

BRIEF COMMUNICATION

COVID-19 mortality among kidney transplant candidates is strongly associated with social determinants of health

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The COVID-19 pandemic has affected all portions of the global population. However, many factors have been shown to be particularly associated with COVID-19 mortality including demographic characteristics, behavior, comorbidities, and social conditions. Kidney transplant candidates may be particularly vulnerable to COVID-19 as many are dialysis-dependent and have comorbid conditions. We examined factors associated with COVID-19 mortality among kidney transplant candidates from the National Scientific Registry of Transplant Recipients from March 1 to December 1, 2020. We evaluated crude rates and multivariable incident rate ratios (IRR) of COVID-19 mortality. There were 131 659 candidates during the study period with 3534 all-cause deaths and 384 denoted a COVID-19 cause (5.00/1000 person years). Factors associated with increased COVID-19 mortality included increased age, males, higher body mass index, and diabetes. In addition, Blacks (IRR = 1.96, 95% C.I.: 1.43–2.69) and Hispanics (IRR = 3.38, 95% C.I.: 2.46–4.66) had higher COVID-19 mortality relative to Whites. Patients with lower educational attainment, high school or less (IRR = 1.93, 95% C.I.: 1.19–3.12, relative to post-graduate), Medicaid insurance (IRR = 1.73, 95% C.I.: 1.26–2.39, relative to private), residence in most distressed neighborhoods (fifth quintile IRR = 1.93, 95% C.I.: 1.28–2.90, relative to first quintile), and most urban and most rural had higher adjusted rates of COVID-19 mortality. Among kidney transplant candidates in the United States, social determinants of health in addition to demographic and clinical factors are significantly associated with COVID-19 mortality.

KEYWORDS

clinical research/practice, ethnicity/race, health services and outcomes research, infection and infectious agents, kidney disease, kidney transplantation/nephrology, organ transplantation in general, risk assessment/risk stratification, waitlist management

1 | INTRODUCTION

The COVID-19 pandemic has had a profound detrimental health effect on the general population across the globe. In the United States,

COVID-19 was the third leading cause of death in 2020.¹ There are numerous demographic and clinical factors that are associated with susceptibility to contracting COVID-19 and health consequences of the virus.^{2–4} While evidence continues to emerge regarding factors

Abbreviations: BMI, body mass index; C.I., confidence interval; COVID-19, coronavirus disease 2019; ESKD, end-stage kidney disease; GN, glomerulonephritis; HRSA, health resources and services administration; IRR, incident rate ratio; OPTN, organ procurement and transplantation network; PKD, polycystic kidney disease; SRTR, scientific registry of transplant recipients.

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resulting in transmission of COVID-19, the pandemic has disproportionately affected certain populations with known disparities in access to health care in the United States. This includes racial and ethnic minorities and patients with increased social risk factors.⁵⁻⁸

Patients with end-stage kidney disease (ESKD) are particularly susceptible to the impact of COVID-19 given increased morbidity and increased need to interact with individuals for health care interventions. Kidney transplant candidates are a select portion of the ESKD population, and factors associated with susceptibility and impact of COVID-19 may be unique from the broader ESKD or general population. There are currently more than 90,000 kidney transplant candidates in the United States.⁹ The effect of demographic characteristics, clinical factors, and social risks on risks of COVID-19 mortality in the United States has not been comprehensively investigated. Understanding candidates who are at highest risk for the severe effects of COVID-19 may inform care management, identify interventions tailored to attenuate patient risks, and provide evidence for potential mechanisms for the effects of COVID-19.

There are a number of reports detailing risks of transmission and health consequences of COVID-19 among the dialysis and transplant recipient population. However, most studies are limited to single center or regional reports and detail different periods of the COVID-19 pandemic.¹⁰⁻¹³ The risks identified in prior studies may be unique to select regions or during the initial phase of the pandemic. In this study, our primary aims were to identify rates and independent risk factors for COVID-19 mortality among kidney transplant candidates in the United States over the first 9 months of the pandemic. In particular, our aim was to evaluate factors associated with COVID-19 mortality comprising demographic characteristics, clinical history, and social conditions to describe the broad array of risks in the population.

2 | METHODS

This study used data from the Scientific Registry of Transplant Recipients (SRTR). The SRTR data system includes data on all donor, wait-listed candidates, and transplant recipients in the United States, submitted by the members of the Organ Procurement and Transplantation Network (OPTN). The Health Resources and Services Administration (HRSA), U.S. Department of Health and Human Services provides oversight to the activities of the OPTN and SRTR contractors. This study was exempted from approval by the Cleveland Clinic Institutional Review Board (IRB# 09-648).

The designation of COVID-19 mortality as a cause of death was implemented by the United Network for Organ Sharing denoted "Infection: Viral - COVID-19" on April 1, 2020. The numeric codes associated with these were 3916 (kidney alone) and 7247 (kidney-pancreas). We used the code associated with this cause of death as an indication of COVID-19 death throughout the study. As these codes we used retrospectively as well (in the weeks prior to April 1), and our study period was March 1-December 1, 2020. We used this period with consideration for the initiation of the pandemic and documentation of COVID-19 causes of death and follow-up when

COVID-19 cases were consistently reported. We considered patients at risk for COVID-19 mortality from March 1, 2020 for prevalent patients (those on the waiting list on that date) or from the time of candidate listing for those placed on the waiting list during the period. Rates were calculated per 1000 patient year follow-up and compared between groups using two-sample t-tests and ANOVA. We evaluated independent factors associated with COVID-19 mortality rates using multivariable Poisson models with time at risk for death on the waiting list as an offset variable and reported adjusted incident rate ratios (IRR).

