OPEN

Solid Organ Transplantation From SARS-CoV-2–infected Donors to Uninfected Recipients: A Single-center Experience

Channa R. Jayasekera, MD,[1] Holenarasipur R. Vikram, MD,[2] Zeeshan Rifat, MBBS,[3] Josiah Wagler, DO,[3] Keita Okubo, MD, PhD,[3] Brandon R. Braaksma, PA-C,[3] Jack W. Harbell, MD,[3] Caroline C. Jadlowiec, MD,[3] Nitin N. Katariya, MD,[3] Amit K. Mathur, MD,[3] Adyr Moss, MD,[3] K. Sudhakar Reddy, MBBS,[3] Andrew Singer, MD, PhD,[3] Robert Orenstein, DO,[2] Christopher F. Saling, MD,[2] Maria T. Seville, MD,[2] Girish K. Mour, MD,[4] Hugo E. Vargas, MD,[1] Thomas J. Byrne, MD,[1] Winston R. Hewitt, Jr, MD,[3] and Bashar A. Aqel, MD[1]

Background. The risk of donor-derived severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) infection in solid organ (heart, lung, liver, kidney, pancreas, and intestine) transplant recipients is poorly understood. Since hematogenous transmission of SARS-CoV-2 has not been documented to date, nonlung solid organs might be suitable for transplantation since they likely portend a low risk of viral transmission. **Methods.** Abdominal solid organs from SARS-CoV-2–infected donors were transplanted into uninfected recipients. **Results.** Between April 18, 2021, and October 30, 2021, we performed transplants of 2 livers, 1 simultaneous liver and kidney, 1 kidney, and 1 simultaneous kidney and pancreas from SARS-CoV-2–infected donors into 5 uninfected recipients. None of the recipients developed SARS-CoV-2 infection or coronavirus disease 2019, and when tested, allograft biopsies showed no evidence of SARS-CoV-2 RNA. **Conclusions.** Transplanting nonlung organs from SARS-CoV-2–infected donors into uninfected recipients demonstrated no evidence of virus transmission.

(*Transplantation Direct* 2022;8: e1286; doi: 10.1097/TXD.0000000000001286).

INTRODUCTION

Almost 6000 individuals die annually because of shortfalls of kidney, liver, lung, heart, intestine, or pancreas donors in the United States. A similar number become ineligible because of disease progression while awaiting transplantation.[1] Healthcare disruptions caused by the severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) pandemic compounded donor organ shortages, leading to excess morbidity and mortality in individuals awaiting organ transplantation.[2-4]

Organs from SARS-CoV-2–infected individuals are not routinely considered for donation because of a perceived risk of transmitting infection to recipients. Early in the pandemic, major professional societies recommended against the use of these organs, whereas the Organ Procurement and Transplantation Network (OPTN) recently classified these donors as subjecting recipients to unknown risk of disease transmission.[5,6] Since SARS-CoV-2 is not known to transmit hematogenously, the risk of donor-derived infection from nonlung solid organs, such as heart, liver, kidney, and pancreas, may be low irrespective of adjunctive antiviral therapies, vaccination status of recipients, or antirejection immunosuppression regimens.[7] We report our successful experience transplanting 2 livers, 1 simultaneous liver and kidney, 1 kidney, and 1 simultaneous kidney and pancreas from SARS-CoV-2–infected deceased donors into 5 SARS-CoV-2–uninfected recipients between April 18, 2021, and October 3, 2021.

MATERIALS AND METHODS

Donor Characteristics

All donors underwent nasopharyngeal swab SARS-CoV-2 real-time polymerase chain reaction (RT-PCR) testing within

Received 7 December 2021. Revision received 8 December 2021.
Accepted 10 December 2021.
[1] Division of Gastroenterology and Hepatology, Department of Medicine, Mayo Clinic Arizona, Phoenix, AZ.
[2] Division of Infectious Diseases, Department of Medicine, Mayo Clinic Arizona, Phoenix, AZ.
[3] Division of Transplant Surgery, Department of Surgery, Mayo Clinic Arizona, Phoenix, AZ.
[4] Division of Nephrology, Department of Medicine, Mayo Clinic Arizona, Phoenix, AZ.
The authors declare no funding or conflicts of interest.
C.R.J., H.R.V., Z.R., J.W., K.O., B.R.B., J.W.H., C.C.J., N.N.K., A.K.M., A.M., K.S.R., A.S., R.O., C.F.S., M.T.S., G.K.M., H.E.V., T.J.B., W.R.H., and B.A.A. made significant contributions to conceiving the transplantation strategy, drafting, and critically revising the article for important intellectual content. All authors reviewed the final article and agreed to its submission. All authors agree to be accountable for all aspects of this article.
C.R.J. and H.R.V. have contributed equally to this article.
Correspondence: Channa R. Jayasekera, MD, Division of Gastroenterology and Hepatology, Department of Medicine, Mayo Clinic Arizona, 5777 E Mayo Blvd, Phoenix, AZ 85054. (jayasekera.channa@mayo.edu).

