due to perceived risks. Despite this underutilization, the risk of viral transmission to recipients is presumably low. We did not observe a significant difference in frequencies of COVID-19 test positivity between recipients of liver allografts from CPD versus CND. However, because the vector of transmission would be neither donor-graft-derived nor airborne, we cannot ascertain whether conventional SARS-CoV-2 testing or whether the absence of conventional symptoms can accurately rule in or out transmission or infection. SARS-CoV-2 has been detected in livers examined at autopsy in patients who died of severe COVID-19 by nucleic acid sequencing and immunohistochemistry. Thus, CPD liver allograft biopsies may be tested similarly preimplantation to determine transmission potential. We did not observe qualitative associations of overall mortality post-CPD LT with pre-LT antispike antibody titers, documented SARS-CoV-2 infection, COVID-19 vaccination, SARS-CoV-2 variants, or post-LT COVID-19 prophylaxis. Also, there was no consistent trend in serial antispike IgG titers from pre- to post-LT in a subset of our recipients, which is recognized as a correlate of protection or immune marker that should reliably change in response to renewed exposure to the SARS-CoV-2 virus.[20] We recognize that peri-LT immunosuppression may have confounded serial antibody measurements, making these measurements difficult to interpret. Recipient testing posttransplant for antinucleocapsid antibodies in those without prior viral exposure may also identify possible transmission. We noted that the qualitative trend toward increased mortality in CPD recipients with pre-LT mRNA-based vaccinations is likely spurious and further evidence of lack of viral transmission.

Limitations to our study include its single-center setting, limiting external validity, and the small sample size, limiting internal validity. Minor limitations include the lack of COVID-19 genotyping data, the relative paucity of data on serial antispike IgG levels, the lack of CPD liver biopsies, and the lack of pediatric recipients. We do not comment on the magnitude of the fold rise of the antispike antibody levels pre- and post-LT because these were not measured at routine times and may be confounded by unknown viral exposures, vaccinations, and immunosuppression. We also do not have measurements of antinucleocapsid antibody levels as an indicator of past SARS-CoV-2 infection. Because we only accepted liver allografts from asymptomatic CPDs, our findings cannot be extended to donors with symptomatic infections and potentially higher viral loads. Graft acceptance was ultimately determined by the LT surgeon on call and, therefore, possibly subjective. The liberalization of posttransplant recipient SARS-CoV-2 testing and postexposure prophylaxis make interpretations more difficult.

TABLE 3.

Analysis of factors associated with mortality in patients undergoing index liver transplant (excluding patients who underwent liver retransplant)

	Univariable		Multivariable	
	HR (95% CI)	*P*	HR (95% CI)	*P*[a]
Recipient variables				
Recipient age, y	1.03 (1.00-1.05)	0.06	1.02 (0.99-1.05)	0.21
Recipient gender				
Female	Reference		---	---
Male	1.01 (0.55-1.86)	0.98	---	---
Time on waitlist, d	1.00 (1.00-1.00)	0.87	–	–
Recipient MELD at transplant				
≤16	Reference		Reference	
>16 and ≤26	1.44 (0.31-6.79)	0.65	1.09 (0.23-5.30)	0.91
>26 and ≤36	1.70 (0.39-7.41)	0.48	1.73 (0.37-8.05)	0.48
>36 and ≤40	2.41 (0.55-10.48)	0.24	2.25 (0.48-10.53)	0.30
Status 1a	13.27 (1.20-147.13)	**0.04**	66.76 (2.21-2018.49)	**0.02**
Condition at transplant				
From home	Reference		–	–
From hospital	0.36 (0.08-1.56)	0.17	–	–
From intensive care	1.61 (0.85-3.06)	0.14	–	–
Primary diagnosis at transplant				
Alcohol-associated liver disease	Reference		Reference	
Nonalcoholic steatohepatitis	2.23 (1.05-4.74)	**0.04**	2.02 (0.86-4.72)	0.11
Hepatitis B or C	1.56 (0.59-4.10)	0.37	1.72 (0.54-5.55)	0.36
Other	1.23 (0.51-2.98)	0.64	1.55 (0.59-4.06)	0.37
Unknown	2.66 (0.57-12.29)	0.21	0.73 (0.07-7.83)	0.79
Organs transplanted				
Liver only	Reference		–	–
Liver-heart	1.02 (0.14-7.46)	0.99	–	–
Liver-heart-kidney	3.64 (0.50-26.67)	0.20	–	–
Liver-kidney	1.66 (0.76-3.60)	0.20	–	–
Liver-lung	2.07 (0.28-15.19)	0.47	–	–
CMV-positive recipient	1.19 (0.57-2.49)	0.65	–	–
EBV-positive recipient	1.81 (0.43-7.63)	0.42	–	–
Donor variables				
Donor age	0.99 (0.97-1.01)	0.26	–	–
Donor gender			–	–
Female	Reference		–	–
Male	1.53 (0.78-2.97)	0.21	–	–
Donor serum creatinine, mg/dL	1.16 (1.05-1.29)	**0.01**	1.20 (1.06-1.36)	**0.01**
Donor SARS-CoV-2 status[a]				
Negative	Reference		Reference	
Positive	1.40 (0.34-5.86)	0.64	1.11 (0.24-5.04)	0.89
CMV-positive donor	0.54 (0.29-0.98)	**0.04**	0.51 (0.27-0.95)	**0.03**
EBV-positive donor	0.42 (0.19-0.95)	**0.04**	0.39 (0.16-0.94)	**0.04**
Donor had urine infection	2.08 (1.00-4.34)	0.051	2.30 (1.05-5.04)	**0.04**
Kidney Donor Profile Index	1.00 (0.99-1.01)	0.82	–	–
Allocation type			–	–
Local	Reference		–	–
Regional	0.82 (0.37-1.82)	0.62	–	–
National	1.20 (0.60-2.38)	0.60	–	–
			C-statistic = 0.72	

Bold values denote $P < 0.05$

[a]Positive SARS-CoV-2 test within 14 d of donation.

CI, confidence interval; CMV, cytomegalovirus; EBV, Epstein-Barr virus; HR, hazard ratio; MELD, Model for End-stage Liver Disease.

Larger studies are needed to conclusively determine the safety of using CPD grafts. Future research should also address recipient risk factors for poor outcomes after receiving a CPD organ. As the utilization of CPDs is likely to continue to increase over time, it will be necessary to standardize testing methods across OPOs for all organ grafts, as has been suggested for lung donors.[21] Additional research on antiviral prophylaxis in CPD recipients is also needed, particularly with the current dearth of effective antibodies against current strains, as well as the potential hepatotoxicity of remdesivir,

which was used for prophylaxis in a subset of patients at our center. We also lack information on risks to healthcare providers during the recovery and transplantation procedures when CPD grafts are used.

Overall, our single-center study contributes to the published experience that LT using grafts from CPDs is safe, with no evidence of viral transmission. CPD liver allografts are likely an underused resource that can be tapped to help fill the large gap between available donors and LT candidates on the waitlist. However, when considering CPD grafts, clinicians should consider that donors with symptomatic COVID-19 and donor viral load could not be assessed here.

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