Kidney Medicine

COVID-19 and Access to Kidney Transplantation for Older Candidates in the United States: A National Registry Study

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Rationale & Objective: Coronavirus disease (COVID)-19 has likely impacted accessibility to transplantation services among older adults (age ≥65 years). We quantified the impact of COVID-19 on kidney transplantation access for older kidney-only candidates registered on the United States (US) kidney waitlist.

Study Design: Retrospective analysis of registry data.

Setting & Participants: 57,222 older adults who were part of or added to the US kidney waitlist between January 1, 2016 and February 28, 2022, identified using the Scientific Registry of Transplant Recipients (SRTR).

Exposures: Four COVID-19 waves and one nonwave period based on the national incidence of COVID-19 in the US (initial: March 15-May 30, 2020; winter 2020-2021: December 1, 2020-January 31, 2021; delta: August 1, 2021-September 30, 2021; omicron: December 1, 2021-February 28, 2022; nonwave: inter-wave periods).

Outcomes: Waitlist registrations, deceased-donor kidney transplants, living-donor kidney transplants, waitlist mortality, and waitlist removals due to deteriorating condition (hereafter referred to as removals).

Analytical Approach: Poisson regression for the adjusted incidence rate ratio (aIRR) of each outcome during the COVID-19 waves and the nonwave period relative to reference (January 1, 2016-December 31, 2019), adjusted for seasonality and secular trends.

Results: Waitlist registrations initially declined and increased henceforth. Deceased-donor kidney transplants and living-donor kidney transplants remained below-expected levels during all waves. Waitlist mortality peaked during the winter 2020-2021 wave (aIRR: $_{1.70}1.98_{2.30}$) and has declined since; mortality rates were 139%, 107%, and 251% above expected for Black candidates, men, and candidates aged ≥75 years, respectively, during the winter 2020-2021 wave. Removals increased from 22% below expected levels (initial wave) to 26% above expected levels (omicron wave); removals were nonsignificantly higher than expected during the omicron wave for older Black and Hispanic candidates.

Limitations: The findings are not generalizable to those listed at earlier ages with prolonged waitlist times. Additionally, using national COVID-19 incidence does not consider local policy and health care variations. Lastly, aIRRs must be interpreted cautiously due to smaller daily event counts.

Conclusions: COVID-19 was associated with fewer transplants and increased mortality and removals in older kidney transplant candidates. Transplant providers should consider this impact and implement policies and practices to ensure the continuity of care.

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Over the past 3 decades, kidney transplantation has achieved remarkable success in treating older (aged ≥65 years) patients with kidney failure. The proportion of older kidney transplant recipients among all kidney transplant recipients has increased from 8.4% in 2000 to 21.2% in 2019, with improvements in patient and graft survival.[1,2] Kidney transplantation is the preferred method of kidney replacement therapy for older individuals with kidney failure, with increased survival, quality of life, cognitive function, lifespan, reduced frailty, and cardiovascular disease risk factors compared to remaining on dialysis.[3-10]

The coronavirus disease (COVID)-19 pandemic exerted a profound impact on health care provision and accessibility worldwide. Kidney transplantation access was negatively impacted early in the pandemic, with decreased waitlist registrations and transplantations across the age spectrum, the latter of which experienced a 19.1% drop globally during the initial wave relative to 2019.[11-13] Older kidney transplant candidates, with the combined effects of immunosenescence and kidney failure, faced increased vulnerability to COVID-19.[14-15] They also experienced higher mortality on the transplant waitlist, possibly affecting deceased-donor kidney transplants more than living-donor kidney transplants due to the suspension of living-donor kidney transplants early in the pandemic, particularly for older candidates.[3,16,17] Therefore, health care providers may hesitate to have older kidney transplant candidate visits in settings with a higher risk of severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) exposure and infection.

Using data from the national registry, the Scientific Registry of Transplant Recipients (SRTR), we characterized

PLAIN-LANGUAGE SUMMARY

The proportion of older adults on the kidney transplant waitlist is increasing, but the impact of COVID-19 on this population is not well characterized. In this study, we looked at incident waitlist registrations, deceased- and living-donor kidney transplants, and waitlist mortality and removals due to deteriorating condition over 4 waves of COVID-19. We found that transplantation services did not fully recover to prepandemic levels as of March 2022. Notably, racial/ethnic minorities and older men experienced lower rates of kidney transplants and higher rates of waitlist mortality, respectively, relative to White candidates and older women. Identifying vulnerable subpopulations affected by COVID-19 and its long-term impact is crucial for creating strategies to ensure the continuity of care in this population during public health emergencies.

waitlist outcomes for older kidney-only candidates on the US national kidney waitlist. We compared waitlist outcomes during each of the COVID-19 waves and a nonwave period to those during the reference period (January 1, 2016-December 31, 2019).

METHODS

Study Design

This study used data from the SRTR. The SRTR data system includes data on all donors, waitlisted candidates, and transplant recipients in the US, submitted by the members of the Organ Procurement and Transplantation Network (OPTN).[18] The Health Resources and Services Administration (HRSA), US Department of Health and Human Services, provides oversight to the activities of the OPTN and SRTR contractors. This dataset has previously been described elsewhere.[19] This study was reviewed and determined to qualify for an ethics approval exemption under i22-00146 by the Institutional Review Board at the New York University Grossman School of Medicine. Informed consent was not required as these analyses are conducted on deidentified data curated by the SRTR. All methods in this study were performed in accordance with the Declaration of Helsinki.

We identified 57,222 older (aged ≥65 years at the time of listing) kidney-only candidates who were part of or added to the US kidney waitlist between January 1, 2016-February 28, 2022 (hereafter referred to as waitlisted candidates). Candidates with missing race and/or listing dates were excluded from the study population. To assess heterogeneity, we determined the rate of waitlist events in racial/ethnic, age (65-74 and ≥75 years), and sex (male and female) groups. We utilized provider-reported race and ethnicity information on the OPTN data collection forms, categorized into 4 groups: non-Hispanic White, non-Hispanic Black, Hispanic/Latino, and Others [Asian American, Native Hawaiian/other Pacific Islander, American Indian/Alaska Native, and multiracial], hereafter referred to as White, Black, Hispanic, and Other, respectively. The outcomes were incident waitlist registrations, deaths, deceased-donor kidney transplants, living-donor kidney transplants, and waitlist removals due to deteriorating condition.

US COVID-19 Cases and Infection Waves

We plotted the running mean smoother of the daily incident cases of COVID-19 between January 21, 2020 and March 8, 2022 using publicly available data from the New York Times GitHub repository.[20] Four major COVID-19 waves were identified using the national incidence of SARS-CoV-2 infection in the United States: March 15, 2020-May 31, 2020 (initial), December 1, 2020-January 31, 2021 (winter 2020-2021), August 1, 2021-September 30, 2021 (delta), and December 1, 2021-February 28, 2022 (omicron) (Table S1).[21] We also identified a fifth (nonwave) period that included January 1, 2020-March 14, 2020; June 1, 2020-November 30, 2020; February 1, 2021-July 31, 2021; and October 1, 2021-November 30, 2021. The period between January 1, 2016 and December 31, 2019 was the reference.

Characteristics of Incidentally Waitlisted Candidates during COVID-19 Waves

We described the demographic (age, sex, race) and clinical (body mass index (BMI), blood group, and cause of kidney failure) characteristics of 42,333 older adults added to the waitlist during each of the COVID-19 waves, the nonwave period, and the reference period. Continuous variables were described using mean and standard deviation (SD), while categorical variables were described using percentages. Missing values were assigned separate categories. Kruskal-Wallis tests and Pearson χ^2 tests were used to compare continuous and categorical variables, respectively, across time eras.