ISSN: 2373-8731
DOI: 10.1097/TXD.0000000000001286

72 h of organ procurement, and results were known at time of organ offer. All organ offers are reviewed on a case-by-case basis to determine suitability for recipients on our waitlists. Once a suitable match is identified, the potential recipient is contacted with the organ offer and has the option of declining without impact on candidacy for future organ offers.

Informed Consent

As part of our Center protocol, waitlisted individuals with an organ offer are informed that donors are tested for SARS-CoV-2 infection immediately before organ procurement, and the results of that testing. We inform potential recipients regarding true-positive and false-negative SARS-CoV-2 PCR results, the possibility of donor-derived transmission, and that the precise risk of virus transmission through organ transplantation is unknown. Recipients provide written informed consent acknowledging such risk.

Ethics Statement

Clinical care provided was exempt from an internal review board.

Recipient Testing

Matched recipients must test negative by nasopharyngeal swab SARS-CoV-2 RT-PCR at the time of an accepted organ offer.

Multidisciplinary Management

Transplant recipients are cared for by specialists in transplant surgery, transplant hepatology, transplant nephrology, transplant infectious disease, and pharmacy.

Antiviral Treatment Regimens

Casirivimab-imdevimab, a monoclonal antibody against the receptor-binding domain of the SARS-CoV-2 spike glycoprotein, was used for postexposure prophylaxis in recipients 1–3. Remdesivir, a nucleoside analog inhibitor of the SARS-CoV-2 RNA-dependent RNA polymerase, was an adjunctive empiric treatment in recipients 2–5, and anti-SARS-CoV-2 convalescent plasma was used in recipient 5.

Evaluation of Donor-derived SARS-CoV-2 Infection

In addition to symptom monitoring, all recipients underwent serial nasopharyngeal SARS-CoV-2 RT-PCR testing. Recipients were placed under modified droplet isolation precautions until the first postoperative negative SARS-CoV-2 RT-PCR result.

In recipients 2, 4, and 5, we retrospectively performed direct SARS-CoV-2 RNA testing of the day 0 allograft protocol biopsy tissue for study purposes using either digital droplet PCR (DD-PCR) or RT-PCR.

Immunosuppression Regimens

All patients received induction immunosuppression at transplantation along our Center's protocol. Our knowledge of donor SARS-CoV-2 infection status did not alter immunosuppression regimens. For recipients of kidney or pancreas allografts, we use the lymphocyte-depleting monoclonal antibody alemtuzumab in recipients <65 y or the interleukin-2 receptor antagonist basiliximab in recipients ≥65 y. Basiliximab is used in simultaneous liver and kidney transplant recipients. Isolated liver transplant recipients receive methylprednisolone for induction. Maintenance immunosuppression in all recipients consists of calcineurin inhibitors, antimetabolite agents, and oral corticosteroid tapers.

RESULTS

Donor and recipient characteristics are detailed in Table 1.

Recipient 1

A 29-y-old male with stage-4 chronic kidney disease due to type 1 diabetes underwent simultaneous kidney and pancreas transplant from a donor who was declared brain dead due to cerebral infarction. The donor tested negative by nasopharyngeal SARS-CoV-2 RT-PCR the day before organ procurement.

The recipient was unvaccinated against SARS-CoV-2 infection, but his domestic partner had documented SARS-CoV-2 infection 5 mo prior. His postoperative course included a bacterial urinary tract infection and a self-limited postoperative ileus. He was discharged on postoperative day 9.

