Received: 1 April 2021 | Revised: 7 May 2021 | Accepted: 10 May 2021

DOI: 10.1111/ctr.14362

Clinical TRANSPLANTATION
The Journal of Clinical and Translational Research
WILEY

ORIGINAL ARTICLE

Comparative incidence and outcomes of COVID-19 in kidney or kidney-pancreas transplant recipients versus kidney or kidney-pancreas waitlisted patients: A single-center study

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Abstract

Background: COVID-19 epidemiologic studies comparing immunosuppressed and immunocompetent patients may provide insight into the impact of immunosuppressants on outcomes.

Methods: In this retrospective cohort study, we assembled kidney or kidney-pancreas transplant recipients who underwent transplant from January 1, 2010, to June 30, 2020, and kidney or kidney-pancreas waitlisted patients who were ever on the waitlist from January 1, 2019, to June 30, 2020. We identified laboratory-confirmed COVID-19 until January 31, 2021, and tracked its outcomes by leveraging informatics infrastructure developed for an outcomes research network.

Results: COVID-19 was identified in 62 of 887 kidney or kidney-pancreas transplant recipients and 20 of 434 kidney or kidney-pancreas waitlisted patients (7.0% vs. 4.6%, $p = .092$). Of these patients with COVID-19, hospitalization occurred in 48 of 62 transplant recipients and 8 of 20 waitlisted patients (77% vs. 40%, $p = .002$); intensive care unit admission occurred in 18 of 62 transplant recipients and 2 of 20 waitlisted patients (29% vs. 10%, $p = .085$); and 7 transplant recipients were mechanically ventilated and died, whereas no waitlisted patients were mechanically ventilated or died (11% vs. 0%, $p = .116$).

Conclusions: Our study provides single-center data and an informatics approach that can be used to inform the design of multicenter studies.

KEYWORDS
COVID-19, epidemiology, kidney transplant, kidney waitlist

1 | INTRODUCTION

Severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2), the causative agent of coronavirus disease 2019 (COVID-19), poses significant threats to kidney transplant recipients. Case series and early cohort studies indicate an unfavorable disease course, with intensive care unit stays in 20%–50% of patients, and death rates of 14%–30%.[1–5] These outcomes are worse than those reported for the general population and may be due to greater age, immunosuppression, and comorbid conditions such as hypertension, diabetes mellitus, and cardiovascular disease.[6]

The impact of chronic immunosuppression on COVID-19 outcomes is being debated. It has been hypothesized that a tempered

immune response may prevent severe cytokine storm that ensues in a subset of patients with COVID-19-induced acute respiratory distress syndrome.[7,8] However, chronic immunosuppression is known to worsen the disease courses of most infections, including but not limited to cytomegalovirus, influenza, *Streptococcus pneumoniae*, and invasive fungal infections.[9–12]

In this retrospective cohort single-center study, we determined the incidence and outcomes of COVID-19 in kidney or kidney-pancreas transplant recipients and kidney or kidney-pancreas waitlisted patients at Rush University Medical Center in Chicago. We hypothesize that these patients have an incidence proportion of COVID-19 similar to the general population, but that transplant recipients have greater occurrences of hospitalization, intensive care unit admission, mechanical ventilation, and death compared to waitlisted patients due to chronic immunosuppression. Epidemiologic studies examining disease courses of COVID-19 between comparable immunosuppressed and immunocompetent patients may provide insight regarding the impact of chronic immunosuppressive therapy on outcomes.

