# Equity in Policy and Care Delivery for People with Kidney Disease

By: Rebecca Thorsness

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This dissertation by Rebecca Thorsness is accepted in its present form by the Department of Health Services, Policy and Practice as satisfying the dissertation requirement for the degree of Doctor of Philosophy.

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Kim D, Lee Y, **Thorsness R**, Nguyen KH, Swaminathan S, Rivera-Hernandez M, Trivedi AN. Racial and Ethnic Disparities in Excess Deaths among Persons with Kidney Failure During the COVID-19 Pandemic, March-July 2020. American Journal of Kidney Diseases. 2021; 77(5): 827-829. doi.org/10.1053/j.ajkd.2021.02.003

Rivera-Hernandez M, Swaminathan S, **Thorsness R**, Lee Y, Mehrotra R, Sommers BD, Trivedi AN. Trends in Mortality Among Patients Initiating Maintenance Dialysis in Puerto Rico Compared to US States, 2006-2015. American Journal of Kidney Disease. 2020; 75(2): 296-298. doi.org/10.1053/j.ajkd.2019.08.006

Swaminathan S, Sommers BD, **Thorsness R**, Mehrotra R, Lee Y, Trivedi AN. Association of Medicaid Expansion With 1-Year Mortality Among Patients With End-Stage Renal Disease. Journal of the American Medical Association (JAMA). 2018; 320(21): 2242–2250. doi.org/10.1001/jama.2018.16504

### Invited Editorials

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**Thorsness R**, Swaminathan S, Lee Y, Sommers BD, Mehrotra R, Nguyen KH, Kim D, Rivera-Hernandez M, Trivedi AN. *Effect of Medicaid Expansion on the Incidence of Kidney Failure among Nonelderly Adults*. AcademyHealth National Health Policy Conference, February 2020, Washington, DC.

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**Thorsness R**, Swaminathan S, Lee Y, Sommers BD, Mehrotra R, Nguyen KH, Kim D, Rivera-Hernandez M, Trivedi AN. *Effect of Medicaid Expansion on the Incidence of Kidney Failure among Nonelderly Adults*. Podium Presentation, Association for Public Policy Analysis & Management Fall Research Conference, November 2019, Denver, CO. *(presented by KH Nguyen)*

Swaminathan S, Sommers BD, **Thorsness R**, Mehrotra R, Lee Y, Trivedi AN. *Effects of Medicaid Expansion on Coverage, Access to Care and Mortality Among Persons with End Stage Renal Disease*. AcademyHealth Annual Research Meeting, June 2018, Seattle, WA.

### Poster Presentations

1. Baranwal N, **Thorsness R**, Swaminathan S, Patzer R, Mehrotra R, Trivedi AN. Racial and Ethnic Disparities in Preemptive Kidney Transplantation Among Incident Kidney Failure Adult Patients from 2006 to 2019. American Society of Nephrology Kidney Week, October 2020, online.

**Thorsness R**, Lee Y, Trivedi AN. Dialysis Facility Quality and Insurance Payer Mix. AcademyHealth Annual Research Meeting, June 2019, Washington, DC.

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## TEACHING EXPERIENCE

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2019 Teaching Assistant, "Health Care in the United States," Brown University School of Public Health (Course Instructor: Dr. Ira B. Wilson)
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2018 Teaching Fellow, "Measuring and Improving the Quality of Health Care," Brown University School of Public Health (Course Instructor: Dr. Amal N. Trivedi)
*Lectured and led discussion on "Public Reporting, Quality Improvement, and Patient Choice," supported 20 MPH and PhD students*

2018 Teaching Assistant, "The U.S. Health Care System: Case Studies in Financing, Delivery, Regulation, & Public Health," Brown University School of Public Health (Course Instructor: Christopher Koller)
*Lectured on "Health Care Costs" and "Rural Health," supported 35 MPH and PhD students*

2017-2021 Writing Associate, Brown University Writing Center
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2013 Teaching Assistant, "Healthcare Reform: Organizing, Financing, and Delivering Care for Low Income Americans," Princeton University School of Public and International Affairs (Course Instructors: Dr. Stephen Somers & James Verdier)
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My fellow students have been my biggest cheerleaders and supporters, role models for the type of human and scholar I aspire to be, and mentors and teachers for skills I needed to develop. My cohort of Lacey Loomer and David Meyers provided me with life-long friends who remain so generous with their time and knowledge. I owe Cyrus Kosar a great debt for teaching me how to write accurate, concise, and replicable code, and for always making time to provide honest and actionable feedback. Kevin Nguyen battled through a pandemic dissertation and

REMIS data with me, and I would not have completed this dissertation without him alongside me every step of the way. And Margot Schwartz will forever be my co-conspirator in my personal and professional quest to improve the US health care system. But I am lucky to call every student in the department a friend and colleague, and have benefitted tremendously from their ideas, questions, and advocacy. While I graduate with efforts to improve the graduate student experience in the department and University ongoing, I know that my fellow students will continue to envision and enact revolutionary change, with Kathryn Thompson leading the charge.