Our Center was informed on postoperative day 8 that the donor had a subsequent positive nasopharyngeal RT-PCR for SARS-CoV-2 when tested after death immediately before a postmortem examination. The recipient was asymptomatic and tested negative for SARS-CoV-2 by RT-PCR, and SARS-CoV-2 spike glycoprotein antibody was positive while nucleocapsid antibody was negative at that timepoint. After obtaining an investigational new drug approval, he was treated with a single dose of casirivimab-imdevimab on postoperative day 11 for postexposure prophylaxis. The recipient tested negative for SARS-CoV-2 by nasopharyngeal swab RT-PCR on postoperative days 8, 10, 15, 19, and 30. Spike glycoprotein and nucleocapsid antibodies remained unchanged at days 24 and 109 after transplant.

Recipient 2

A 65-y-old male with alcohol-related cirrhosis with hepatorenal syndrome requiring hemodialysis underwent simultaneous liver and kidney transplant from a donor who was declared brain dead due to a gunshot wound to the head. The donor tested positive for SARS-CoV-2 by nasopharyngeal swab twice, 4 d and 1 d before organ procurement.

Because of the recipient's ongoing vasopressor support and coagulopathy, the biliary anastomosis was completed on postoperative day 2. The patient's postoperative course included *Candida kefyr* fungemia treated with caspofungin and then fluconazole, severe epistaxis requiring endotracheal intubation for airway protection and nasal packing, and postoperative delirium managed with supportive care. He was discharged on postoperative day 21.

The recipient received the Pfizer-BioNTech mRNA coronavirus disease 2019 (COVID-19) vaccine 101 and 80 d before transplant. He had a negative nasopharyngeal swab RT-PCR but detectable SARS-CoV-2 nucleocapsid and spike glycoprotein antibodies immediately before transplant, suggesting recent exposure and vaccination response. He was empirically treated with remdesivir on postoperative days 1–5 and received casirivimab-imdevimab for postexposure prophylaxis on postoperative day 2. The recipient tested negative for SARS-CoV-2 by nasopharyngeal swab RT-PCR on day of transplant and postoperative days 1–5 and 18. Antibodies against the SARS-CoV-2 nucleocapsid became negative, but those against the spike protein remained positive on postoperative days 4, 11, and 20. Day 0 liver and kidney allograft

TABLE 1.