2 | METHODS

2.1 | Study design and patient population

We performed a retrospective cohort study of kidney and kidney-pancreas transplant recipients who underwent transplantation from January 1, 2010, to June 30, 2020 (total *n* = 981), and kidney and kidney-pancreas waitlisted patients who were ever on the waitlist from January 1, 2019, to June 30, 2020 (total *n* = 687). We excluded transplant recipients who died before November 1, 2019 (*n* = 94), since they could not have had the opportunity to develop COVID-19. We excluded waitlisted patients with a previous transplant since they had already been exposed to immunosuppression (*n* = 125), waitlisted patients who underwent transplant on or before June 30, 2020, since they would be in the transplant cohort (*n* = 121), and waitlisted patients who died before November 1, 2019, since they could not have had the opportunity to develop COVID-19 (*n* = 7). The final study populations consisted of 887 transplant recipients, of whom 828 were kidney transplant recipients (631 deceased donor, 197 living donor) and 59 were kidney-pancreas transplant recipients, and 434 waitlisted patients, of whom 418 were waitlisted for kidney transplant and 16 were waitlisted for kidney-pancreas transplant. For kidney transplant recipients, induction immunosuppression consisted of either thymoglobulin or alemtuzumab plus intravenous methylprednisolone, and initial maintenance immunosuppression consisted of a calcineurin inhibitor or a MTOR inhibitor plus an antimetabolite with or without low-dose prednisone. For kidney-pancreas transplant recipients, induction immunosuppression consisted of thymoglobulin plus intravenous methylprednisolone, and initial maintenance immunosuppression consisted of a calcineurin inhibitor plus an antimetabolite. Maintenance immunosuppression for patients was adjusted based on effectiveness and tolerability. The study protocol was approved by the Institutional Review Board of Rush University Medical Center.

2.2 | Data sources

To facilitate obtaining data from the electronic health record in our center, we leveraged existing informatics infrastructure developed for the Chicago Area Patient-Centered Outcomes Research Network (CAPriCORN),[13] a clinical data research network that is part of the Patient-Centered Outcomes Research Network (PCORnet), and adapted it to populate normalized datasets with a monthly refresh from November 1, 2019, to capture conditions and events during the COVID-19 pandemic.[14] Demographics, healthcare encounters, vital signs, laboratory results, medications administered in the inpatient setting, and death were electronically collected according to CAPriCORN common data model specifications and augmented with ancillary datasets on bed information to capture patient movement within hospital stays, and mechanical ventilation, to capture intubation and duration of ventilator use. Information outside of these domains was gathered by manual chart review of free text notes in the electronic health record using a standardized data collection tool by one physician-epidemiologist author (YR) and validated for accuracy by another physician-epidemiologist author (CS).

2.3 | COVID-19 identification, clinical characteristics, and outcomes

COVID-19 was identified by querying the electronic datasets for detection of SARS-CoV-2 RNA by RT-PCR or nucleic acid amplification from nasal or nasopharyngeal swab specimens from November 1, 2019, to January 31, 2021. Demographic data, vital signs (temperature and body mass index), laboratory results, hospitalization, intensive care unit admission, mechanical ventilation, and death were captured from the electronic datasets, whereas comorbidities, organ type, cause of renal disease, induction, and maintenance immunosuppression, presenting symptoms for COVID-19, oxygen supplementation, chest radiographic findings, and treatments tried for COVID-19 were collected by manual chart review. Demographics, comorbidities, and maintenance immunosuppression were determined at the time of COVID-19 identification, whereas cause of renal disease and induction immunosuppression were determined at the time of transplant. All laboratory tests, radiologic evaluations, and treatments were performed at the discretion of the healthcare team. Laboratory values were obtained from one day prior to 30 days after COVID-19 identification. Outcomes such as hospitalization, intensive care unit admission, mechanical ventilation, and death were identified with at least a 30-day follow-up censored for death or March 2, 2021, the time for data cutoff. These outcomes were first identified electronically and then validated with manual chart review to ensure accuracy.

TABLE 1 Demographics and baseline characteristics of kidney or kidney-pancreas transplant recipients and kidney or kidney-pancreas waitlisted patients with COVID-19