Daily Counts of Waitlist Events

Waitlist events are defined as incident waitlist registrations (hereafter referred to as registrations), deceased-donor kidney transplants, living-donor kidney transplants, waitlist mortality (hereafter referred to as mortality), and waitlist removals due to deteriorating condition (hereafter referred to as removals). Removals were identified based on the removal code provided with waitlist records from the SRTR dataset. We also determined the daily count of active and inactive older candidates on the waitlist from January 1, 2020 to February 28, 2022, which we plotted. Over the same period, we plotted the daily counts of waitlist registrations, deceased-donor kidney transplants, living-donor kidney transplants, waitlist deaths, and removals due to deteriorating condition for older candidates, overlaid with the running mean smoother. We excluded weekends for waitlist registrations, removals, and living-

donor kidney transplants, as >99% of them occurred on weekdays.

Statistical Analyses: Waitlist Events During Infection Waves

We determined the daily counts of waitlist events for older kidney-only candidates who were part of or added to the US kidney waitlist from January 1, 2016 to February 28, 2022. We defined the expected event rate as the average daily event count during the reference period. Poisson regression was used to model relative changes in the average daily count of waitlist events during each COVID-19 wave compared to the reference period. All models included season indicator variables to identify the specific seasons for each year (March 15-May 31; August 1-September 30; December 1-February 28) and a continuous variable for secular trends, defined as the number of days from January 1, 2016. The models for waitlist deaths and removals included the waitlist size as an offset. For descriptive analyses, we aggregated the daily counts into weekly averages and characterized waitlist events during COVID-19 waves and the reference period. To assess heterogeneity, we modeled average daily counts of waitlist events for age, sex, and racial/ethnic groups using Poisson regression, where expected event rates were calculated for each racial/ethnic, age, and sex group during the reference period, and reported the adjusted incidence rate ratio (aIRR) adjusted for seasonality and temporal trends. We also determined the aIRR of waitlist events during COVID-19 waves within race, age, and sex categories using interaction terms between infection waves and subgroups.

For the sensitivity analysis, we determined the daily counts of waitlist events in kidney transplants aged 18-64 years at listing from January 1, 2016 to February 28, 2022. We used Poisson models to determine the relative changes in the average daily count of waitlist events compared to the reference period, adjusting for seasonality and secular trends as described above. Lastly, we compared outcomes in candidates aged ≥65 years to those aged 18-64 years over the waves.

We reported the confidence intervals according to the method proposed by Louis and Zeger[22] and used a 2-sided α value of 0.05 to determine statistical significance. All analyses were performed using Stata 17/MP for Linux (StataCorp LLC, College Station, TX).

RESULTS

Our study population of 57,222 older (aged ≥ 65 years) waitlisted candidates was 54.8% White (N=31,358), 22.9% Black (N=13,075), 12.6% Hispanic/Latino (N=7,248), and 9.7% Other (N=5,541). In addition, 37.0% were female (N=21,170), and 6.5% (N=3,742) were aged ≥75 years at listing. Among older incidentally waitlisted candidates, the distribution of race/ethnicity, BMI, and causes of kidney failure differed across infection waves, while the age distribution was similar across infection waves (Table 1).

The average weekly count of incident waitlist events among older adults increased over time (Table 2); in contrast, the number of older active waitlisted candidates declined steadily through the 4 COVID-19 waves from 11,189 on January 1, 2020 to 9,632 on February 28, 2022 (Figs S1-S3). The most notable increase in the daily count of deceased-donor kidney transplants, living-donor kidney transplants, and registrations occurred after the initial wave (Fig 1, Fig S4). Daily mortality rates peaked during the winter 2020-2021 wave and decreased thereafter (Fig 2A). In contrast, the rate of removals increased over time (Fig 2B).

Changes in Waitlist Events over Infection Waves and Nonwave Period

Among older candidates, registrations remained significantly below-expected values throughout the pandemic (Table 3). Deceased-donor kidney transplants were significantly below-expected levels during all waves except the winter 2020-2021 wave (Table 3). The daily incidence of living-donor kidney transplants was 76% below expected (aIRR: $_{0.19}0.24_{0.32}$) during the initial wave and remained below expected throughout the study period despite increasing over time (Table 3).

Mortality was 49%, 98%, 54%, 32%, and 26% greater than expected during the initial, winter 2020-2021, delta, omicron, and nonwave periods, respectively. Removals increased from below-expected levels during the initial wave (aIRR: $_{0.68}0.78_{0.91}$) to 26% higher-than-expected levels during the omicron wave (aIRR: $_{1.09}1.26_{1.46}$) (Table 3).

Waitlist Events by Race, Sex, and Age Groups

Waitlist Registrations

The rate of registrations increased over time for all racial/ethnic groups but remained below-expected levels for all waves, including the nonwave period; they were at their lowest primarily during the initial (23%-37% below expected) and winter 2020-2021 waves (19%-39% below expected) (Table 4). For older men and women, registrations increased over time but remained significantly below expected during all time periods (Tables S2-S5). Registrations remained below-expected rates during the pandemic era for candidates aged 65–74 and ≥75 years (Table S5). Lastly, incident registrations were lower among racial/ethnic minorities, older women, and candidates aged ≥75 years than White candidates, older men, and those aged 65-74 years, respectively (Tables S2, S4, S6).

Deceased-Donor Kidney Transplants and Living-Donor Kidney Transplants

Overall, the rate of deceased-donor kidney transplants showed an increasing trend across all racial/ethnic groups (Table 4). Notably, the rate of deceased-donor kidney

Table 1. Characteristics of Older (Age ≥65 Years) Incident Waitlisted Candidates, by Eras of Listing (2016-2022)