Transplant organ recipient and donor characteristics

	Recipient 1	Recipient 2	Recipient 3	Recipient 4	Recipient 5
Transplanted organ(s)	**Kidney and pancreas**	**Liver and kidney**	**Kidney**	**Liver**	**Liver**
Donor					
Age	24	18	18	56	47
Body mass index	29.7	31.1	31.1	33.1	32.3
Liver donor risk index	–	1.27	–	1.94	1.49
Kidney donor profile index	17%	2%	2%	–	–
SARS-CoV-2 RT-PCR at transplant	Negative nasopharyngeal swab by 1 d before organ procurement. Donor tested positive by nasopharyngeal swab RT-PCR 9 d after organ procurement, at time of postmortem	Positive nasopharyngeal swab 4 d and 1 d before organ procurement	Positive nasopharyngeal swab 4 d and 1 d before organ procurement	Positive endotracheal aspirate 2 d before organ procurement	Positive by bronchoalveolar lavage 3 d before organ procurement. Negative nasopharyngeal swab 2 d before organ procurement
Donor organ	Donation after brain death	Donation after brain death	Donation after brain death	Donation after brain death	Donation after brain death
Cause of death	Cerebral infarction	Gunshot wound to head	Gunshot wound to head	Intracranial hemorrhage	Intracranial hemorrhage
SARS-CoV-2 infection symptoms	None reported	None reported	None reported	COVID-19 pneumonia requiring intubation 24 d before organ procurement, intubated at time of organ procurement	None reported
Recipient					
Kidney disease at transplant	Chronic, stage-4	Hepatorenal syndrome, requiring dialysis	Chronic, stage-5, requiring dialysis	-	-
MELDNa score at transplant	–	35	–	17	31
SARS-CoV-2 vaccination status at transplant	Unvaccinated	Pfizer-BioNTech, first dose 101 d prior, second dose 80 d prior	Moderna, first dose 181 d prior, second dose 143 d prior	Pfizer-BioNTech, first dose 182 d prior, second dose 159 d prior	Moderna, first dose 10 d prior. Second dose administered after transplant
SARS-CoV-2 nasopharyngeal swab RT-PCR at transplant	Negative	Negative	Negative	Negative	Negative
SARS-CoV-2 spike glycoprotein at transplant	Not checked at time of transplant. Positive on postoperative day 8.	Positive	Positive	Positive	Positive
SARS-CoV-2 nucleocapsid antibody at transplant	Not checked at time of transplant. Negative on postoperative day 8.	Positive	Negative	Negative	Positive
Patient-reported or confirmed SARS-CoV-2 infection prior to transplant	None	None	None	None	Symptomatic infection not requiring treatment or hospitalization 11 mo before transplant
SARS-CoV-2 postexposure prophylaxis and/or empiric treatment regimen	1.Casirivimab-imdevimab single dose postoperative day 11	1.Remdesivir 200 mg (postoperative day 1) then 100 mg daily for 4 d. 2.Casirivimab-imdevimab single dose postoperative day 2	1.Remdesivir 200 mg (postoperative day 1) then 100 mg daily for 2 d. 2.Casirivimab-imdevimab single dose postoperative day 1	1.Remdesivir 200 mg (postoperative day 1) then 100 mg daily for 4 d	1.Remdesivir 200 mg (postoperative day 1) then 100 mg for 4 d. 2.Anti–SARS-CoV-2 convalescent plasma 1 unit.
Allograft SARS-CoV-2 testing	–	Liver day 0 biopsy RT-PCR: SARS-CoV-2 RNA not detected. Kidney day 0 biopsy RT-PCR: SARS-CoV-2 RNA not detected	–	Liver day 0 biopsy DD-PCR: SARS-CoV-2 RNA not detected	Liver day 0 biopsy RT-PCR: SARS-CoV-2 RNA not detected
Induction immunosuppression regimen	Alemtuzumab 30 mg (postoperative day 0), tacrolimus, mycophenolate mofetil, methylprednisolone	Basiliximab 20 mg (postoperative day 0), tacrolimus, mycophenolate mofetil, methylprednisolone	Alemtuzumab 30 mg (postoperative day 0), tacrolimus, mycophenolate mofetil, methylprednisolone	Tacrolimus, mycophenolate mofetil, methylprednisolone	Tacrolimus, mycophenolate mofetil, methylprednisolone
Allograft status at day 14	Functioning	Functioning	Functioning	Functioning	Functioning
Allograft status at day 30	Functioning	Functioning	Functioning	Functioning	Functioning
Allograft status at day 60	Functioning	Functioning	Functioning	Functioning	Functioning
Allograft status at day 90	Functioning	Functioning	Functioning	–	–

COVID-19, coronavirus disease 2019; DD-PCR, digital droplet polymerase chain reaction; MELDNa, model for end-stage liver disease score with sodium correction; RT-PCR, reverse transcriptase polymerase chain reaction; SARS-CoV-2, severe acute respiratory syndrome coronavirus 2.

biopsy tissue were retrospectively tested for SARS-CoV-2 RNA by RT-PCR and were negative.

Recipient 3

A 60-y-old male with stage-5 kidney disease from autosomal dominant polycystic kidney disease on peritoneal dialysis underwent kidney transplant from the same donor as recipient 2. Postoperative course was uncomplicated, and the patient was discharged on postoperative day 2.

The recipient received the Moderna mRNA COVID-19 vaccine 181 and 143 d before transplant. He had a negative nasopharyngeal swab SARS-CoV-2 RT-PCR immediately before transplant, with detectable spike glycoprotein antibody and undetectable nucleocapsid antibody confirming vaccination response. He was empirically treated with remdesivir on postoperative days 1–3 and received casirivimab-imdevimab for postexposure prophylaxis on postoperative day 1. The recipient tested negative for SARS-CoV-2 by nasopharyngeal swab RT-PCR on postoperative days 0–5.

Recipient 4

A 53-y-old male with cirrhosis due to alcohol-related liver disease concurrent with metabolic-associated fatty liver disease underwent liver transplant from a donor who was declared brain dead due to intracranial hemorrhage. At the time of organ procurement, the donor was admitted in an intensive care unit for 24 d with severe COVID-19 infection, mechanically ventilated with endotracheal intubation. The donor tested positive for SARS-CoV-2 by endotracheal aspirate 2 d before organ procurement.

The recipient underwent simultaneous sleeve gastrectomy for morbid obesity and portal vein thrombectomy at time of transplant. On postoperative day 1, the patient was taken back for evaluation of perihepatic fluid collections. No active bleeding was found, and the bile duct was revised. He was discharged on day 7 following transplant.