In addition to the SRTR data, we used primary candidate residential zip code information to merge other data sources. We merged data with the distressed community index generated from the Economic Innovation Group.¹⁴ These data include an index (0%-100%) of the level of residential distress by zip code in the United States based on residential education, housing vacancy, employment, poverty, income, and changes in business establishments. For the purpose of these analyses, we used the measured quintile of the residential zip code of candidates to merge with SRTR data. Candidates without an available zip code were coded as missing level for the purpose of the analyses. We also merged data from the Economic Research Service and the United States Department of Agriculture with rural-urban continuum codes. These data contain an indicator of the most urban to the most rural (scale of 1-9) counties in the United States. We merged zip codes within counties and based on sample size converted the existing codes to four levels with sufficient event rates to estimate the association of COVID-19 mortality. We also used data available from the Centers for Disease Control and Prevention (CDC) and US Census to assess the relative proportion of COVID-related deaths in the kidney transplant candidate population with the general population.^{15,16} Specifically, we calculated the relative proportion of deaths by age (limited to 18-74), race/ethnicity, and gender in the general population and compared these with the candidate population. Of note, the mortality data in the general population were only available over a broader time period (through February 27, 2021) and the distribution of race/ethnicity and gender was for all ages rather than limited to the 18-74-year-old population. All analyses were conducted in SAS (v.9.4) and two-sided type-I error probabilities of 0.05 were considered for statistical significance.

3 | RESULTS

There were 131 659 candidates on the kidney transplant or kidney/pancreas waiting list between March 1, 2020 and December 1, 2020. This included 28 065 patients newly listed during the study period and other prevalent candidates on the list as of March 1, 2020. The mean age at the time of listing or March 1, 2020 was 53.9 years (s.d. = 12.9). Candidates were 37% White, 31% Black, and 20% Hispanic. Sixty-two percent were male and the most common primary diagnosis was diabetes (38%). Patients with a prior transplant comprised 12% of the population and 43% had Medicare as primary insurance.

TABLE 1 Transplant candidate characteristics and COVID-19-related mortality

Candidate characteristics	Level	N	% COVID-19 deaths	p-value ^a	All-cause deaths	% of Deaths that were COVID	p-value
Age	18–34	11 765	0.08%	<.001	115	8.7%	.006
	35–49	31 332	0.14%		561	7.7%	
	50–64	56 154	0.36%		1586	12.7%	
	65+	32 408	0.40%		1272	10.2%	
Race/Ethnicity	White	49 719	0.14%	<.001	1342	5.1%	<.001
	Black	41 105	0.33%		1125	12.0%	
	Hispanic	26 368	0.49%		732	17.8%	
	Other	14 467	0.35%		335	15.2%	
Gender	Female	50 137	0.23%	.001	1251	9.2%	.02
	Male	81 522	0.33%		2283	11.8%	
Body mass index (kg/m ²)	13–20	4667	0.11%	<.001	133	3.8%	<.001
	21–25	27 435	0.17%		678	7.1%	
	26–30	42 701	0.30%		1128	11.2%	
	31–35	35 154	0.37%		948	13.7%	
	36+	20 708	0.34%		617	11.4%	
	Missing	991	0.50%		30	16.7%	
Primary diagnosis	GN	23 643	0.15%	<.001	373	9.7%	.046
	Diabetes	50 294	0.46%		1921	12.0%	
	PKD	8915	0.21%		140	13.6%	
	Hypertension	26 027	0.23%		604	10.1%	
	Other	22 780	0.17%		496	7.7%	
Prior transplant	No	116 208	0.29%	.87	3100	10.9%	.98
	Yes	15451	0.30%		434	10.8%	
Prior malignancies	No	121 050	0.29%	.57	3219	11.0%	.32
	Yes	10 609	0.27%		315	9.2%	
Peripheral vascular disease	No	119 719	0.27%	<.001	3042	10.5%	.10
	Yes	11 940	0.54%		492	13.0%	
Primary insurance	Private	56 783	0.22%	<.001	1256	10.1%	<.001
	Medicaid	13 285	0.48%		372	17.2%	
	Medicare	56 146	0.33%		1826	10.2%	
	Other	5445	0.11%		80	7.5%	
Pre-listing dialysis time	Preemptive	51 658	0.24%	.006	1086	11.4%	.38
	1–12 months	32 716	0.27%		951	9.2%	
	13–24 months	22 650	0.36%		725	11.2%	
	25–36 months	10 584	0.38%		333	12.0%	
	37+ months	14 051	0.37%		439	11.9%	
Educational attainment	High school or Less	56 266	0.41%	<.001	1674	13.6%	<.001
	Some college	59 284	0.21%		1469	8.4%	
	Post-graduate	10 515	0.18%		267	7.1%	
	Unknown	5594	0.23%		124	10.5%	
Working for income	No or unknown	83 879	0.32%	.010	2644	10.2%	.02
	Yes	47 780	0.24%		890	12.9%	

(Continues)

TABLE 1 (Continued)

Candidate characteristics	Level	N	% COVID-19 deaths	p-value ^a	All-cause deaths	% of Deaths that were COVID	p-value
Blood type	A	37 655	0.28%	.69	976	10.8%	.74
	B	21 269	0.28%		529	11.3%	
	AB	3619	0.39%		100	14.0%	
	O	69 116	0.30%		1929	10.6%	
Residential distress index quintile	1 (Least distressed)	19 412	0.18%	<.001	425	8.2%	.001
	2	15 845	0.36%		448	12.7%	
	3	15 941	0.33%		467	11.4%	
	4	16 558	0.36%		487	12.1%	
	5 (Most distressed)	20 912	0.45%		662	14.2%	
	Missing	42 991	0.20%		1045	8.2%	
Urban-rural continuum code ^a	1 (Most urban)	54 082	0.40%	<.001	1478	14.6%	<.001
	2	16 644	0.19%		444	7.0%	
	3	9636	0.24%		300	7.7%	
	4 (Most rural)	8306	0.34%		267	10.5%	
	Missing	42 991	0.20%		1045	8.2%	
Overall		131 659	0.29%		3534	10.9%	

Abbreviations: GN, glomerulonephritis; PKD, polycystic kidney disease.