Variable[a]	Kidney or kidney-pancreas transplant recipients	Kidney or kidney-pancreas waitlisted patients
Age–median (range)[b]	58 (28–78)	52 (22–73)
Demographics–no./total no. (%)		
Male	41/62 (66)	15/20 (75)
African-American	31/62 (50)	7/20 (35)
Non-Hispanic	40/62 (65)	12/20 (60)
Organ type–no./total no. (%)		
Kidney	57/62 (92)	20/20 (100)
Kidney-pancreas	5/62 (8)	0
Cause of renal disease–no./total no. (%)		
Diabetic nephropathy	22/62 (36)	12/20 (60)
Hypertensive nephroangiosclerosis	21/62 (34)	2/20 (10)
Glomerulonephritis	15/62 (24)	3/20 (15)
Others	4/62 (6)	3/20 (15)
Comorbidities–no./total no. (%)		
Hypertension	60/62 (97)	20/20 (100)
Diabetes mellitus	29/62 (47)	13/20 (65)
Heart disease	29/62 (47)	7/20 (35)
Lung disease	4/62 (6)	2/20 (10)
Cancer	7/62 (11)	3/20 (15)
Smoking	2/62 (3)	2/20 (10)
BMI–median (range)–kg/m[c]	29.4 (18.4–42.8)	29.2 (17.5–38.3)
Induction immunosuppression–no./total no. (%)		
Anti-thymocyte globulin	42/62 (68)	
Alemtuzumab	19/62 (31)	
Basiliximab	1/62 (2)	
High-dose corticosteroids	62/62 (100)	
Maintenance immunosuppression–no./total no. (%)		
Tacrolimus or Cyclosporine	57/62 (92)	
Mycophenolate or Azathioprine	59/62 (95)	
Prednisone	58/62 (94)	
Sirolimus	5/62 (8)	
Everolimus	1/62 (2)	

Note: COVID-19 indicates coronavirus disease 2019.

Abbreviations: BMI, body mass index; CAPriCORN, chicago area patient-centered outcomes research network.

[a]Age, demographics and BMI were derived from electronically generated datasets mapped to CAPriCORN common data model specifications; organ type, cause of renal disease, comorbidities, induction immunosuppression, and maintenance immunosuppression were identified by manual chart review.

[b]Age at time of COVID-19 identification.

[c]Most recent BMI prior to COVID-19 identification.

2.4 | Statistical analysis

Descriptive statistics were used to describe the demographic and clinical characteristics of the study populations, the incidence proportions of COVID-19 in the study populations, as well as the clinical features and outcomes of COVID-19. Chi-square or Fisher's exact test was used as appropriate to determine if there were nonrandom associations between categorical variables, and t tests were performed to determine if there were nonrandom associations between continuous variables. All analyses were performed in SAS version 9.3.

3 | RESULTS

3.1 | Incidence proportion of COVID-19

COVID-19 was identified in 62 of 887 kidney or kidney-pancreas transplant recipients, equaling an incidence proportion of 7.0%, compared to 20 of 434 kidney or kidney-pancreas waitlisted patients, equaling an incidence proportion of 4.6% (p = .092). For transplant recipients, the median time to COVID-19 identification was 1560 days from time of transplant (range 128–3744 days). For waitlisted patients, the median time to COVID-19 identification was 422 days from time of listing (range 81–2813 days).

3.2 | Demographics and baseline characteristics of persons with COVID-19

The median ages of transplant recipients and waitlisted patients with COVID-19 were 58 (range 28–78) and 52 (range 22–73) years, respectively (p = .14) (Table 1). Transplanted and waitlisted patients with COVID-19 were predominantly male (66% vs. 75%), non-Hispanic (65% vs. 60%), and kidney transplanted or waitlisted (92% vs. 100%). Common causes of renal disease for transplanted and waitlisted patients were diabetic nephropathy (36% vs. 60%) and hypertensive nephroangiosclerosis (34% vs. 10%), and commonly identified comorbidities were hypertension (97% vs. 100%), diabetes mellitus (47% vs. 65%), and heart disease (47% vs. 35%). The median body mass index (BMI) for transplanted and waitlisted patients with COVID-19 was 29.4 and 29.2 kg/m^2, respectively. Antithymocyte globulin was more frequently used than alemtuzumab in transplanted patients for induction immunosuppression (68% vs. 31%), and maintenance immunosuppression typically consisted of a calcineurin inhibitor (tacrolimus or cyclosporine), an antimetabolite (mycophenolate or azathioprine), and prednisone.