The recipient received the Pfizer-BioNTech mRNA COVID-19 vaccine 182 and 159 d before transplant. He had a negative RT-PCR but detectable antibody to the SARS-CoV-2 spike glycoprotein and negative nucleocapsid antibody immediately before transplant.

The recipient was treated with remdesivir on postoperative days 1–5. He had negative nasopharyngeal swab SARS-CoV-2 RT-PCRs on postoperative days 0, 3, and 5. Antibodies against the SARS-CoV-2 nucleocapsid were negative on postoperative day 0 but were positive on postoperative day 1 and negative again on postoperative day 24. Antibodies against the spike antibody remained positive on postoperative days 0, 1, and 24. Liver allograft biopsy tissue on day 0 tested negative for SARS-CoV-2 by DD-PCR.

Recipient 5

A 62-y-old male with cirrhosis due to alcohol-related liver disease underwent liver transplant from a donor declared brain dead due to intracranial hemorrhage. The donor was in an intensive care unit for an intracranial hemorrhage without symptomatic SARS-CoV-2 infection but had a positive bronchoalveolar lavage RT-PCR 3 d before organ procurement and a negative nasopharyngeal swab RT-PCR 2 d before organ procurement.

The transplant surgery was notable for a planned return to the operating room on postoperative day 1 for completion of the biliary anastomosis. His postoperative course included atrial fibrillation with rapid ventricular response treated with beta blocker and chylous ascites treated with total parenteral nutrition for 21 d with subsequent return to a regular diet.

The recipient had PCR-confirmed COVID-19 with mild upper respiratory tract symptoms not requiring treatment or hospitalization 11 mo before transplant. He was vaccinated with the first dose of the Moderna mRNA COVID-19 vaccine 10 d before transplant. Immediately before transplant the recipient had negative nasopharyngeal SARS-CoV-2 RT-PCR testing and detectable SARS-CoV-2 nucleocapsid and spike glycoprotein antibodies.

The recipient was treated with remdesivir on postoperative days 0–5 and received a unit of anti–SARS-CoV-2 convalescent plasma. The recipient tested negative for SARS-CoV-2 by nasopharyngeal swab RT-PCR on postoperative days 5 and 14. Antibodies against SARS-CoV-2 nucleocapsid remained positive at postoperative days 5 and 15. Liver allograft biopsy tissue on day 0 tested negative for SARS-CoV-2 by RT-PCR.

DISCUSSION

We describe transplanting 7 abdominal organs from SARS-CoV-2–infected donors to 5 uninfected recipients without evidence of virus transmission. Four of the 5 transplants were performed with knowledge of positive donor SARS-CoV-2 PCR testing. We confirmed absence of viral RNA in allograft tissue in recipients 2, 4, and 5 by PCR. This absence of apparent viral transmission is in context of 1 recipient being unvaccinated, 1 being partially vaccinated, and 3 being fully vaccinated. We also followed our standard immunosuppression protocols with lymphocyte-depleting therapy in 1 recipient and interleukin-2 receptor inhibitor therapy in 2 recipients, in addition to calcineurin inhibitors, antimetabolites, and corticosteroids.

We also describe liver transplantation from a donor with severe COVID-19 pneumonia requiring mechanical ventilation for 24 d but succumbed to an intracranial hemorrhage (recipient 4). Despite this donor's endotracheal aspirate testing positive for SARS-CoV-2 PCR 2 d before organ procurement, there was no transmission of virus as confirmed by PCR testing of the day 0 allograft biopsy tissue.

To date, there are only 13 single case reports and 1 multicenter case series (N = 10) cumulatively of 24 nonlung organ transplants (16 kidneys, 15 livers, and 3 hearts) from SARS-CoV-2–infected donors.[8-18] Fifteen of those 24 recipients had no previous SARS-CoV-2 infection or vaccination (8/16 kidney recipients, 5/15 liver recipients, 2/3 heart recipients), and there was no virus transmission. There are also reports of at least 45 kidneys, 14 livers, and 6 hearts transplanted from 55 donors with fully resolved SARS-CoV-2 infection with no evidence of virus transmission.[8,9,19-26] The OPTN's recent guidance, reflecting this sparse data, concludes that the precise virus transmission risk with this transplantation strategy remains unknown and that transplantation decisions should balance this unknown risk against the recipient's morbidity and mortality risk while awaiting transplantation.[6] Our case series of 7 organ transplants contributes to the literature supporting the safety of solid organ transplantation from infected donors to uninfected recipients.