Characteristics	All Incident Waitlisted N=42,333	Reference N=26,562	Initial N=1,173	Winter 2020-21 N=1,176	Delta N=1,290	Omicron N=2,005	Nonwave N=10,127	*P* Value[a]
Age at listing, mean (SD)	68.8 (3.3)	68.7 (3.3)	68.9 (3.3)	68.9 (3.4)	69.2 (3.4)	69.0 (3.4)	68.9 (3.4)	<0.01[b]
Age categories, y, N (%)								0.88
65-74	39,459 (93.2)	24,751 (93.2)	1,101 (93.9)	1,095 (93.1)	1,197 (92.8)	1,861 (92.8)	9,454 (93.4)	
75-84	2,850 (6.7)	1,796 (6.8)	71 (6.1)	81 (6.9)	91 (7.1)	143 (7.1)	668 (6.6)	
≥85	24 (0.1)	15 (0.1)	1 (0.1)	0 (0.0)	2 (0.2)	1 (0.0)	5 (0.0)	
Female, N (%)	15,534 (36.7)	9,729 (36.6)	416 (35.5)	412 (35.0)	460 (35.7)	760 (37.9)	3,757 (37.1)	0.44
Race/ethnicity, N (%)								0.02[b]
White	23,738 (56.1)	14,865 (56.0)	612 (52.2)	678 (57.7)	723 (56.0)	1,118 (55.8)	5,742 (56.7)	
Black	9,458 (22.3)	5,915 (22.3)	263 (22.4)	254 (21.6)	291 (22.6)	456 (22.7)	2,279 (22.5)	
Hispanic/Latino	5,195 (12.3)	3,330 (12.5)	182 (15.5)	119 (10.1)	155 (12.0)	233 (11.6)	1,176 (11.6)	
Other	3,942 (9.3)	2,452 (9.2)	116 (9.9)	125 (10.6)	121 (9.4)	198 (9.9)	930 (9.2)	
Body mass index, kg/m², mean (SD)	28.8(5.0)	28.8(5.0)	29.0(5.1)	28.7(4.9)	28.8(5.2)	28.6(5.0)	28.9(5.0)	0.27
Body mass index, categories, N (%)								0.05[b]
≤25 kg/m²	11,308 (26.7)	7,058 (26.6)	320 (27.3)	314 (26.7)	367 (28.4)	562 (28.0)	2,687 (26.5)	
26-30 kg/m²	15,827 (37.4)	9,956 (37.5)	418 (35.6)	460 (39.1)	463 (35.9)	760 (37.9)	3,770 (37.2)	
>30 kg/m²	14,991 (35.4)	9,443 (35.6)	429 (36.6)	392 (33.3)	452 (35.0)	669 (33.4)	3,606 (35.6)	
Missing[c]	207 (0.5)	105 (0.4)	6 (0.5)	10 (0.9)	8 (0.6)	14 (0.7)	64 (0.6)	
Cause of kidney failure, N (%)								0.01[b]
Diabetes mellitus	18,700 (44.2)	11,795 (44.4)	520 (44.3)	497 (42.3)	566 (43.9)	843 (42.0)	4,479 (44.2)	
Hypertension	8,912 (21.1)	5,674 (21.4)	237 (20.2)	253 (21.5)	265 (20.5)	443 (22.1)	2,040 (20.1)	
Glomerulonephritis	4,305 (10.2)	2,752 (10.4)	124 (10.6)	121 (10.3)	123 (9.5)	199 (9.9)	986 (9.7)	
Others	10,416 (24.6)	6,341 (23.9)	292 (24.9)	305 (25.9)	336 (26.0)	520 (25.9)	2,622 (25.9)	
Blood group, N (%)								0.28
A	14,698 (34.7)	9,192 (34.6)	431 (36.7)	406 (34.5)	490 (38.0)	687 (34.3)	3,492 (34.5)	
B	6,103 (14.4)	3,852 (14.5)	152 (13.0)	160 (13.6)	181 (14.0)	310 (15.5)	1,448 (14.3)	
AB	1,724 (4.1)	1,078 (4.1)	41 (3.5)	54 (4.6)	41 (3.2)	93 (4.6)	417 (4.1)	
O	19,808 (46.8)	12,440 (46.8)	549 (46.8)	556 (47.3)	578 (44.8)	915 (45.6)	4,770 (47.1)	

Abbreviation: SD = standard deviation.
[a]*P* values from Kruskal-Wallis (continuous) and Pearson's χ^2 (categorical) tests compare the value for each variable for incidentally waitlisted candidates over the time eras. Clinical and demographic variables were obtained at the time of listing.
[b]Statistically significant at a two-sided α of 0.05.
[c]Individuals with missing body mass index data at listing were not excluded from subsequent analyses.

transplants in older Black candidates was 16%-29% below expected for all 4 waves of COVID-19, but not the nonwave period (Table 4). The sharpest decline in deceased-donor kidney transplants during the initial wave was noted among older Hispanic candidates (aIRR: $_{0.33}0.46_{0.65}$). The rate of deceased-donor kidney transplants improved over time for older men and women, respectively, after the initial wave, where it was 23% and 36% below expected, respectively (Table S3). For candidates aged 65-74 years, the rate of deceased-donor kidney transplants was significantly below expected during all but the initial and omicron waves, while that for candidates aged ≥75 years was comparable to expected during all but the initial wave (Table S5).

Table 2. Average Weekly Counts of Waitlist Events During Each Time Era

	Average weekly count (SD)				
	Registration[b]	Deceased-donor kidney transplant[c]	Living-donor kidney transplant[d]	Mortality[e]	Removal[f]
Time Era[a]					
Initial	120 (35)	43 (15)	7 (8)	25 (7)	22 (6)
Winter 2020-2021	154 (33)	57 (9)	14 (6)	37 (6)	22 (6)
Delta	166 (20)	57 (4)	16 (5)	23 (2)	28 (6)
Omicron	163 (46)	59 (16)	16 (7)	23 (8)	28 (11)
Nonwave	169 (23)	64 (9)	20 (5)	21 (5)	26 (7)
Reference	146 (28)	44 (10)	17 (6)	18 (5)	28 (7)

Notes: Daily counts of waitlist events were aggregated by calendar week.
Abbreviation: SD = standard deviation.
[a]Reference period: January 1, 2016-December 31, 2019; initial: March 15, 2020-May 31, 2020; winter 2020-2021: December 1, 2020-January 31, 2021; delta: August 1, 2021-September 30, 2021; omicron: December 1, 2021-February 28, 2022; nonwave: January 1, 2020-March 14, 2020, June 1, 2020-November 30, 2020, February 1, 2021-July 31, 2021, and October 1, 2021-November 30, 2021.
[b]Incident waitlist registrations.
[c]Deceased donor kidney transplant.
[d]Living donor kidney transplant.
[e]Waitlist mortality.
[f]Waitlist removals due to deteriorating condition.

During the initial wave, the rate of living-donor kidney transplants was significantly below-expected values for all racial/ethnic groups (Table 4). Living-donor kidney transplant rates initially increased for all races but declined to below-expected rates for all except older Hispanic candidates during the omicron wave (Table 2). Living-donor kidney transplant rates in older men and women increased after the decline during the initial wave, but remained below expected thereafter (Table S3). Living-donor kidney transplants occurred at lower-than-expected rates for candidates aged 65-74 years for all 4 waves and during all except the delta wave for candidates aged ≥75 years (Table S5). Deceased-donor kidney transplants and living-donor kidney transplants remained significantly below expected among racial/ethnic minorities, older women, and candidates aged ≥75 years relative to White candidates, older men, and candidates aged 65-74 years, respectively (Tables S2, S4, and S6, respectively).

Deaths and Waitlist Removals

Mortality rates peaked during the winter 2020-2021 wave for all racial/ethnic groups (Table 2). Mortality rates in older men were 56%, 107%, 44%, and 21% higher than expected during the initial, winter 2020-2021, delta, and nonwave periods, respectively, while that in older women was substantially greater than expected only during the initial and winter 2020-2021 waves (Table S3).

The rate of removals increased over time for all racial/ethnic groups and was significantly higher than expected during the omicron wave only for older Black candidates (Table 2). For both older men and women, the rate of waitlist removals, despite increasing over time, were comparable to expected during all waves except the initial wave (Table S3). For candidates aged 65-74 years, the rate of waitlist removals was significantly below expected only during the initial wave (Table S4). Mortality and removals were consistently higher throughout the COVID-19 waves in Black and Hispanic candidates and candidates aged ≥75 years, respectively, compared to White candidates and those aged 65-74 years (Tables S2 and S6, respectively). However, mortality rates were lower in older women compared to older men (Table S4).

Sensitivity Analysis

Trends in waitlist events among younger adults (age 18-64 years) were similar to those observed in older adults (Table S7). However, relative to older adults, registrations, deceased-donor kidney transplants, and living-donor kidney transplants among younger adults were significantly higher, while deaths and removals were significantly lower (Table S8).