3.3 | Clinical and laboratory features of COVID-19

Common presenting symptoms of COVID-19 in transplant recipients and waitlisted patients were fever (55% vs. 55%), cough (47% vs. 50%), and dyspnea (39% vs. 30%) (Table 2). Supplementary oxygen was provided to 35% of transplanted patients, and 30% of waitlisted patients. Very high grade fever greater than 104°F was identified in two kidney transplant recipients. Frequent laboratory abnormalities in transplanted and waitlisted patients with COVID-19 were lymphopenia (81% vs. 69%), thrombocytopenia (43% vs. 54%), and elevations in aspartate aminotransferase (26% vs. 50%), C-reactive protein (100% vs. 100%), ferritin (74% vs. 89%), and D-dimer (79% vs. 86%). Among transplant recipients on an antimetabolite for immunosuppression, the antimetabolite was withdrawn in 78% of patients. High-dose glucocorticoids were administered to 27% and 15% of transplant recipients and waitlisted patients, respectively, and remdesivir was given to 26% and 5% of transplant recipients and waitlisted patients, respectively. Transplanted and waitlisted patients were infrequently given hydroxychloroquine and tocilizumab.

3.4 | Allograft function

Of 62 kidney or kidney-pancreas transplant recipients with COVID-19, acute kidney injury defined as increase in serum creatinine ≥1.5 times baseline occurred in 15 patients (24%), and new renal replacement therapy defined as acute need for dialysis occurred in 4 patients (6%) (Table 2). Acute kidney injury was attributed to acute tubular necrosis in 11 patients, tacrolimus toxicity in two patients, dehydration in one patient, and osmotic diuresis secondary to hyperglycemia in one patient. There were no instances of clinically suspected or biopsy-proven kidney allograft rejection. One kidney-pancreas transplant recipient with COVID-19 had lipase elevation that peaked at 152 U/L. Biopsy of the transplanted pancreas showed mild acute cellular rejection that was managed with increased tacrolimus and oral steroid dosing. Lipase normalized after two weeks.

3.5 | Outcomes of COVID-19

Hospitalization occurred in 48 of 62 transplant recipients, and 8 of 20 waitlisted patients with COVID-19 (77% vs. 40%, p = .002) (Table 2). Intensive care unit admission occurred in 18 of 62 transplant recipients and 2 of 20 waitlisted patients with COVID-19 (29% vs. 10%, p = .085). Seven of 62 transplant recipients with COVID-19 were mechanically ventilated and died, whereas no waitlisted patients with COVID-19 were mechanically ventilated or died (11% vs. 0%, p = .116). The median time to death for the seven transplant recipients who died was 18 days from time of COVID-19 identification (range 2–82 days).

3.6 | Subset analysis

We performed a subset analysis wherein we examined the incidence and outcomes of COVID-19 in kidney transplant recipients and kidney waitlisted patients only. COVID-19 was identified in 57 of 828 kidney transplant recipients and 20 of 418 kidney waitlisted patients (6.9% vs. 4.8%, p = .146). Hospitalization occurred in 45 of 57 kidney transplant recipients with COVID-19 and 8 of 20 kidney waitlisted patients (79% vs. 40%, p = .001); intensive care unit admission occurred in 18 of 57 kidney transplant recipients, and 2 of 20 kidney waitlisted patients (32% vs. 10%, p = .058); ventilation and death occurred in 7 of 57 kidney transplant recipients, and no kidney waitlisted patients (12% vs. 0%, p = .100).

4 | DISCUSSION

We found in this retrospective cohort single-center study that the incidence proportion of laboratory-confirmed COVID-19 in kidney

TABLE 2 Clinical features and outcomes of COVID-19 in kidney or kidney-pancreas transplant recipients and kidney or kidney-pancreas waitlisted patients