Limited data at the time of our cases required a cautious approach in the care of these recipients. Despite the successful

transplantations described, our experience raises questions that warrant further study. For instance, that SARS-CoV-2 is not known to transmit hematogenously could obviate need for postexposure prophylaxis and empiric antiviral treatments. The need for and the duration of modified droplet precautions in such recipients is also unknown. Likewise, serial nasopharyngeal swab RT-PCR testing of recipients might be unnecessary after initial negative testing. If SARS-CoV-2 infection is confirmed in the recipient, it might be difficult to determine if the infection was donor- or community-derived. Our utilization of a liver from a donor with severely symptomatic COVID-19 pneumonia, with the allograft confirmed negative for viral RNA on the day of transplant, suggests the possibility of utilizing potentially higher-risk nonlung organs. Whether the risk of transmission from nonlung organs is higher from a donor with recent symptomatic COVID-19 infection with presumed high viral load compared with a donor with prolonged hospitalization for severe COVID-19 pneumonia when inflammatory processes predominate requires study. Finally, despite the apparent low risk of virus transmission, we now require organ recipients to be vaccinated against SARS-CoV-2 because of risk of posttransplant infection while pharmacologically immunosuppressed. Our center criteria for SARS-CoV-2–positive deceased donor and living donor organ acceptance mirrors the recently updated OPTN guidelines.[6]

Recent publications indicate a correlation between SARS-CoV-2 viremia and clinical outcomes such as disease severity, mechanical ventilation, and mortality. Among 103 hospitalized children with COVID-19, SARS-CoV-2 viremia was detected in 26%. Median duration of viremia was 6 d.[27] In a cross-sectional study of 85 inpatients and outpatients with confirmed COVID-19 infection, RNAemia was detected in 33%, including 79% requiring hospitalization, and in all 4 patients who died. Maximum duration of RNAemia was 10 d.[28] In another study from Japan, SARS-CoV-2 RNAemia was detected in 19.6% of patients on admission. Subsequently, 1%, 50%, and 100% had documented RNAemia with moderate, severe, or critical illness.[29] Although not conclusive, these studies seem to indicate a potential higher risk of ongoing viremia and transmission from nonlung organs of hospitalized and critically ill donors versus asymptomatic or minimally symptomatic donors. Moreover, RNAemia does not necessarily mean viremia with viable virus. Prospective studies addressing duration and quantitation of SARS-CoV-2 viremia in patients with varying disease severity may provide information on virus transmission from nonlung organs including hematopoietic stem cells.

The strengths of our study include a heterogenous cohort receiving various abdominal organs from SARS-CoV-2 positive donors without evidence of transmission—recipients 1 and 2 with dual-organ transplants, recipient 1 who was unvaccinated, and recipient 4 whose donor was hospitalized in intensive care for 24 d with severe COVID-19 infection. In addition, we tested day 0 allograft biopsies with SARS-CoV-2 PCR in recipients 2, 4, and 5 and all were negative. This provides further substantiation of the low risk of virus transmission.