DISCUSSION

In this national study of 57,222 older waitlisted candidates, the initial COVID-19 wave between March and May 2020 had a considerable impact on waitlist outcomes: a 34% reduction in registrations, 30% reduction in deceased-donor kidney transplants, 76% reduction in living-donor kidney transplants, 22% reduction in removals, and 49% increase in mortality. There was also a 7% decline in the average daily count of active older candidates during the omicron wave relative to the reference period (calculated using daily counts of active older candidates on the waitlist during each wave). During the winter 2020-2021 and delta waves, there were notable changes in registrations (23% and 22% reduction, respectively), deceased-donor kidney transplants (8% and 19% reduction, respectively), living-donor kidney transplants (40% and 37% reduction, respectively), and waitlist mortality (98% and 54% increase, respectively). During the omicron wave, the rate of registrations and deaths were 19% below and 32% above expected, respectively. In addition, the rate of deceased-donor kidney transplants

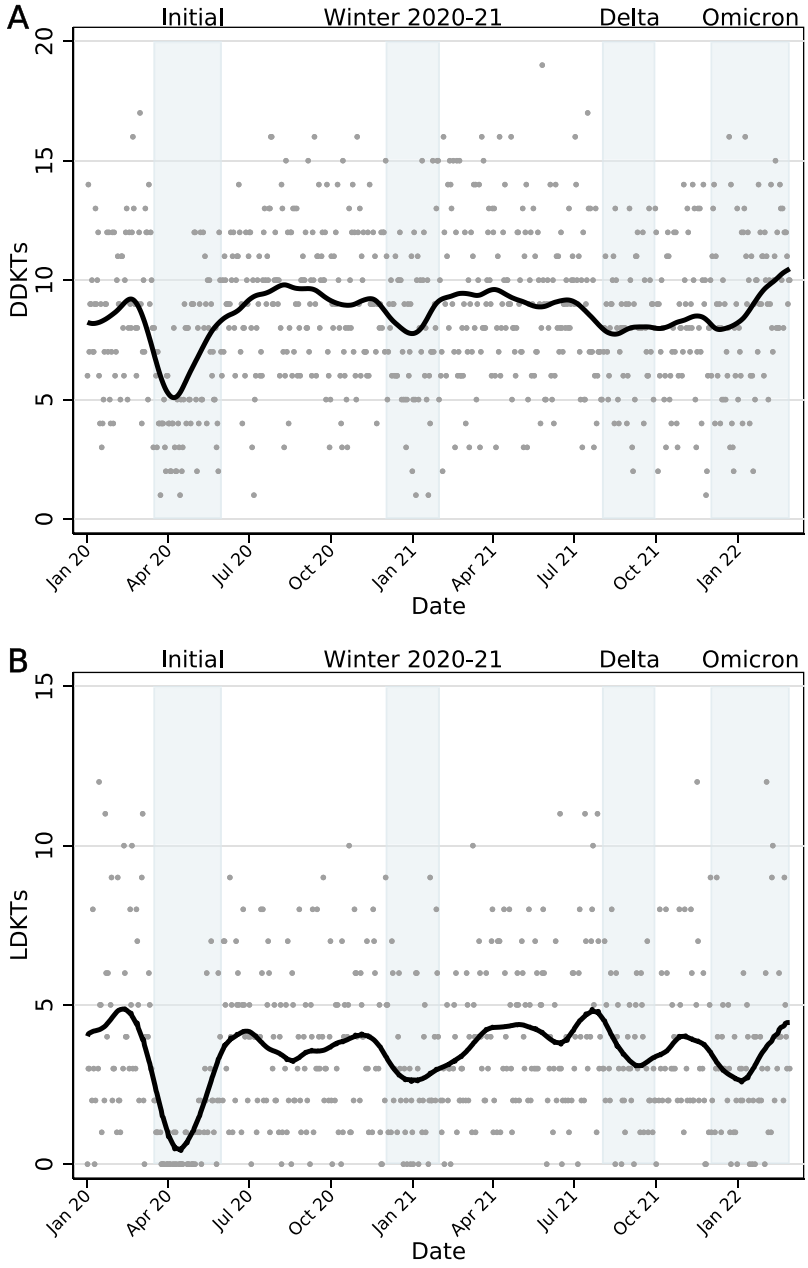

Figure 1. Deceased-donor kidney transplants (DDKTs) (A) and living-donor kidney transplants (LDKTs) (B) among older adults (age ≥ 65 years) from January 2020 to February 2022. Running mean smoother applied to daily counts. Shaded areas depict the 4 COVID-19 waves. Weekends are excluded for living-donor kidney transplants. Source: Scientific Registry of Transplant Recipients, June 2022.

and living-donor kidney transplants were 10% and 43% below expected, respectively, and waitlist removals due to deteriorating condition were 26% above expected. The decline in deceased-donor kidney transplants was most pronounced in older Black candidates, who, along with older men and candidates aged ≥75 years, also experienced higher-than-expected waitlist mortality rates, especially during the winter 2020-2021 wave. Racial/ethnic minority candidates, older women, and candidates aged ≥75 years had lower rates of registrations, deceased-donor kidney transplants, and living-donor kidney transplants. Notably, older Black and Hispanic candidates also experienced higher rates of waitlist mortality and removals over the infection waves relative to their White counterparts;

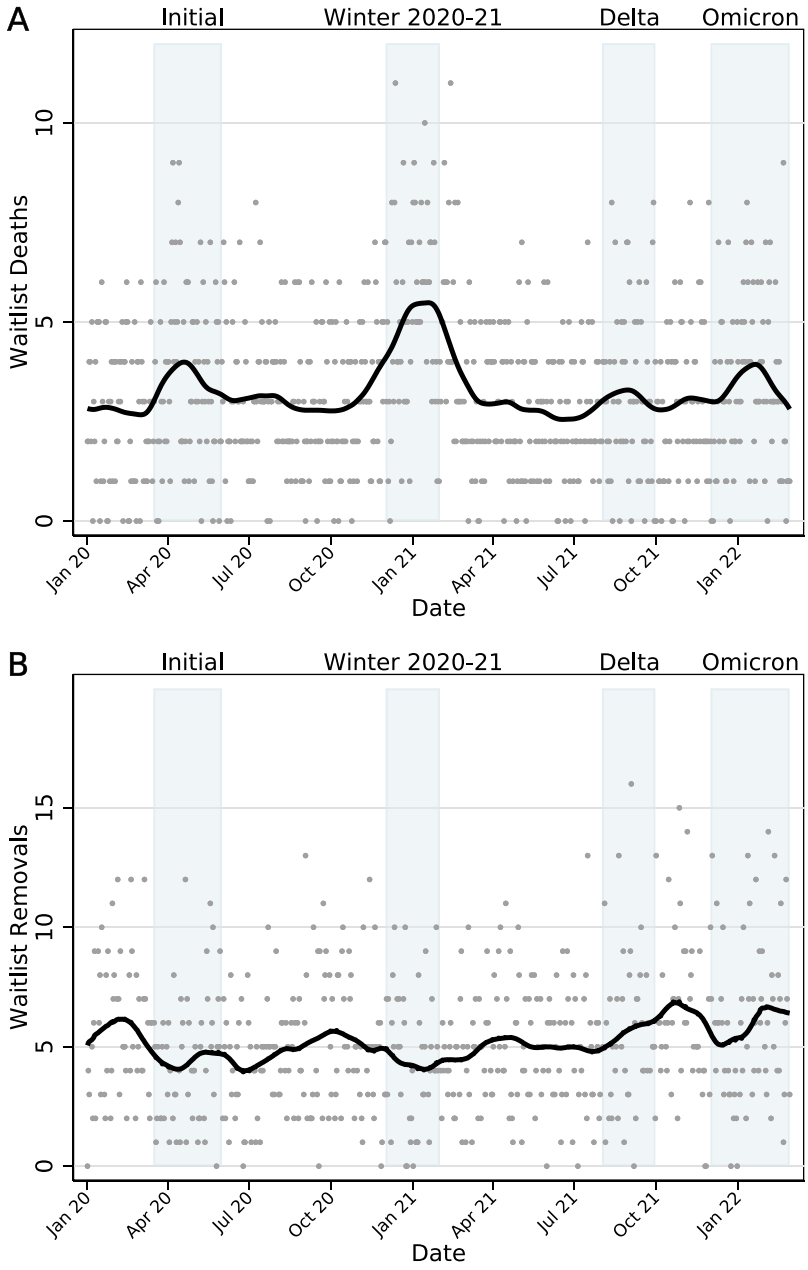

Figure 2. Waitlist deaths (A) and removals (B) among older adults (age ≥ 65 years) from January 2020 to February 2022. Running mean smoother applied to daily counts. Shaded areas depict COVID-19 waves. Weekends were excluded from waitlist removals. Source: Scientific Registry of Transplant Recipients, June 2022.

older women experienced lower rates of mortality and removals than older men.