And finally, I must thank my family and friends for their unconditional support and belief in me. This dissertation is as much theirs as it is mine. Graduate school can be an isolating experience, and a global infectious disease pandemic only amplifies that. I'm so lucky to have family and friends who prevented that isolation, who understood the paradox of having nearly unlimited schedule flexibility but a workload (or rather, guilt about a perceived workload) that was eager to seep into any and all time accessible to it. Thank you to all of you for acknowledging that graduate school is work, and important work, but not work that should deny me a fulfilling life outside of it.

My professional interest in how people with chronic disease and disability navigate the health care system grew from a personal one, and I am so appreciative of my parents for teaching me how to operate within the system without being overwhelmed by it. I recognize my privilege in my ability to coexist as both a patient within the system and as a research studying it, and strive for my work to always center and learn from those who do not have the same opportunity.

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## INTRODUCTION

Chronic kidney disease (CKD), which affects 15% of US adults and one third of individuals over the age of 65, is a severe chronic condition with high morbidity, mortality, and health system spending.[1] Annually, nearly 125,000 individuals develop kidney failure, which requires treatment with dialysis or kidney transplantation for survival, and over 725,000 Americans are living with kidney failure.[1] The one-year mortality rate after dialysis initiation exceeds 50% for older adults,[2] and on average kidney failure accounts for nearly 20 life-years lost.[3] Medicare fee-for-service spending on enrollees with kidney failure, which, like advanced age and disability, is a reason for entitlement to the program, was over $35 billion in 2016, and annual per-person costs for hemodialysis patients approached $100,000.[1]

In recognition of this large burden of disease, the Centers for Medicare & Medicaid Services (CMS) has implemented a number of quality improvement and cost containment initiatives for dialysis care, namely a prospective bundled payment system for dialysis services paid by Medicare established in 2011, the End-Stage Renal Disease (ESRD) Quality Incentive Program (QIP) beginning in 2012, the 5-star rating introduced in 2015, and the ESRD Treatment Choices (ETC) in 2021. However, wide variation in dialysis facility quality remains,[4–6] as measured by kidney transplant referral and waitlisting,[7–9] hospitalization rates,[10,11] and patient mortality.[12,13]

Despite these initiatives, large racial and socioeconomic disparities persist in kidney failure incidence, access to care, and outcomes.[1,7,14–21] These disparities may be exacerbated if quality reporting and improvement initiatives result in greater benefits for white or higher-income patients, as has been observed with the star rating system for nursing homes,[22] or if facilities that serve more vulnerable patients are disproportionately penalized. A number of

studies have found dialysis facilities in low-income and majority Black neighborhoods are lower quality and more likely to be penalized than those in higher-income and non-majority Black neighborhoods.[5,15,23–27] However, prior work using patient residential ZIP codes found that in urban areas, African American patients lived closer to their nearest high-quality facility than white patients did, but were still less likely to dialyze at high-quality facilities.[28] This suggests that non-geographic barriers to high quality hemodialysis are responsible at least in part for disparities in access, quality, and outcomes.

While racial/ethnic disparities in kidney disease have been well documented, the COVID-19 pandemic further exposed many existing inequities, including among people with CKD and kidney failure. Studies have consistently found CKD, which is more prevalent among racial and ethnic minority populations, to be a risk factor for hospitalization and mortality among people with COVID-19.[29–36] The kidney failure population in the United States experienced significantly higher mortality than expected, with excess deaths concentrated among Black and Hispanic patients.[29–32]

This dissertation focuses on some of the inequities people with kidney disease – and especially racial and ethnic minority patients – face as they navigate the U.S. health care system. The first chapter investigates the role of modifiable health system factors, including insurance coverage type and receipt of pre-dialysis nephrology care, and geographic and neighborhood factors that influence the large racial/ethnic disparities in receiving hemodialysis at a high-quality dialysis facility. The second chapter explores how dialysis facilities that serve patients with high social risk, such as exposure to racism and poverty, may perform in the randomized ETC alternative payment model that launched in 2021. And driven by the impact of the COVID-19 pandemic on vulnerable populations, the third chapter focuses on nursing home residents who

were infected with SARS-CoV-2, the virus that causes COVID-19, and examines the association between CKD stage and mortality following SARS-CoV-2 infection. Taken together, these chapters demonstrate how institutionalized and systemic racism operate both at the person level and at the neighborhood level to create and sustain racial/ethnic disparities in kidney disease care and outcomes.