We recognize the following limitations. First, recipients were heterogeneous in prior infection, COVID-19 vaccination, and serologic statuses at time of transplant. Although this heterogeneity reflects the exposure and vaccination statuses of the general population, larger case series and stratified assessment of transplant outcomes by vaccination and serologic status would be beneficial. Second, we adopted varying postexposure prophylaxis and empiric treatment regimens, reflecting our evolving understanding of this novel transplantation strategy. The use of casirivimab-imdevimab for recipients 1–3 required an investigational new drug agreement with the manufacturer. Our choice of remdesivir in recipients 2–5 was based on providing rapid antiviral activity presuming donor-derived infection and pharmacologic immunosuppression. Recipient 5 received anti–SARS-CoV-2 convalescent plasma, since he had only received 1 dose of the Moderna mRNA vaccine 10 d prior and had minimally symptomatic COVID-19 infection 11 mo before transplantation. We felt his neutralizing antibodies may be inadequate in the event of donor-derived infection, although it is now understood that neither monoclonal antibodies nor convalescent plasma appear to provide benefit in recipients who are fully vaccinated at least 2 wks before transplantation. Third, we did not adopt protocolized monitoring of nucleocapsid and spike antibodies pretransplant and posttransplant to determine if organ transplantation from SARS-CoV-2–positive donors prompted unique changes in recipients' serologic response concurrent to immunosuppression. The unknown durability of serologic responses posttransplant and the influence of monoclonal antibodies and convalescent plasma on endogenous antibody titers and its measurement further potentially confound their significance and interpretation. Fourth, our case series represents organ transplantation during widespread circulation of SARS-CoV-2 delta variant and its elevated risk of transmission and asymptomatic infection even in vaccinated individuals.[30] Finally, despite the possibility of false-positive SARS-CoV-2 donor testing, and since we did not have cycle threshold (Ct) values for positive donor tests, every positive PCR result was interpreted as a true-positive given the unknown implications to recipients and risk of healthcare worker exposure. This reflects real world scenarios wherein organ acceptance decisions commonly need to be made without Ct values. Ct values can also vary based on the SARS-CoV-2 PCR testing modality utilized. Without a clear correlation between nasophargyngeal swab Ct values, SARS-CoV-2 viremia, and risk of transmission via nonlung organs, it is unlikely that nasopharyngeal swab Ct values would have influenced our decision to accept or reject organs described.

Almost 800 000 individuals have died because of SARS-CoV-2 infection in the United States at the time of this article's submission. We believe that a more comprehensive understanding of the safety of utilizing these solid organs for transplantation, and peritransplant donor and recipient monitoring and treatment protocols to minimize transmission risk, may expand the organ donor pool and mitigate disruptions to transplant rates during this and future pandemics of severe respiratory viral infections.

ACKNOWLEDGMENTS

The authors acknowledge the assistance of Erin Graf, PhD; Erin Kaleta, PhD; and Deanna Penning for donor and recipient testing.