To the best of our knowledge, this is the first comprehensive analysis of waitlist outcomes in this population using national data, with a comparison of outcomes among younger waitlisted candidates to contextualize the impact of a pandemic. The trends we report are consistent with the literature, particularly from early in the pandemic, and are important in light of the age disparities in access to kidney transplant.[13,17,23-25] There is limited research on the effect of COVID-19 on kidney transplant trends in older candidates, but our findings mirror those from adult candidates. The OPTN/SRTR 2020 Annual Data Report found a decrease in waitlist registrations, active waitlist candidates, kidney transplants, and removals due to deteriorating condition, and an increase in

Table 3. Waitlist Events Among Older (Age ≥ 65 Years) Kidney Transplant Candidates During the COVID-19 Waves (N=57,222)

	Adjusted Incidence Rate Ratio (aIRR)[a]				
COVID-19 wave[b]	Registration[c]	Deceased-donor kidney transplant	Living-donor kidney transplant[c]	Mortality[d]	Removal[c,d]
Initial	$_{0.62}0.66_{0.70}$[e]	$_{0.63}0.70_{0.77}$[e]	$_{0.19}0.24_{0.32}$[e]	$_{1.29}1.49_{1.73}$[e]	$_{0.68}0.78_{0.91}$[e]
Winter 2020-21	$_{0.72}0.77_{0.82}$[e]	$_{0.82}0.92_{1.02}$	$_{0.49}0.60_{0.73}$[e]	$_{1.70}1.98_{2.30}$[e]	$_{0.77}0.91_{1.07}$
Delta	$_{0.73}0.78_{0.84}$[e]	$_{0.72}0.81_{0.90}$[e]	$_{0.51}0.63_{0.77}$[e]	$_{1.28}1.54_{1.85}$[e]	$_{0.97}1.14_{1.34}$
Omicron	$_{0.76}0.81_{0.86}$[e]	$_{0.81}0.90_{0.99}$[e]	$_{0.47}0.57_{0.68}$[e]	$_{1.12}1.32_{1.57}$[e]	$_{1.09}1.26_{1.46}$[e]
Nonwave	$_{0.80}0.82_{0.85}$[e]	$_{0.96}1.02_{1.08}$	$_{0.71}0.78_{0.86}$[e]	$_{1.14}1.26_{1.39}$[e]	$_{0.94}1.02_{1.11}$
***P* value**[f]	<0.001[e]	<0.001[e]	<0.001[e]	<0.001[e]	<0.001[e]

Notes: Registration: incident waitlist registrations; removal: waitlist removals due to deteriorating condition. Source: Scientific Registry of Transplant Recipients, June 2022.
[a]Reference period: January 1, 2016-December 31, 2019.
[b]Initial: March 15, 2020-May 31, 2020, winter 2020-2021: December 1, 2020-January 31, 2021; delta: August 1, 2021-September 30, 2021; omicron: December 1, 2021-February 28, 2022; nonwave: January 1, 2020-March 14, 2020, June 1, 2020-November 30, 2020, February 1, 2021-July 31, 2021, and October 1, 2021-November 30, 2021.
[c]Model excludes weekends.
[d]Poisson models offset by waitlist size.
[e]Measures of association and 95% confidence intervals (CIs) indicate statistically significant at α=0.05.
[f]*P* value for Wald test to determine whether the coefficients during the 4 waves are equal.

waitlist deaths in 2020, in line with our findings.[26] The decline in registrations during the initial wave may reflect the disruption in kidney transplant evaluations during the pandemic, restrictions in transplant center practices, and a shortage of resources.[17] Researchers also noted a decrease in the US adult kidney transplant waitlist size during the pandemic and increasing waitlist removals due to death during the initial and winter 2020-2021 waves.[27] This is consistent with our findings and with early trends reporting a higher mortality rate among adult kidney-only waitlisted candidates.[12,15,28,29]

Another study reported that 11% of the deaths in 2020 in adult waitlisted candidates were attributed to COVID-19, and they were more likely to be male, obese, and belong to racial/ethnic minority groups.[26,28,30,31] This is consistent with our findings of elevated mortality rates among older Black and Hispanic candidates relative to White candidates, which may be in part due to the disproportionate COVID-19-related mortality rates among Black and Hispanic candidates.[32] The pandemic likely exacerbated persistent structural inequalities in health care (and consequently, transplant) access, which in conjunction with differences in socioeconomic status and vaccination uptake, may have contributed to decreased kidney transplant rates and increased mortality observed among racial/ethnic minority candidates relative to White candidates.[33-39] Lower mortality rates among older women relative to older men could be attributed to sex-based immunologic differences, behavioral variations, or a higher burden of comorbidities among men.[40-44] Overall, the reduction in waitlist size for older adults may be due to delays in obtaining appropriate health care due to COVID-19 restrictions, or, on a somber note, elevated mortality among waitlisted candidates.[15,45] COVID-19 exerts a disproportionate burden of disease on older adults, especially those with kidney failure, consistent with our findings of heightened mortality among older adults relative to younger adults.[17,46-48] Furthermore, individuals receiving dialysis are at an elevated risk of SARS-CoV-2 exposure and severe COVID-19-related outcomes due to their frequent visits to health care facilities.[48,49]

Our results also indicated a substantial increase in the rate of waitlist removals of older adults due to deteriorating condition over time, which was not observed in younger waitlisted candidates who had a higher burden of SARS-CoV-2 infections.[50] This discrepancy could be due to the early mortality of older and high-risk adults early in the pandemic, while comparatively healthier individuals were able to survive longer on dialysis despite the COVID-19-related restrictions and guideline changes. Older adults with kidney failure also have comorbidities impacting their health; the effect of delaying vital health care visits compounded with COVID-19 sequelae may have contributed to the increasing rates of removals in this population, consistent with our findings.[51-53] Racial/ethnic minorities may face delayed health care access relative to their White counterparts due structural and societal factors.[54] This, combined with a higher burden of COVID-19 and comorbidities, may have contributed to the observed increase in waitlist removals among older Black and Hispanic candidates. Lastly, the decline in active older candidates throughout the pandemic despite the relatively stable waitlist size may be attributed to a combination of candidate safety concerns, restrictions in transplant center practices, and resource shortages (including testing capacity).[55]