^aOriginal urban-rural continuum categories collapsed to maintain sufficient sample sizes; categories displayed are metropolitan area (population >1 million), metropolitan (population 250 000 ≤ 1 million), urban counties with >20 000 population, and metropolitan areas with <250 000 population and non-metropolitan counties to rural communities.

Over the study period, there were 3534 all-cause deaths (2.7% of the study population) and 384 denoted a COVID-19 cause (0.29% of the study population). The COVID-19 crude mortality rate was 5.00 per 1000 person years of follow-up. The proportion of patients with COVID-19 mortality varied significantly by patient characteristics (Table 1). Increasing age, non-Whites, males, candidates with higher body mass indices, candidates with diabetes as primary diagnosis, peripheral vascular disease, Medicaid primary insurance, lower educational attainment, and residing in higher distressed communities had higher proportion of COVID-19 deaths. Patients placed on the waiting list after March 1, 2020 had lower COVID-19 mortality rates (3.31/1000 patient years) relative to prevalent patients (5.22/1000 patient years, $p < .01$). These associations were largely consistent considering COVID-19 deaths as a proportion of all-cause deaths (Table 1). COVID-19 deaths comprised 10.9% of all deaths during the study period and this proportion varied significantly by patient characteristics.

The rate of COVID-19 mortality was significantly higher for non-White candidates and increasing age (p -values <.01). The increased rates by race/ethnic group were consistent in each age group with the highest mortality rates among Hispanics (Figure 1). The COVID-19 mortality rate in men was 5.67/1000 patient years versus 3.93/1000 patient years in women. These rates also varied by primary diagnosis with the highest rates among diabetics (7.74/1000 patient years). Rates by primary diagnosis group and gender are displayed in Figure 2. Higher rates of COVID-19 deaths among men were present among candidates

with glomerulonephritis and diabetes as primary diagnosis but not polycystic disease or hypertension. COVID-19 mortality rates varied significantly by candidate's primary insurance, educational attainment, and residential distress index. Figure 3 displays COVID-19 mortality rates for race/ethnic groups by insurance and education attainment. Candidates with non-private insurance had higher COVID-19 mortality in each race/ethnic group. COVID-19 mortality rates were also higher among patients with lower educational attainment in each race/ethnic group. In addition, for both Blacks and Hispanics, COVID-19 mortality rates increased associated with increasing distress index (Figure 4). However, COVID-19 mortality did not increase among Whites by residential distress index. There was also a modest "U-shaped" pattern of COVID-19 mortality by rural-urban designation. Patients in the most urban counties (>1 million population) and rural counties had the highest COVID-19 mortality rates relative to candidates in mid-size residential communities. However, this pattern appeared to vary by race/ethnic group (Figure 5). In addition, there was significant variation of COVID-19 mortality rates by UNOS region. As displayed in Figure 6, COVID-19 mortality rates were highest in region 9, and non-Whites generally had higher rates in each region.

The multivariate incident rate ratios for COVID-19 mortality are displayed in Table 2. After adjustment for candidate characteristics, age, gender, race/ethnicity, body mass index, primary diagnosis, primary insurance, educational attainment, urban-rural location, and residential distress index were associated with adjusted COVID-19

FIGURE 1 Rate of COVID-19 mortality by race/ethnicity and age. *Candidate age on March 1, 2020 or the date of listing if after March 1, 2020. "Other" race/ethnic group not displayed [Color figure can be viewed at wileyonlinelibrary.com]

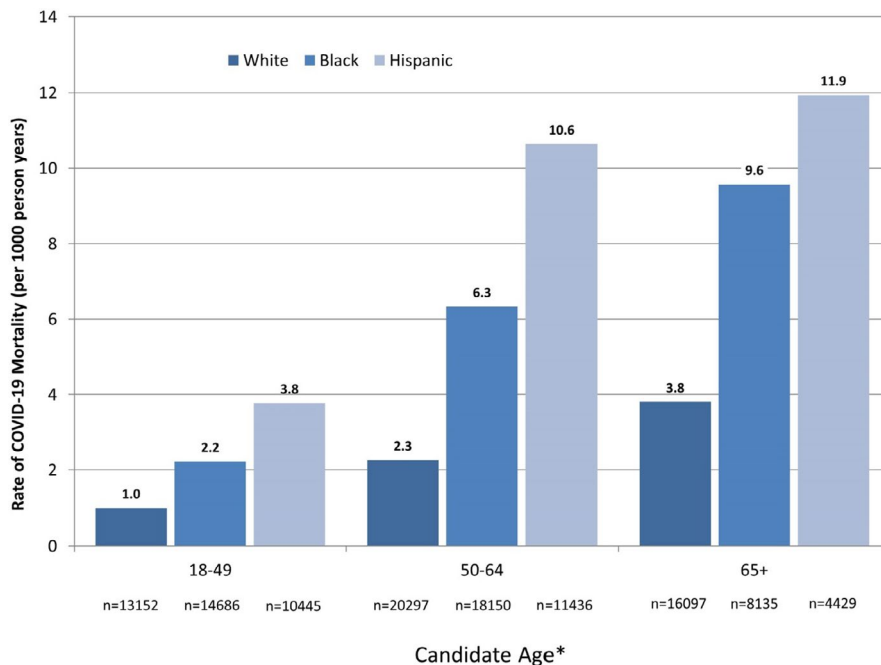
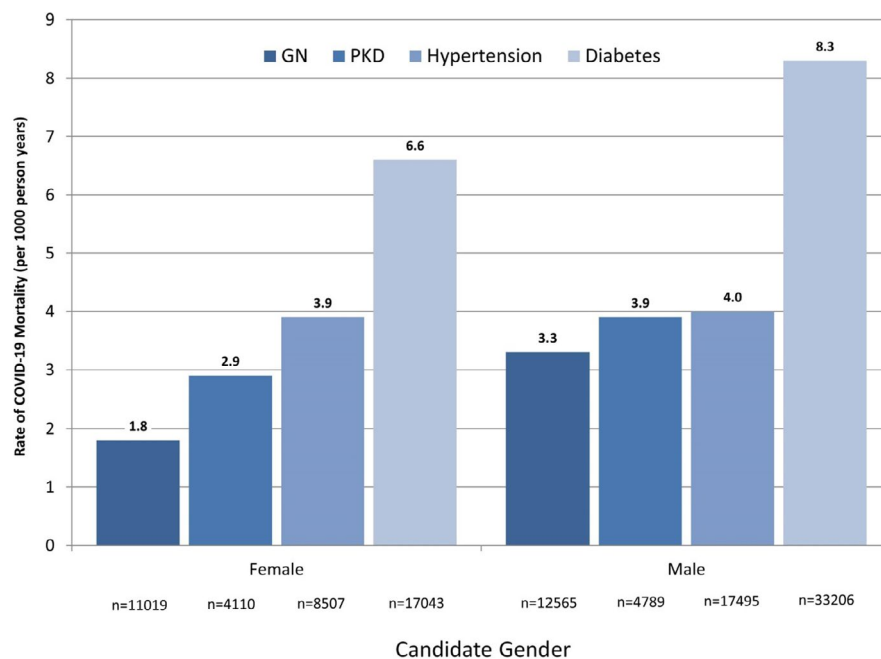