Variable[a]	Kidney or kidney-pancreas transplant recipients	Kidney or kidney-pancreas waitlisted patients
Presenting symptom–no./total no. (%)		
Fever	34/62 (55)	11/20 (55)
Cough	29/62 (47)	10/20 (50)
Dyspnea	24/62 (39)	6/20 (30)
Myalgias	19/62 (31)	5/20 (25)
Diarrhea	13/62 (21)	4/20 (20)
Oxygen requirement–no./total no. (%)	22/62 (35)	6/20 (30)
Temperature >104°F–no./total no. (%)[b]	2/62 (3)	0
Laboratory values[b]		
White-cell count		
Median (range)–per mm^3	7225 (1950–37 780)	8805 (1880–19 200)
Patients with count <4000 per mm^3 (leukopenia)–no./total no. (%)	25/54 (46)	4/13 (31)
Lymphocyte count		
Median (range)–per mm^3	680 (110–17 550)	790 (260–2500)
Patients with count <1000 per mm^3 (lymphopenia)–no./total no. (%)	44/54 (81)	9/13 (69)
Patients on alemtuzumab with count <1000 per mm^3 (lymphopenia) at baseline–no./total no. (%)	10/18 (56)	
Platelet count		
Median (range)–per mm^3	196 000 (4000–467 000)	206 000 (63 000–515 000)
Patients with count <150 000 per mm^3 (thrombocytopenia)–no./total no. (%)	23/54 (43)	7/13 (54)
Creatinine		
Median (range)–mg/dl	1.9 (0.6–17.4)	8.4 (3.0–16.1)
Patients with level >1.2 mg/dl–no./total no. (%)	45/54 (83)	13/13 (100)
Aspartate aminotransferase		
Median (range)–mg/dl	25 (8–19,668)	31 (12–147)
Patients with level >50 mg/dl–no./total no. (%)	14/53 (26)	6/12 (50)
Alanine aminotransferase		
Median (range)–mg/dl	20 (6–8,718)	22 (7–196)
Patients with level >50 mg/dl–no./total no. (%)	12/53 (23)	3/12 (25)
C-reactive protein		
Median (range)–mg/dl	120 (5–396)	154 (10–351)
Patients with level >5 mg/dl–no./total no. (%)	30/30 (100)	7/7 (100)
Ferritin		
Median (range)–mg/dl	5453 (41–25 677)	3821 (552–7425)
Patients with level >900 mg/dl–no./total no. (%)	26/35 (74)	8/9 (89)
D-dimer		
Median (range)–mg/dl	11.0 (1.3–93.2)	11.2 (3.8–47.8)
Patients with level >5 mg/dl–no./total no. (%)	22/28 (79)	6/7 (86)
Chest radiographic findings consistent with viral pneumonia–no./total no. (%)	37/47 (79)	9/12 (75)
Treatment–no./total no. (%)[c]		
Withdrawal of antimetabolite	46/59 (78)	
Withdrawal of calcineurin inhibitor	4/57 (7)	
Withdrawal of mTOR inhibitor	3/6 (50)	

(Continues)

TABLE 2 (Continued)

Variable[a]	Kidney or kidney-pancreas transplant recipients	Kidney or kidney-pancreas waitlisted patients
Hydroxychloroquine	4/62 (6)	0
Tocilizumab	1/62 (2)	1/20 (5)
High-dose glucocorticoids	17/62 (27)	3/20 (15)
Remdesivir	16/62 (26)	1/20 (5)
Allograft function		
Patients with acute kidney injury–no./total no. (%)[d]	15/62 (24)	
New renal replacement therapy–no./total no. (%)[e]	4/62 (6)	
Clinically suspected or biopsy-proven kidney allograft rejection	0	
Lipase >60 u/L[a,f]	1/5 (20)	
Outcomes at a median of 156 days of follow-up (range, 2–345)–no./total no. (%)[g]		
Hospitalization–no./total no. (%)	48/62 (77)	8/20 (40) $p = .002$
Intensive care unit admission–no./total no. (%)	18 (29)	2/20 (10) $p = .085$
Mechanical ventilation	7/62 (11)	0 $p = .116$
Death	7/62 (11)	0 $p = .116$

Note: COVID-19 indicates coronavirus disease 2019.

Abbreviation: CAPriCORN, chicago area patient-centered outcomes research network.

[a]Temperature, laboratory values and outcomes (hospitalization, intensive care unit admission, mechanical ventilation and death) were derived from electronically generated datasets mapped to CAPriCORN common data model specifications; outcomes were subsequently validated with manual chart review; presenting symptoms, oxygen requirement, chest radiographic findings and treatment were identified by manual chart review.

[b]Body temperature and laboratory tests taken from one day prior through 30 days after COVID-19 identification; some patients did not have laboratory tests performed.

[c]Antimetabolite includes mycophenolate or azathioprine; calcineurin inhibitors include tacrolimus and cyclosporine; mTOR inhibitors include sirolimus and everolimus.