REFERENCES

1. OPTN/SRTR 2019 annual data report: introduction. *Am J Transplant*. 2021;21 (suppl 2):11–20.

2. Loupy A, Aubert O, Reese PP, et al. Organ procurement and transplantation during the COVID-19 pandemic. *Lancet.* 2020;395:e95–e96.
3. Merola J, Schilsky ML, Mulligan DC. The impact of COVID-19 on organ donation, procurement, and liver transplantation in the United States. *Hepatol Commun*. 2021;5:5–11.
4. Yuan Q, Haque O, Coe TM, et al. The heterogenous effect of COVID-19 on liver transplantation activity and waitlist mortality in the United States. *Front Surg.* 2021;8:669129.
5. Kates OS, Fisher CE, Rakita RM, et al. Use of SARS-CoV-2-infected deceased organ donors: should we always "just say no?" *Am J Transplant.* 2020;20:1787–1794.
6. Organ Procurement and Transplantation Network, US Department of Health and Human Services. Summary of current evidence and information-donor SARS-CoV-2 testing & organ recovery from donors with a history of COVID-19. 2021. Available at: https://optn.transplant.hrsa.gov/media/kkhnlwah/sars-cov-2-summary-of-evidence.pdf. Accessed December 2, 2021.
7. Gaussen A, Hornby L, Rockl G, et al. Evidence of SARS-CoV-2 infection in cells, tissues, and organs and the risk of transmission through transplantation. *Transplantation.* 2021;105:1405–1422.
8. Koval CE, Poggio ED, Lin YC, et al. Early success transplanting kidneys from donors with new SARS-CoV-2 RNA positivity: a report of 10 cases. *Am J Transplant.* 2021;21:3743–3749.
9. Frattaroli P, Anjan S, Coro A, et al. Is it safe to perform abdominal transplantation from SARS-CoV-2 polymerase chain reaction positive donors? *Transpl Infect Dis.* 2021;23:e13688.
10. Hong HL, Kim SH, Choi DL, et al. A case of coronavirus disease 2019-infected liver transplant donor. *Am J Transplant.* 2020;20:2938–2941.
11. Nguyen MC, Lee EJ, Avery RK, et al. Transplant of SARS-CoV-2-infected living donor liver: case report. *Transplant Direct.* 2021;7:e721.
12. Perlin DV, Dymkov IN, Terentiev AV, et al. Is kidney transplantation from a COVID-19-positive deceased donor safe for the recipient? *Transplant Proc.* 2021;53:1138–1142.
13. Puodziukaite L, Serpytis M, Kundrotaite A, et al. Kidney transplantation from a SARS-CoV-2-positive donor for the recipients with immunity after COVID-19. *Transpl Infect Dis.* 2021;23:e13666.
14. Sigler R, Shah M, Schnickel G, et al. Successful heart and kidney transplantation from a deceased donor with PCR positive COVID-19. *Transpl Infect Dis.* 2021;23:e13707.
15. Manzia TM, Gazia C, Lenci I, et al. Liver transplantation performed in a SARS-CoV-2 positive hospitalized recipient using a SARS-CoV-2 infected donor. *Am J Transplant.* 2021;21:2600–2604.
16. Dhand A, Gass A, Nishida S, et al. Successful transplantation of organs from a deceased donor with early SARS-CoV-2 infection. *Am J Transplant.* 2021;21:3804–3805.
17. Barros N, Ermel A, Mihaylov P, et al. Deceased donor liver transplantation from a SARS-CoV-2-positive donor to a SARS-CoV-2-positive recipient. *Liver Transpl.* 2021;27:1849–1851.
18. Royo-Villanova Reparaz M, Dominguez-Gil B, Moreno Docón A, et al. Organ donor with PCR positive for SARS-CoV-2, it has been always no? *Med Intensiva (Engl Ed)*. [Epub ahead of print. April 17, 2021]. doi:10.1016/j.medin.2021.03.011.
19. Kucuk EV, Sit D, Kayabasi H, et al. The first kidney transplantation after recipient and living donor recovered from COVID-19. *North Clin Istanb.* 2021;8:187–189.
20. Neidlinger NA, Smith JA, D'Alessandro AM, et al. Organ recovery from deceased donors with prior COVID-19: a case series. *Transpl Infect Dis.* 2021;23:e13503.
21. Meshram HS, Kute VB, Patel H, et al. A case report of successful kidney transplantation from a deceased donor with terminal COVID-19-related lung damage: ongoing dilemma between discarding and accepting organs in COVID-19 era! *Transpl Infect Dis.* 2021;23:e13683.
22. Kute VB, Godara S, Guleria S, et al. Is it safe to be transplanted from living donors who recovered from COVID-19? experience of 31 kidney transplants in a multicenter cohort study from india. *Transplantation.* 2021;105:842–850.
23. Kanchi P, Sambandam S, Siddhan R, et al. Successful kidney transplantation after COVID-19 infection in two cases. *Nefrologia (Engl Ed)*. [Epub ahead of print. January 9, 2021]. doi:10.1016/j.nefro.2020.12.004.
24. Safa K, Elias N, Gilligan HM, et al. Successful living kidney donation after COVID-19 infection. *Transplantation.* 2021;105:e4–e5.
25. Tuncer A, Akbulut S, Baskiran A, et al. A recipient and donor both have COVID-19 disease. should we perform a liver transplant? *J Gastrointest Cancer.* 2021;52:1143–1147.
26. Malleeswaran S, Mohanka R, Yalakanti RB, et al. Living donor hepatectomy after proven SARS-CoV-2 infection: first report of 9 cases from 3 centers. *Transplantation.* 2021;105:e70–e71.
27. Mertz C, Glowinski R, Cohen SH, et al. Severe acute respiratory syndrome coronavirus 2 RNAemia and clinical outcomes in children with COVID-19. *J Infect Dis*. [Epub ahead of print. October 7, 2021]. doi:10.1093/infdis/jiab491.
28. Hogan CA, Stevens BA, Sahoo MK, et al. High frequency of SARS-CoV-2 RNAemia and association with severe disease. *Clin Infect Dis.* [Epub ahead of print. October 7, 2021]. doi:10.1093/infdis/jiab491.
29. Kawasuji H, Morinaga Y, Tani H, et al. SARS-CoV-2 RNAemia with a higher nasopharyngeal viral load is strongly associated with disease severity and mortality in patients with COVID-19. *J Med Virol.* 2022;94:147–153.
30. Brown CM, Vostok J, Johnson H, et al. Outbreak of SARS-CoV-2 infections, including COVID-19 vaccine breakthrough infections, associated with large public gatherings—Barnstable County, Massachusetts, July 2021. *MMWR Morb Mortal Wkly Rep.* 2021;70:1059–1062.