FIGURE 2 Rate of COVID-19 mortality by gender and primary diagnosis. * "Other" primary diagnosis not displayed [Color figure can be viewed at wileyonlinelibrary.com]



mortality rates. Notably, Blacks had a 1.96 IRR (95% C.I. 1.43–2.69) and Hispanics had a 3.38 IRR (95% C.I. 2.46–4.66) relative to Whites. Patients with Medicaid had a 1.73 IRR (95% C.I. 1.26–2.39) relative to patients with private insurance. In addition, patients living in the most distressed residential neighborhoods (Q5) had an IRR of 1.93 (95% C.I. 1.28–2.90) relative to patients living in the least distressed neighborhoods.

The distribution of the general population and COVID-19 deaths in the general population and the kidney transplant candidate population is displayed in Figure 7. In the general population, there were slightly more deaths among Whites and Blacks as compared to the distribution

of individuals in the population. In contrast, there were fewer deaths among Hispanics than the proportion of individuals in the population. There was a substantially higher proportion of deaths with increasing age than the distribution of the population and a higher number of deaths among males. In contrast, among the candidate population, there was a lower relative COVID-19 mortality proportion among Whites and a higher proportion of deaths among Hispanics relative to the distribution in the population. Increasing age was also associated with increased COVID-19 mortality but not as elevated in older groups as in the general population. Males had a higher relative proportion of deaths which was also evident in the general population.

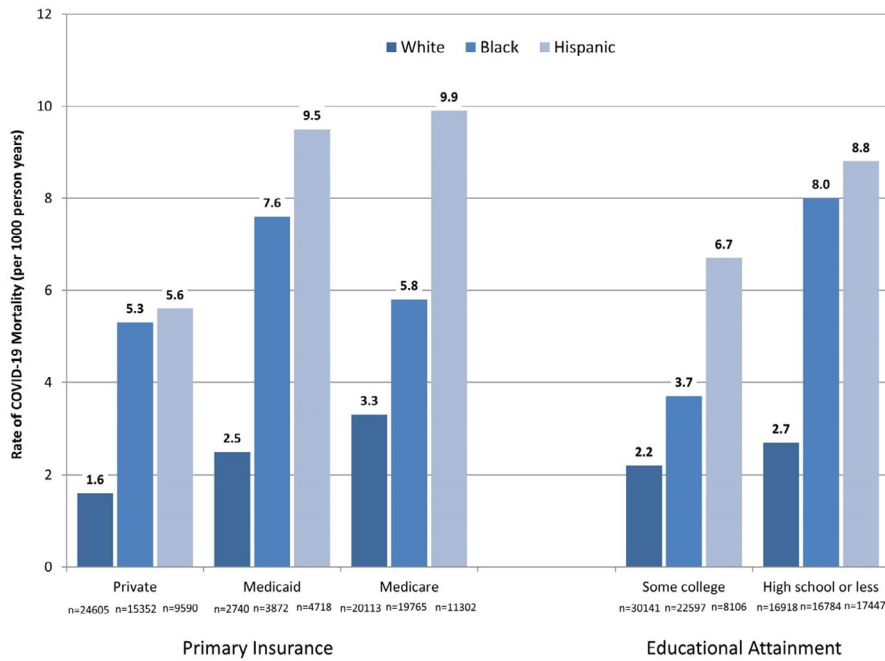


FIGURE 3 Rate of COVID-19 mortality by race/ethnicity, primary insurance, and educational attainment. * “Other” race/ethnicity, “other” insurance, and missing distress index not displayed [Color figure can be viewed at wileyonlinelibrary.com]