[d]Acute kidney injury defined as increase in serum creatinine ≥1.5 times baseline which is known or presumed to have occurred within the prior seven days.

[e]Acute renal replacement therapy during hospital admission.

[f]Elevated lipase in kidney-pancreas transplant recipients.

[g]Hospitalization, intensive care unit admission and mechanical ventilation were first electronically identified from three days prior through 30 days after COVID-19 identification and then validated with manual chart review.

or kidney-pancreas transplant recipients was similar to that of kidney or kidney-pancreas waitlisted patients, and that transplant recipients had numerically higher occurrences of hospitalization, intensive care unit admission, mechanical ventilation, or death compared to waitlisted patients. Tests for nonrandom associations showed a statistically significantly greater occurrence of hospitalization in transplant recipients compared to waitlisted patients, and trends toward statistically significantly greater occurrences of intensive care unit admission, mechanical ventilation, or death in transplant recipients compared to waitlisted patients. Subset analysis of kidney transplant recipients and kidney waitlisted patients showed similar results. The use of CAPriCORN and PCORnet common data models employed by this study to capture some data domains and outcomes promotes replicability in other centers and may enable the conduct of multicenter studies in the United States.

Initial epidemiologic studies on COVID-19 in kidney transplant recipients and patients with end-stage renal disease focused on assembling cohorts of patients diagnosed with COVID-19 and describing their clinical features and outcomes.[1–5,15,16] These early studies did not assemble cohorts of transplant recipients and waitlisted patients who were followed over time to identify COVID-19 infection, which precluded the determination of its incidence and comparative outcomes. Subsequent studies comparing the incidence and outcomes of COVID-19 in kidney transplant recipients and kidney waitlisted patients have shown conflicting results. A national cohort study in England showed greater mortality after COVID-19 identification in kidney transplant recipients compared to kidney waitlisted patients (25.8% vs. 10.1%),[17] whereas a single-center study in New York City showed lower mortality after COVID-19 identification in kidney transplant recipients compared to kidney waitlisted patients (16% vs. 34%).[18] These disparate results may be due to differences in cohort inception. The national cohort study in England included any kidney transplant recipient with a functioning graft as of February 1, 2020, and patients who were active on the kidney waitlist as of February 1, 2020. Patients who were suspended on the waitlist or recipients of tissue or cell transplant were not included. The New York City study did not describe its cohort inception in detail and only stated that kidney transplant recipients and kidney waitlisted patients with COVID-19 were identified. The results of

our study are more similar to the national cohort study in England, because our approach to cohort inception was more congruent and adhered to guidelines for reporting observational studies.[19] However, our study differs from the national cohort study in England in that it includes transplant recipients from a more current era and excludes waitlisted patients with a previous solid-organ transplant since they had already been exposed to chronic immunosuppression. Our study also differs from the national cohort study in terms of locale and demographic characteristics of the study population.

The clinical features of COVID-19 in kidney transplanted and waitlisted patients were comparable and similar to what has already been reported in the literature.[1–5,16] Fever and cough were common presenting symptoms, but less common symptoms such as myalgias and diarrhea were also identified. Leukopenia, lymphopenia, and thrombocytopenia were frequently found among patients in whom a complete blood count was done, and elevations in C-reactive protein and ferritin were prominent among patients in whom these markers of inflammation were checked. Kidney allograft dysfunction occurred in close to a quarter of transplant recipients and was predominantly attributed to acute tubular necrosis. The most commonly tried treatment was discontinuation of the antimetabolite, similar to the management of viral infections such as cytomegalovirus or BK virus.[20,21] Remdesivir was given to over a quarter of transplant recipients. Randomized controlled trials on remdesivir for COVID-19 have shown conflicting results, with the ACTT-1 Study Group reporting that remdesivir administration is associated with shorter recovery times and a trend toward lower mortality,[22] and the WHO Solidarity Trial Consortium reporting that remdesivir administration had no effect with regard to duration of hospital stay, initiation of mechanical ventilation, or overall mortality.[23] High-dose glucocorticoids were given to over a quarter of transplant recipients. A randomized controlled trial comparing dexamethasone to usual care conducted by the RECOVERY Collaborative Group showed that dexamethasone was associated with lower 28-day mortality among those who were on mechanical ventilation or oxygen alone at randomization, but not among those receiving no respiratory support.[24]