Living-donor kidney transplants drove the decline in transplants among older adults, mirroring the trend among adult kidney transplant recipients, where the lowest rate of living-donor kidney transplants occurred in states with the highest COVID-19 rates early in the pandemic.[17] A registry study noted a substantial decline in kidney transplant in candidates aged ≥50 years relative to younger candidates during the winter 2020-2021 wave.[27] The reduction in living-donor kidney transplants may be due to the risk of SARS-CoV-2 infections, deferrals of elective procedures due to patient concerns, elective case restrictions, disruptions in

Table 4. Waitlist Events During COVID-19 Waves Among Older (Age ≥ 65 Years) Kidney Transplant Candidates, Stratified by Candidate Race/Ethnicity (N=57,222)

		Adjusted Incidence Rate Ratio (aIRR)[a]				
	COVID-19 wave[b]	Registration[c]	Deceased-donor kidney transplant	Living-donor kidney transplant[c]	Mortality[c]	Removal[c,d]
White[e]	Initial	$_{0.58}0.64_{0.69}$[f]	$_{0.63}0.72_{0.84}$[f]	$_{0.20}0.27_{0.36}$[f]	$_{1.13}1.39_{1.72}$[f]	$_{0.63}0.77_{0.94}$[f]
	Winter 2020-2021	$_{0.75}0.81_{0.88}$[f]	$_{0.92}1.07_{1.24}$	$_{0.52}0.65_{0.81}$[f]	$_{1.33}1.65_{2.04}$[f]	$_{0.77}0.97_{1.20}$
	Delta	$_{0.74}0.80_{0.88}$[f]	$_{0.70}0.82_{0.96}$[f]	$_{0.52}0.66_{0.83}$[f]	$_{1.18}1.52_{1.95}$[f]	$_{0.87}1.09_{1.35}$
	Omicron	$_{0.76}0.83_{0.90}$[f]	$_{0.87}1.00_{1.15}$	$_{0.47}0.58_{0.71}$[f]	$_{1.07}1.34_{1.59}$[f]	$_{0.92}1.12_{1.38}$
	Nonwave	$_{0.81}0.84_{0.88}$[f]	$_{0.97}1.05_{1.15}$	$_{0.69}0.78_{0.87}$[f]	$_{1.16}1.32_{1.51}$[f]	$_{0.90}1.01_{1.13}$
Black[e]	Initial	$_{0.55}0.63_{0.72}$[f]	$_{0.57}0.71_{0.88}$[f]	$_{0.13}0.28_{0.63}$[f]	$_{1.49}1.98_{2.62}$[f]	$_{0.60}0.80_{1.07}$
	Winter 2020-2021	$_{0.62}0.71_{0.82}$[f]	$_{0.68}0.85_{1.06}$	$_{0.19}0.41_{0.85}$[f]	$_{1.77}2.39_{3.23}$[f]	$_{0.56}0.78_{1.08}$
	Delta	$_{0.72}0.82_{0.95}$[f]	$_{0.59}0.75_{0.96}$[f]	$_{0.26}0.52_{1.04}$	$_{1.05}1.53_{2.20}$[f]	$_{0.70}0.96_{1.32}$
	Omicron	$_{0.69}0.78_{0.89}$[f]	$_{0.68}0.84_{1.04}$	$_{0.20}0.39_{0.75}$[f]	$_{0.74}1.06_{1.73}$	$_{0.88}1.17_{1.54}$
	Nonwave	$_{0.76}0.82_{0.89}$[f]	$_{0.95}1.07_{1.20}$	$_{0.51}0.71_{0.99}$[f]	$_{0.85}1.06_{1.31}$	$_{0.76}0.90_{1.07}$
Hispanic/Latino	Initial	$_{0.65}0.77_{0.91}$[f]	$_{0.33}0.46_{0.65}$[f]	$_{0.01}0.04_{0.32}$[f]	$_{0.96}1.43_{2.12}$[f]	$_{0.64}0.94_{1.38}$
	Winter 2020-2021	$_{0.50}0.61_{0.75}$[f]	$_{0.53}0.72_{0.98}$[f]	$_{0.20}0.46_{1.05}$	$_{1.54}2.24_{3.28}$[f]	$_{0.47}0.77_{1.26}$
	Delta	$_{0.61}0.74_{0.89}$[f]	$_{0.49}0.85_{1.16}$	$_{0.30}0.61_{1.25}$	$_{0.77}1.26_{2.08}$	$_{0.62}0.99_{1.58}$
	Omicron	$_{0.63}0.76_{0.90}$[f]	$_{0.74}0.66_{0.89}$[f]	$_{0.49}0.90_{1.65}$	$_{0.70}1.10_{1.72}$	$_{0.92}1.37_{2.04}$
	Nonwave	$_{0.70}0.77_{0.85}$[f]	$_{0.74}0.88_{1.04}$	$_{0.64}0.89_{1.26}$	$_{0.79}1.04_{1.38}$	$_{0.99}1.24_{1.57}$
Other[e,g]	Initial	$_{0.59}0.72_{0.87}$[f]	$_{0.61}0.84_{1.15}$	$_{0.04}0.17_{0.70}$[f]	$_{0.56}0.92_{1.51}$	$_{0.33}0.53_{0.92}$[f]
	Winter 2020-2021	$_{0.68}0.82_{1.02}$	$_{0.44}0.64_{0.94}$[f]	$_{0.18}0.43_{1.02}$	$_{0.92}1.50_{2.43}$	$_{0.43}0.75_{1.24}$
	Delta	$_{0.52}0.65_{0.80}$[f]	$_{0.54}0.78_{1.11}$	$_{0.18}0.43_{1.06}$	$_{0.48}0.93_{1.78}$	$_{0.67}1.10_{1.82}$
	Omicron	$_{0.67}0.81_{0.99}$[f]	$_{0.62}0.86_{1.20}$	$_{0.16}0.35_{0.81}$[f]	$_{0.48}0.84_{1.45}$	$_{0.43}0.71_{1.16}$
	Nonwave	$_{0.70}0.78_{0.87}$[f]	$_{0.73}0.89_{1.08}$	$_{0.54}0.81_{1.24}$	$_{0.87}1.18_{1.60}$	$_{0.53}0.71_{0.93}$[f]

Notes: Registration: incident waitlist registrations; removal: waitlist removals due to deteriorating condition. Source: Scientific Registry of Transplant Recipients, June 2022.

[a]Reference period: January 1, 2016-December 31, 2020. Expected event rates were determined for each racial/ethnic group during the reference period.

[b]Initial: March 15, 2020-May 31, 2020; winter 2020-21: December 1, 2020-January 31, 2021; delta: August 1, 2021-September 30, 2021; omicron: December 1, 2021-February 28, 2022, and nonwave: January 1, 2020-March 14, 2020, June 1, 2020-November 30, 2020, February 1, 2021-July 31, 2021, and October 1, 2021-November 30, 2021.

[c]Model excludes weekends.

[d]Poisson models offset by waitlist size.

[e]non-Hispanic.

[f]Measures of association and 95% confidence intervals (CIs) indicate statistically significant at α=0.05.

[g]Asian American, Native Hawaiian and Pacific Islander, American Indian and Alaska Native, and multiracial.

referrals and evaluations, and the diversion of institutional resources to address the burden of COVID-19.[17,24,56-58] Living-donor kidney transplants pose a risk of SARS-CoV-2 infection to recipients and donors, especially those of advanced age and with comorbidities increasing their susceptibility to poor health outcomes.[28,29] Racial/ethnic disparities in living-donor kidney transplant likely worsened during the pandemic, and differential living-donor kidney transplant rates among older women compared to older men require further investigation.[59,60] Over time, increasing knowledge about the nature of SARS-CoV-2 transmission has contributed to the modification of transplant center practices to better align with public health guidelines and ensure the safety of older candidates. Although improvements have been made at the institutional level, the rate of transplants in older adults had not returned to prepandemic levels as of the omicron wave.