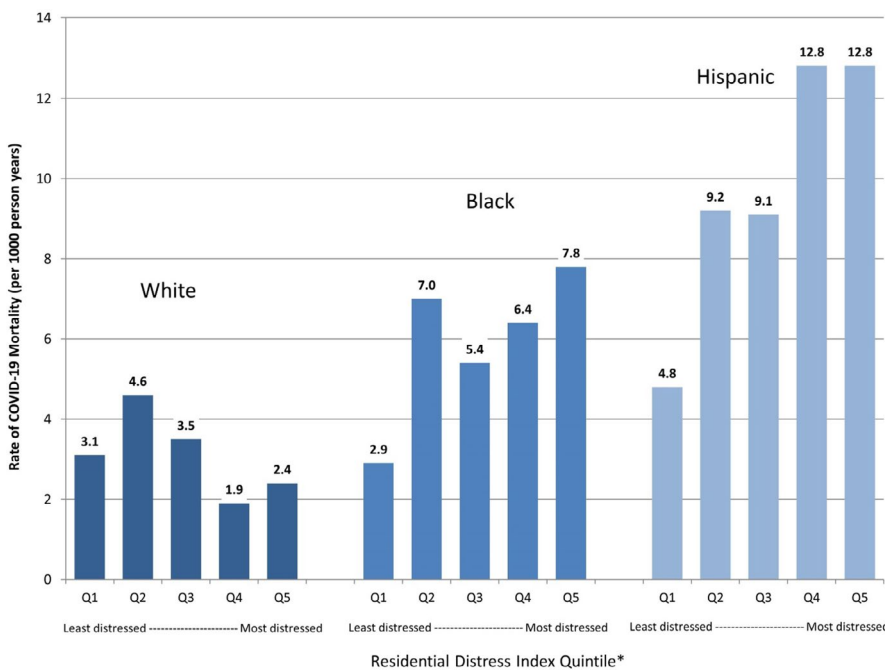


FIGURE 4 Rate of COVID-19 mortality by race/ethnicity and residential distress index. *Other race and missing residential distress index not shown [Color figure can be viewed at wileyonlinelibrary.com]

4 | DISCUSSION

The primary findings of the study indicate that in the first 9 months of the pandemic, there were a significant number of deaths attributed to COVID-19 among kidney transplant candidates. Approximately 11% of all deaths among candidates were coded with COVID-19 cause of death. COVID-19 mortality rates were highly variable within the candidate population based on patients’ demographic characteristics, clinical, and social conditions. Increased age, males, higher body mass index and diabetic status, and rates were significantly associated with higher COVID-19 mortality rates. In

addition, COVID-19 mortality rates were higher among candidates with public insurance, lower educational attainment, and residing in highest quintile distressed communities. Cumulatively, these results affirm that the risks of COVID-19 mortality are related to a complex combination of demographic, clinical, and social factors, and efforts to attenuate risk and improve care in this population should incorporate both medical and social conditions of patients.

There is substantial evidence to date regarding factors associated with mortality associated with COVID-19 in the general population. Factors associated with COVID-19 mortality include increasing age, higher body mass index, and various comorbid conditions.^{2-4,17}

FIGURE 5 Rate of COVID-19 mortality by race/ethnicity and urban-rural residential continuum. *Other race not shown; original urban-rural continuum categories collapsed to maintain sufficient sample sizes; categories displayed are metropolitan area (population >1 million), metropolitan (population 250 000 ≤ 1 million), urban counties with >20 000 population, and metropolitan areas with <250 000 population and non-metropolitan counties to rural communities. [Color figure can be viewed at wileyonlinelibrary.com]

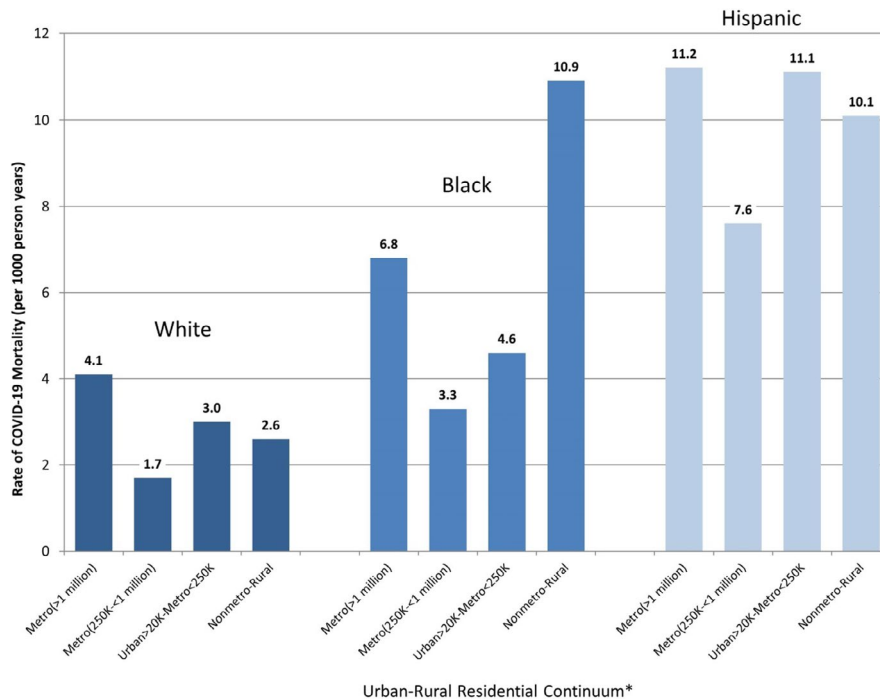
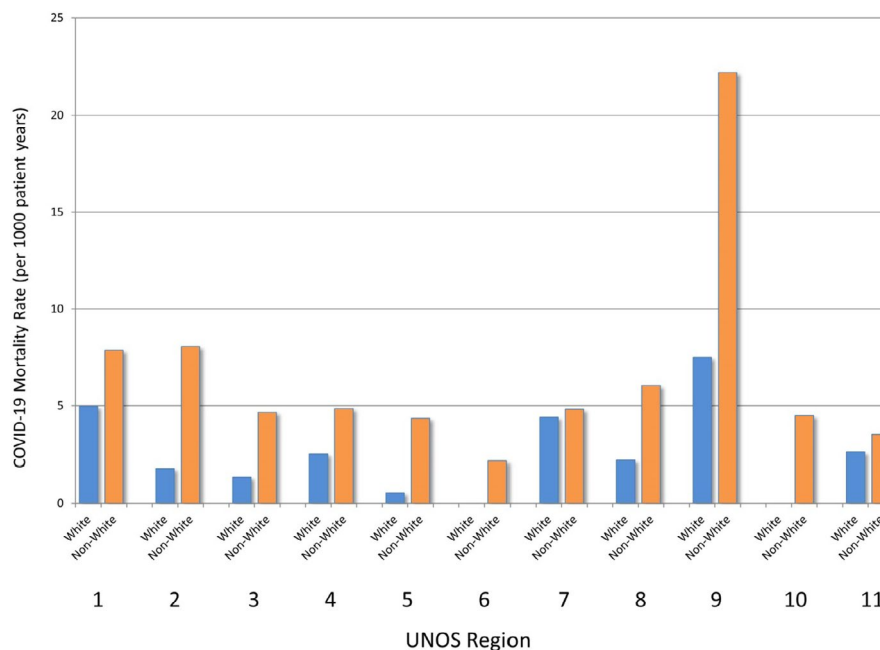