The case fatality rates we found for transplanted and waitlisted patients with COVID-19 were 11% and 0%, respectively, which is similar to reported rates in other studies of kidney transplant recipients[1-5] and patients on hemodialysis.[16] While our study is based in a single center, it provides data that can be used for power calculations to inform the design of a multicenter study in the United States or elsewhere to validate the relative acquisition risks and case fatality rates of COVID-19 in kidney transplanted and waitlisted patients. Presuming a 10% difference in mortality between kidney transplanted and waitlisted patients with COVID-19, and an alpha of 0.05 and beta of 0.2, 73 transplanted and 73 waitlisted patients with COVID-19 would need to be identified. These numbers are likely more than achievable among the five transplant centers participating in CAPriCORN,[13] whose common data model was employed by this study.

Our findings add to existing literature that informs clinical decision-making on whether to transplant patients during the COVID-19 pandemic or delay transplant until after the pandemic. A simulation and machine learning study identifying scenarios of benefit or harm from kidney transplantation during the COVID-19 pandemic showed that immediate kidney transplant provided survival benefit in most scenarios and that kidney transplant only began showing evidence of harm in scenarios when case fatality rates for COVID-19 were greater than 50% among transplant recipients.[25] The 11% case fatality rate we found in our center for kidney transplant recipients is below this threshold, as was the case fatality rate reported in the national cohort study from England.[17]

The strengths of our study are direct comparison of kidney or kidney-pancreas transplanted and waitlisted patients with respect to incidence and outcomes of COVID-19, and the use of CAPriCORN and PCORnet common data models to capture these measures that promotes replicability in other centers. It however has limitations. First, it is a single-center study with lower numbers. However, it provides important data that can be used for power calculations to inform the design of multicenter studies especially in the United States where a significant number of hospitals participate in PCORnet. Second, the incidence proportions of COVID-19 identified for these patients represent minimum estimates since some cases of COVID-19 may have been identified outside of our healthcare system and missed by our electronic health record. However, minimum estimates are still useful as it provides the lowest possible incidence proportions for the populations of interest. Third, our findings may not be generalizable since it is a single-center study. However, it provides data and an informatics approach that may inform the design of multicenter studies in the United States that may have more generalizable results.

In summary, we found that the incidence proportion of COVID-19 in kidney or kidney-pancreas transplant recipients was similar to that of kidney or kidney-pancreas waitlisted patients and that transplant recipients had numerically higher occurrences of hospitalization, intensive care unit admission, mechanical ventilation, or death compared to waitlisted patients. This study provides single-center data that can be used for power calculations, as well as an informatics approach that can enable the conduct of multicenter studies.

ACKNOWLEDGEMENTS

The authors would like to acknowledge Ronda Billerbeck, Sandra Delgado, Ekta Kishen and Karthikeyan Swaminathan for their help with database management. The authors would also like to acknowledge Graeme Forrest for his critical review.

CONFLICTS OF INTEREST

The authors declare no conflicts of interest.

AUTHORS CONTRIBUTIONS

Carlos A. Q. Santos – participated in research design, writing of the paper, performance of the research and data analysis. Yoona Rhee

– participated in research design, writing of the paper and performance of the research. Edward F. Hollinger – participated in research design and writing of the paper. Oyedolamu K. Olaitan – participated in research design and writing of the paper. Erik Schadde – participated in research design and writing of the paper. Vasil Peev – participated in research design and writing of the paper. Samuel N. Saltzberg – participated in research design and writing of the paper. Martin Hertl – participated in research design, writing of the paper and performance of the research.

DATA AVAILABILITY STATEMENT

The data that support the findings of this study are available on request from the corresponding author. The data are not publicly available due to privacy or ethical restrictions.

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How to cite this article: Santos CAQ, Rhee Y, Hollinger EF, et al. Comparative incidence and outcomes of COVID-19 in kidney or kidney-pancreas transplant recipients versus kidney or kidney-pancreas waitlisted patients: A single-center study. *Clin Transplant*. 2021;35:e14362. https://doi.org/10.1111/ctr.14362