A key strength of our study is that it provides a national-level perspective on the impact of COVID-19 on older waitlisted adults, a population that has been understudied in this area of research. While our insights could inform policy and clinical practice, several limitations affect the generalizability of our results. Our study is limited to kidney-only candidates aged ≥65 years, potentially missing the impact on younger candidates with longer waitlist durations. Additionally, our study did not adjust for the impact of geography, which would have affected local guidelines and policies leading to differences in COVID-19 timeline and disease burden, health care access, and utilization. Furthermore, we were unable to characterize removals and deaths caused due to COVID-19, which would provide greater nuance to this analysis. Moreover, relative rates in the comparison of subgroups should be interpreted with caution as they are sensitive to minor variations due to small event counts. Lastly, a limitation of this waitlist event analysis is the absence of an offset for the national dialysis census, as SRTR does not include data on kidney failure populations.

In summary, our study highlights the resiliency of the US national transplant system despite the initial impact of the pandemic. It quickly adapted and continued to provide necessary services to an at-risk group at levels similar to prepandemic times. Despite a near-complete restoration of transplantation services, the gap in care in the initial phase of the pandemic had a deleterious effect on the health of older adults with kidney failure, potentially manifesting as

excess mortality and removals during subsequent COVID-19 waves. With the ending of the public health emergency in May 2023, it may be challenging to determine the prevalence of SARS-COV-2 infections on a broader scale. Nonetheless, continued research into the recognition of disproportionately affected communities during the pandemic is imperative to ensure improved health care outcomes among older adults. Monitoring older adults who experienced higher mortality, removals, and health care deferrals is vital to understanding the long-term effects of COVID-19. Such research will inform operational strategies and guidelines to protect vulnerable populations during future public health emergencies, ensuring the continuity of care, informed decision making, and timely interventions for all demographics.

SUPPLEMENTARY MATERIAL

Supplementary File (PDF)

Figure S1. Daily COVID-19 cases in the United States between January 21, 2020, and March 8, 2022.

Figure S2. Older (age ≥ 65 years) kidney-only transplant waitlist candidates between January 1, 2020 and February 28, 2022.

Figure S3. Older (age ≥ 65 years) kidney-only transplant waitlist candidates between January 1, 2016 and February 28, 2022.

Figure S4. Kidney-only waitlist registrations among older adults (age ≥ 65 years) from January 1, 2020 to February 28, 2022 (N=57,222).

Table S1. Average daily number of COVID-19 cases during the four COVID-19 waves

Table S2. Waitlist events during COVID-19 waves among older (age ≥ 65 years) kidney transplant candidates (N=57,222)

Table S3. Waitlist events during COVID-19 waves among older (age ≥ 65 years) kidney transplant candidates, stratified by candidate sex (N=57,222).

Table S4. Waitlist events during COVID-19 waves among older (age ≥ 65 years) kidney transplant candidates, comparing older women to older men (N=57,222).

Table S5. Waitlist events during COVID-19 waves among older (age ≥ 65 years) kidney transplant candidates, stratified by age groups (N=57,222).

Table S6. Waitlist events during COVID-19 waves among older (age ≥ 65 years) kidney transplant candidates, comparing older to younger candidates (N=57,222).

Table S7. Waitlist events among kidney transplant candidates aged 18-64 years during the COVID-19 waves (N=233,630).

Table S8. Waitlist events during COVID-19 waves among older kidney transplant candidates (age ≥ 65 years) relative to younger kidney transplant candidates (aged 18-64 years).

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REFERENCES

1. 2021 USRDS Annual Data Report: Epidemiology of kidney disease in the United States. United States Renal Data System. Accessed August 12, 2022. https://usrds-adr.niddk.nih.gov/2021
2. McAdams-DeMarco MA, James N, Salter ML, et al. Trends in kidney transplant outcomes in older adults. *J Am Geriatr Soc*. 2014;62(12):2235-2242.
3. Heldal K, Hartmann A, Grootendorst DC, et al. Benefit of kidney transplantation beyond 70 years of age. *Nephrol Dial Transplant*. 2010;25(5):1680-1687.
4. Lønning K, Heldal K, Bernklev T, et al. Improved health-related quality of life in older kidney recipients 1 year after transplantation. *Transplant Direct*. 2018;4(4):e351.
5. Tsarpali V, Midtvedt K, Lønning K, et al. Health-related quality of life in older kidney transplant recipients: a national cohort study of short- and longer-term outcomes. *Kidney Med*. 2021;3(6):974-983.e1.
6. Chu NM, Gross AL, Shaffer AA, et al. Frailty and changes in cognitive function after kidney transplantation. *J Am Soc Nephrol*. 2019;30(2):336.