FIGURE 6 Rate of COVID-19 mortality by UNOS region and race/ethnic groups. Race/ethnic groups consolidated to White and non-White (which include Hispanic ethnicity) [Color figure can be viewed at wileyonlinelibrary.com]



These characteristics are highly represented in the kidney transplant candidate population and render patients particularly vulnerable to the impact of COVID-19. In addition, the risks for patients treated with maintenance dialysis are particularly elevated related to both health status and frequent need for interaction with health-care providers and patients.^{11,18-21} This study provided evidence that many of the risk factors in the general and dialysis populations are salient in the transplant candidate population in the United States. Among transplant candidates, increasing age, male gender, diabetes as primary diagnosis, and obesity are risk factors for COVID-19

mortality. Interestingly, duration of dialysis nor blood type was associated with increased COVID-19 causes of death relative to all other deaths despite some reports to the contrary.²²⁻²⁴ Type of dialysis was unknown for the majority of the current study population, but the impact of patients who are treated with in-center hemodialysis versus other forms of maintenance dialysis is important to understand in future studies.

Results of this study indicated substantially increased rates of COVID-19 mortality among Blacks and Hispanics. These were disproportionate with rates of all-cause mortality among candidates

TABLE 2 Multivariable incident rate ratios of COVID-19 death

Candidate characteristics	Level	IRR	95% C.I.
Age (reference: 18–34)	35–49	1.34	0.67–2.70
	50–64	3.82	1.99–7.31
	65+	4.90	2.52–9.53
Race/Ethnicity (reference: White)	Black	1.96	1.43–2.69
	Hispanic	3.38	2.46–4.66
	Other	2.82	1.92–4.14
Gender (reference: female)	Male	1.45	1.16–1.81
Body mass index (reference: 21–25 kg/m ²)	13–20 kg/m ²	0.83	0.33–2.09
	26–30 kg/m ²	1.65	1.18–2.30
	31–35 kg/m ²	2.05	1.47–2.88
	36+ kg/m ²	1.92	1.32–2.80
	Missing	2.92	1.16–7.36
Primary diagnosis (reference: GN)	Diabetes	2.07	1.43–3.00
	PKD	1.37	0.78–2.40
	Hypertension	1.01	0.66–1.54
	Other	1.07	0.67–1.69
Prior transplant (reference: no)	Yes	1.47	1.06–2.02
Prior malignancies (reference: no)	Yes	0.90	0.61–1.33
Peripheral vascular disease (reference: no)	Yes	1.15	0.87–1.52
Primary insurance (reference: private)	Medicaid	1.73	1.26–2.39
	Medicare	1.17	0.91–1.50
	Other	0.39	0.17–0.89
Pre-listing dialysis time (reference: preemptive)	1–12 months	0.96	0.72–1.27
	13–24 months	1.16	0.87–1.55
	25–36 months	1.07	0.74–1.54
	37+ months	1.12	0.80–1.58
Educational attainment (reference: post-graduate)	High school or less	1.93	1.19–3.12
	Some college	1.26	0.78–2.05
	Unknown	1.41	0.68–2.88
Working for income (reference: no or unknown)	Yes	1.15	0.90–1.46
Blood type (reference: A)	B	0.85	0.62–1.18
	AB	1.17	0.67–2.06
	O	1.07	0.85–1.36
Residential distress index quintile (reference: 1 = lowest risk)	2	1.77	1.16–2.70
	3	1.50	0.97–2.31
	4	1.50	0.97–2.30
	5 (highest risk)	1.93	1.28–2.90
	Missing	3.28	0.44–24.4

(Continues)

TABLE 2 (Continued)

Candidate characteristics	Level	IRR	95% C.I.
Urban-rural continuum code (metropolitan [population 250 000 ≤ 1 million])	Metro (>1 million pop.)	2.25	1.53–3.28
	Urban (<250,000 pop. / non-metro)	1.40	0.81–2.40
	Small Urban/Rural	2.05	1.21–3.45

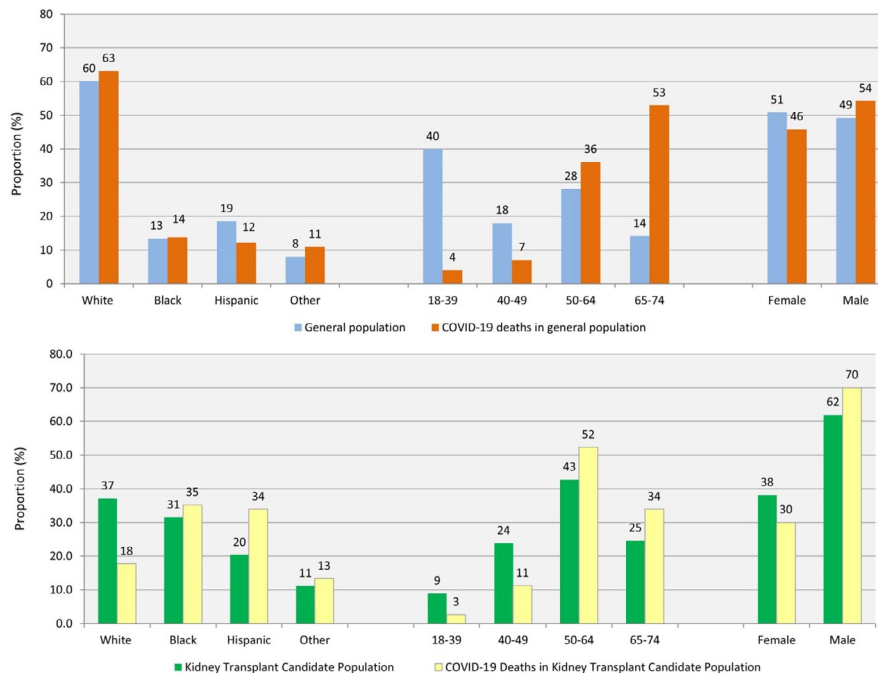
Note: Residential distress index and urban-rural continuum based on zip code of primary residence.