7. Chu NM, Bae S, Chen X, et al. Delirium, changes in cognitive function, and risk of diagnosed dementia after kidney transplantation. *Am J Transplant*. 2022;22(12):2892-2902.
8. Chu NM, Ruck J, Chen X, et al. Long-term trajectories of frailty and its components after kidney transplantation. *J Gerontol A Biol Sci Med Sci*. 2022;77(12):2474-2481.
9. McAdams-DeMarco MA, Isaacs K, Darko L, et al. Changes in frailty after kidney transplantation. *J Am Geriatr Soc*. 2015;63(10):2152-2157.
10. Liu Y, Bendersky VA, Chen X, et al. Post-kidney transplant body mass index trajectories are associated with graft loss and mortality. *Clin Transplant*. 2023;37(5):e14947.
11. Nimmo A, Gardiner D, Ushiro-Lumb I, et al. The global impact of COVID-19 on solid organ transplantation: two years into a pandemic. *Transplantation*. 2022;106(7):1312-1329.
12. Cholankeril G, Podboy A, Alshuwaykh OS, et al. Early impact of COVID-19 on solid organ transplantation in the United States. *Transplantation*. 2020;104(11):2221-2224.
13. Aubert O, Yoo D, Zielinski D, et al. COVID-19 pandemic and worldwide organ transplantation: a population-based study. *Lancet Public Health*. 2021;6(10):e709-e719.
14. Crépin T, Legendre M, Carron C, et al. Uraemia-induced immune senescence and clinical outcomes in chronic kidney disease patients. *Nephrol Dial Transplant*. 2020;35(4):624-632.
15. Ravanan R, Callaghan CJ, Mumford L, et al. SARS-CoV-2 infection and early mortality of waitlisted and solid organ transplant recipients in England: A national cohort study. *Am J Transplant*. 2020;20(11):3008-3018.
16. Hernández D, Alonso-Titos J, Armas-Padrón AM, et al. Mortality in elderly waiting-list patients versus age-matched kidney transplant recipients: where is the risk? *Kidney Blood Press Res*. 2018;43(1):256-275.
17. 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(11):3131-3139.
18. Leppke S, Leighton T, Zaun D, et al. Scientific registry of transplant recipients: collecting, analyzing, and reporting data on transplantation in the United States. *Transplant Rev (Orlando)*. 2013;27(2):50-56.
19. Massie AB, Kuricka LM, Segev DL. Big Data in Organ Transplantation: Registries and Administrative Claims. *Am J Transplant*. 2014;14(8):1723-1730.
20. Coronavirus (COVID-19) data in the United States. The New York Times. Accessed August 29, 2022. https://github.com/nytimes/covid-19-data
21. Dong E, Du H, Gardner L. An interactive web-based dashboard to track COVID-19 in real time. *Lancet Infect Dis*. 2020;20(5):533-534.
22. Louis TA, Zeger SL. Effective communication of standard errors and confidence intervals. *Biostatistics*. 2008;10(1):1-2.
23. Loupy A, Aubert O, Reese PP, et al. Organ procurement and transplantation during the COVID-19 pandemic. *Lancet*. 2020;395(10237):e95-e96.
24. Lentine KL, Vest LS, Schnitzler MA, et al. Survey of US living kidney donation and transplantation practices in the COVID-19 Era. *Kidney Int Rep*. 2020;5(11):1894-1905.
25. Chen Y, Churilla B, Ahn JB, et al. Age disparities in access to first and repeat kidney transplantation. *Transplantation*. 2023.
26. Lentine KL, Smith JM, Hart A, et al. OPTN/SRTR 2020 annual data report: kidney. *Am J Transplant*. 2022;22(S2):21-136.
27. Miller J, Wey A, Valapour M, et al. Impact of COVID-19 pandemic on the size of US transplant waiting lists. *Clin Transplant*. 2022;36(5):e14596.
28. Mohan S, King KL, Husain SA, et al. COVID-19–associated mortality among kidney transplant recipients and candidates in the United States. *Clin J Am Soc Nephrol*. 2021;16(11):1695.
29. Azzi Y, Bartash R, Scalea J, et al. COVID-19 and solid organ transplantation: a review article. *Transplantation*. 2021;105(1).
30. Schold JD, King KL, Husain SA, et al. COVID-19 mortality among kidney transplant candidates is strongly associated with social determinants of health. *Am J Transplant*. 2021;21(7):2563-2572.
31. Miller J, Wey A, Musgrove D, et al. Mortality among solid organ waitlist candidates during COVID-19 in the United States. *Am J Transplant*. 2021;21(6):2262-2268.
32. Golestaneh L, Neugarten J, Fisher M, et al. The association of race and COVID-19 mortality. *EClinicalmedicine*. 2020;25:100455.
33. Yancy CW. COVID-19 and African Americans. *JAMA*. 2020;323(19):1891-1892.
34. Yanez ND, Weiss NS, Romand JA, et al. COVID-19 mortality risk for older men and women. *BMC Public Health*. 2020;20(1):1742.
35. Tai DBG, Shah A, Doubeni CA, et al. The disproportionate impact of COVID-19 on racial and ethnic minorities in the United States. *Clin Infect Dis*. 2021;72(4):703-706.
36. Rhee TG, Marottoli RA, Van Ness PH, et al. Impact of perceived racism on healthcare access among older minority adults. *Am J Prev Med*. 2019;56(4):580-585.
37. Murphy KA, Jackson JW, Purnell TS, et al. Association of socioeconomic status and comorbidities with racial disparities during kidney tansplant evaluation. *Clinical Clin J Am Soc Nephrol*. 2020;15(6):843-851.
38. Williams DR. Race, socioeconomic status, and health: the added effects of racism and discrimination. *Ann N Y Acad Sci*. 1999;896(1):173-188.
39. Njoku A, Joseph M, Felix R. Changing the narrative: structural barriers and racial and ethnic inequities in COVID-19 vaccination. *Int J Environ Res Public Health*. 2021;18(18):9904.
40. Oudit GY, Pfeffer MA. Plasma angiotensin-converting enzyme 2: novel biomarker in heart failure with implications for COVID-19. *Eur Heart J*. 2020;41(19):1818-1820.
41. Barber SJ, Kim H. COVID-19 worries and behavior changes in older and younger men and women. *J Gerontol B Psychol Sci Soc Sci*. 2021;76(2):e17-e23.
42. Griffith DM, Sharma G, Holliday CS, et al. Men and COVID-19: A Biopsychosocial Approach to Understanding Sex Differences in Mortality and Recommendations for Practice and Policy Interventions. *Prev Chronic Dis*. 2020;17:E63.
43. Nguyen NT, Chinn J, De Ferrante M, et al. Male gender is a predictor of higher mortality in hospitalized adults with COVID-19. *PLOS ONE*. 2021;16(7):e0254066.
44. Klang E, Soffer S, Nadkarni G, et al. Sex differences in age and comorbidities for COVID-19 mortality in urban New York City. *SN Compr Clin Med*. 2020;2(9):1319-1322.
45. Hilbrands LB, Duivenvoorden R, Vart P, et al. COVID-19-related mortality in kidney transplant and dialysis patients: results of the ERACODA collaboration. *Nephrol Dial Transplantation*. 2020;35(11):1973-1983.
46. Arregocés-Castillo L, Fernández-Niño J, Rojas-Botero M, et al. Effectiveness of COVID-19 vaccines in older adults in Colombia: a retrospective, population-based study of the ESPERANZA cohort. *Lancet Healthy Longev*. 2022;3(4):e242-e252.
47. Mueller AL, McNamara MS, Sinclair DA. Why does COVID-19 disproportionately affect older people? *Aging*. 2020;12(10):9959-9981.
48. Salerno S, Messana JM, Gremel GW, et al. COVID-19 risk factors and mortality outcomes among Medicare patients

receiving long-term dialysis. *JAMA Netw Open*. 2021;4(11):e2135379-e2135379.
49. Kaballo MA, Canney M, O'Kelly P, et al. A comparative analysis of survival of patients on dialysis and after kidney transplantation. *Clinical Kidney Journal*. 2018;11(3):389-393.
50. Estimated COVID-19 burden. Centers for Disease Control and Prevention. Accessed August 12, 2022. https://www.cdc.gov/coronavirus/2019-ncov/cases-updates/burden.html
51. Pérez Fernández M, Martínez Miguel P, Ying H, et al. Comorbidity, Frailty, and Waitlist Mortality among Kidney Transplant Candidates of All Ages. *Am J Nephrol*. 2019;49(2):103-110.
52. Cohen K, Ren S, Heath K, et al. Risk of persistent and new clinical sequelae among adults aged 65 years and older during the post-acute phase of SARS-CoV-2 infection: retrospective cohort study. *BMJ*. 2022;376:e068414.
53. Zhong S, Huisingh-Scheetz M, Huang ES. Delayed medical care and its perceived health impact among US older adults during the COVID-19 pandemic. *J Am Geriatr Soc*. 2022;70(6):1620-1628.
54. Ahmed A, Song Y, Wadhera RK. Racial/ethnic disparities in delaying or not receiving medical care during the COVID-19 pandemic. *J Gen Intern Med*. 2022;37(5):1341-1343.
55. Contributors to the Ca. C4 article: Implications of COVID-19 in transplantation. *Am J Transplant*. 2021;21(5):1801-1815. doi:10.1111/ajt.16346
56. 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*. 2021;21(4):1576-1585.
57. Perez A, Retzloff S, Browne T, et al. Dialysis staff-reported impact of COVID-19 on early kidney transplant steps. *Kidney Internat Rep*. 2022;7(4):904-907.
58. Emanuel EJ, Persad G, Upshur R, et al. Fair allocation of scarce medical resources in the time of Covid-19. *N Engl J Med*. 2020;382(21):2049-2055.
59. Singh N, Li R, Alhamad T, et al. Exacerbation of racial disparities in living donor kidney transplantation during the COVID-19 pandemic. *Kidney360*. 2022;3(6).
60. Purnell TS, Luo X, Cooper LA, et al. Association of race and ethnicity with live donor kidney transplantation in the United States from 1995 to 2014. *JAMA*. 2018;319(1):49-61.