Abbreviations: GN, glomerulonephritis; PKD, polycystic kidney disease.

and suggest particular susceptibility to transmission and/or severity of COVID-19 in these populations. The increased rate among Blacks and Hispanics was consistent by age group, insurance type, educational attainment, and residential location. Certainly, these results are concerning in a context in which health disparities by race/ethnic group have been longstanding and suggest additional barriers to transplantation related to higher prevalence of COVID-19.^{25–28} These disparities were also evident for patients based on indicators of social determinants of health including residential income and location, insurance, and education. Interestingly, the effects of residential distress were evident among Blacks and Hispanics but not Whites. These results may suggest a synergistic association of race and disadvantaged residential communities. Certainly, the association of race/ethnicity with increased mortality may have multiple etiologies, and understanding the specific mechanisms and nuanced etiologies of these associations is critical for prospective investigations. Further understanding the degree to which results are based on the prevalence of COVID-19 in the respective groups, the health consequences from COVID-19, and the impact of access and quality of care is critically important. COVID-19 mortality rates also varied by urban-rural location of candidates. The effects of COVID-19 were largely centered in urban areas initially but transitioned to rural communities. Findings highlight the important observation that social risks are critically important to address with the impact of COVID-19 and the need to develop interventions for modifiable factors.^{5,7,29}

Without question, the COVID-19 pandemic has affected all aspects of the transplantation process including donor procurement, living donor transplantation, and care and management of transplant candidates and recipients.^{30–34} For transplant candidates and caregivers, shared decision-making regarding organ acceptance often accounts for the balance of risks for respective treatment modalities. In this context, transplant candidates, and, in particular, candidates with certain risk factors may have an imperative to access transplantation expeditiously during the pandemic. Management of current transplant candidates should also incorporate the risk profile of patients and consider both clinical as well as social risk factors to enhance care. As compared to the general population, Whites had a lower relative proportion of COVID-19 deaths and Black and particularly Hispanics had a

FIGURE 7 Distribution of COVID-19 mortality in the general population and kidney transplant candidate population by demographic characteristics. Deaths in the general population derived from CDC data through (February 27, 2021) and population demographic characteristics from the US Census (2019). Mortality in the general population by race/ethnicity and gender reflects all available death data; mortality by age only displayed between ages 18–74 for comparison to the transplant candidate population [Color figure can be viewed at wileyonlinelibrary.com]



much higher proportion of deaths among transplant candidates. This suggests that the kidney transplant candidate population may have unique sources of risk, and particular focus on interventions to mitigate risks among the Black and Hispanic candidate populations is needed. Increased age among candidates did not have the same relative mortality distribution as the general population which may in some part reflect selection criteria of older transplant candidates. Overall, results highlight that a multifactorial approach may be needed to guide effective health-care delivery to transplant candidates including potential prioritization of COVID-19 vaccine deployment to the most vulnerable groups.

There are several limitations of the study that are important to acknowledge and incorporate for inferences about the findings. COVID-19 death reporting is likely not comprehensive and there may be lagged data that affect the estimation of incidence rates as reported in this study. While missing causes of death may not be systematically different by patient characteristics, the total number of deaths related to COVID-19 is likely higher and may often be a contributory factor if not listed as primary cause of death. As the UNOS coding for COVID-19 deaths is based on death as a cause of waitlist removal, deaths after removal that may have been attributed to COVID-19 are not known. Over the study period, there were 48 total deaths after waitlist removal, some of which may have been attributed to COVID-19. In addition, as there is no information about COVID-19 positivity available in these data, mortality rates reflect both vulnerability to contractive COVID-19 as well as severity of the effects if contracted. These data are retrospective observational data and are subject to residual confounding and associations may be affected by underlying factors. Moreover, as the pandemic evolves, risk factors for susceptibility and the health consequences of COVID-19 are certain to change.

In summary, the study demonstrated significant rates of COVID-19 mortality among kidney transplant candidates in the United States. COVID-19 mortality was disproportionately represented in the population and patients who were older, diabetic, higher body mass index, and male were significantly more likely to have a COVID-19 death during the study period. In addition, social determinants of health including education, insurance, residential distress, geographic location, and racial/ethnic background were strongly associated COVID-19 mortality. These social factors in conjunction with clinical factors should be strongly considered for risk assessment and care management in the kidney transplant candidate population.

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CONFLICT OF INTEREST

The authors of this manuscript have no conflicts of interest to disclose as described by the *American Journal of Transplantation*.

DATA AVAILABILITY STATEMENT

These data may be made available by the Scientific Registry of Transplant Recipients.

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REFERENCES

1. Woolf SH, Chapman DA, Lee JH. COVID-19 as the leading cause of death in the United States. *JAMA*. 2021;325:123-124.
2. Crespo M, Pérez-Sáez MJ, Redondo-Pachón D, et al. COVID-19 in elderly kidney transplant recipients. *Am J Transplant*. 2020;20:2883-2889.
3. Mehra MR, Desai SS, Kuy SR, Henry TD, Patel AN. Cardiovascular disease, drug therapy, and mortality in Covid-19. *N Engl J Med*. 2020;382:e102.
4. Price-Haywood EG, Burton J, Fort D, Seoane L. Hospitalization and mortality among black patients and white patients with Covid-19. *N Engl J Med*. 2020;382:2534-2543.
5. Egede LE, Walker RJ. Structural racism, social risk factors, and Covid-19 - A dangerous convergence for Black Americans. *N Engl J Med*. 2020;383:e77.
6. Friedman DJ. COVID-19 and APOL1: understanding disease mechanisms through clinical observation. *J Am Soc Nephrol*. 2021;32:1-2.
7. Lopez L 3rd, Hart LH 3rd, Katz MH. Racial and ethnic health disparities related to COVID-19. *JAMA*. 2021;325(8):719.
8. Page KR, Flores-Miller A. Lessons we've learned - Covid-19 and the undocumented latinx community. *N Engl J Med*. 2021;384:5-7.
9. United Network for Organ Sharing. Transplant trends. 2020; <https://unos.org/data/transplant-trends/>. Accessed December 15, 2020.
10. Chaudhry ZS, Williams JD, Vahia A, et al. Clinical characteristics and outcomes of COVID-19 in solid organ transplant recipients: a cohort study. *Am J Transplant*. 2020;20:3051-3060.
11. Corbett RW, Blakey S, Nitsch D, et al. Epidemiology of COVID-19 in an Urban dialysis center. *J Am Soc Nephrol*. 2020;31:1815-1823.
12. Craig-Schapiro R, Salinas T, Lubetzky M, et al. COVID-19 outcomes in patients waitlisted for kidney transplantation and kidney transplant recipients. *Am J Transplant*. 2020; <https://doi.org/10.1111/ajt.16351>.
13. Elias M, Pievani D, Randoux C, et al. COVID-19 infection in kidney transplant recipients: disease incidence and clinical outcomes. *J Am Soc Nephrol*. 2020;31:2413-2423.
14. Economic Innovation Group. Distressed communities index. 2020; <https://eig.org/dci>. Accessed July 1, 2020.
15. US Census Bureau. Population. 2021; <https://www.census.gov/topics/population.html>. Accessed February 27, 2021.
16. Centers for Disease Control and Prevention. Demographic trends of COVID-19 cases and deaths in the US reported to the CDC. 2021; <https://covid.cdc.gov/covid-data-tracker/#demographics>. Accessed February 27, 2021.
17. Donnelly JP, Wang XQ, Iwashyna TJ, et al. Readmission and death after initial hospital discharge among patients with COVID-19 in a large multihospital system. *JAMA*. 2021;325:304-306.
18. Flythe JE, Assimon MM, Tugman MJ, et al. characteristics and outcomes of individuals with pre-existing kidney disease and COVID-19 admitted to intensive care units in the United States. *Am J Kidney Dis*. 2021;77(190-203):e1.
19. Gupta S, Coca SG, Chan L, et al. AKI Treated with renal replacement therapy in critically ill patients with COVID-19. *J Am Soc Nephrol*. 2021;32:161-176.
20. Hsu CM, Weiner DE, Aweh G, et al. COVID-19 infection among US dialysis patients: risk factors and outcomes from a national dialysis provider. *Am J Kidney Dis*. 2021;S0272-S6386:00025-1.
21. Pei G, Zhang Z, Peng J, et al. Renal involvement and early prognosis in patients with COVID-19 pneumonia. *J Am Soc Nephrol*. 2020;31:1157-1165.
22. Amoroso A, Magistrone P, Vespasiano F, et al. HLA and ABO polymorphisms May influence SARS-CoV-2 infection and COVID-19 severity. *Transplant*. 2021;105:193-200.
23. Ray JG, Schull MJ, Vermeulen MJ, et al. Association between ABO and Rh blood groups and SARS-CoV-2 infection or severe COVID-19 illness : a population-based cohort study. *Ann Intern Med*. 2020;174(3):308-315.
24. Rubin R. Investigating whether blood type is linked to COVID-19 risk. *JAMA*. 2020;324:1273.
25. Alexander GC, Sehgal AR. Transplant task force of the renal network I. Variation in access to kidney transplantation across dialysis facilities: using process of care measures for quality improvement. *Am J Kidney Dis*. 2002;40:824-831.
26. Epstein AM, Ayanian JZ. Racial disparities in medical care. *N Engl J Med*. 2001;344:1471-1473.
27. Mohan S, Mutell R, Patzer RE, et al. Kidney transplantation and the intensity of poverty in the contiguous United States. *Transplant*. 2014;98:640-645.
28. Patzer RE, Pastan SO. Measuring the disparity gap: quality improvement to eliminate health disparities in kidney transplantation. *Am J Transplant*. 2013;13:247-248.
29. Crews DC, Purnell TS. COVID-19, racism, and racial disparities in kidney disease: galvanizing the kidney community response. *J Am Soc Nephrol*. 2020;31:1-3.
30. Ahmed O, Brockmeier D, Lee K, et al. Organ donation during the COVID-19 pandemic. *Am J Transplant*. 2020;20:3081-3088.
31. Boyarsky BJ, Werbel WA, Durand CM, et al. Early national and center-level changes to kidney transplantation in the United States during the COVID-19 epidemic. *Am J Transplant*. 2020;20:3131-3139.
32. Galvan NTN, Moreno NF, Garza JE, et al. Donor and transplant candidate selection for solid organ transplantation during the COVID-19 pandemic. *Am J Transplant*. 2020;20:3113-3122.
33. Loupy A, Aubert O, Reese PP, et al. Organ procurement and transplantation during the COVID-19 pandemic. *Lancet*. 2020;395:e95-e96.
34. Nair V, Jandovitz N, Hirsch JS, et al. An early experience on the effect of solid organ transplant status on hospitalized COVID-19 patients. *Am J Transplant*. 2020.

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