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32. Weinhandl ED, Gilbertson DT, Wetmore JB, Johansen KL. COVID-19−Associated Decline in the Size of the End-Stage Kidney Disease Population in the United States. *Kidney International Reports*. 2021;0(0). doi:10.1016/j.ekir.2021.07.019

# CHAPTER 1: MEDIATORS OF RACIAL/ETHNIC DISPARITIES IN HIGH-QUALITY DIALYSIS FACILITY SELECTION

## Introduction

Kidney failure is a severe chronic condition with high morbidity, mortality, and health care spending. Significant racial/ethnic disparities exist in incidence, access to and quality of care, and outcomes of kidney failure.[1–5] There is wide variation in the quality of dialysis facilities, and Black patients in particular are less likely to be treated at high-quality dialysis facilities than their White counterparts.[6–9] The Centers for Medicare & Medicaid Services (CMS) has implemented a number of initiatives to improve the quality of care in dialysis facilities, namely the End-Stage Renal Disease (ESRD) Quality Incentive Program (QIP) beginning in 2012, the 5-star rating introduced in 2015, and the ESRD Treatment Choices Model (ETC) in 2021.

Despite these initiatives, racial/ethnic disparities have persisted. Dialysis facilities located in neighborhoods with larger proportions of Black residents have, on average, lower quality, higher hospitalization and mortality rates, and are more likely to receive QIP payment penalties.[6,10–16] However, in urban areas, Black patients lived closer to their nearest high-quality facility than White patients, but were still less likely to dialyze at high-quality facilities.[8] This suggests that non-geographic barriers to high quality hemodialysis may play a role in selecting high-quality facilities.

Identifying the mechanisms by which institutionalized and structural racism creates racial/ethnic disparities in access to high-quality dialysis facilities can help policymakers and health care providers develop targeted interventions to address these factors. Broad quality improvement efforts have the potential to exacerbate disparities if improvements do not reach

facilities that serve low-income and minority patients or if strategies disproportionately penalize facilities that serve vulnerable patients. This study sought to identify mediators of racial/ethnic disparities in use of high-quality dialysis facilities. We hypothesized that insurance coverage type, access to pre-dialysis nephrology care, and neighborhood characteristics would mediate a large portion of the disparity in high-quality dialysis facility selection.

## Methods

### Study Design and Data Sources

We used a cross-sectional study design to identify patient- and neighborhood-level factors associated with initiating dialysis at a high-quality facility, and assess the extent to which these factors served as mediators for the racial disparity in use of high-quality dialysis facilities. The study period spanned from January 2017 through December 2019. The Renal Management Information System (REMIS) includes the End-Stage Renal Disease Medical Evidence Form (CMS 2728), which we used to identify individuals initiating treatment for kidney failure. Completion of the CMS 2728 form is required for all incident kidney failure patients initiating treatment at a Medicare-certified facility, regardless of insurance coverage type or treatment modality, and collects demographic and clinical information. We obtained information on dialysis facilities from Medicare's Dialysis Facility Compare (DFC) datasets for our study years Brown University's Institutional Review Board approved the study and waived the requirement for informed consent.

**Study Population**

We identified all adults (age 18 and older) with incident kidney failure who initiated in-center hemodialysis at a Medicare-certified dialysis facility in the 50 states and District of Columbia during the study period. We excluded people who did not initiate dialysis at a Medicare-certified facility in the Dialysis Facility Compare datasets, as well as those with Veterans Administration (VA) health insurance coverage, as they also have access to dialysis facilities in the VA system. We also excluded individuals whose selected dialysis facility was not proximate to the mailing address they reported on the CMS 2728 form (Supplemental Appendix).

**Exposure**

The main exposure of interest was race/ethnicity, which we conceptualized as a social rather than biologic construct that served as a proxy for exposure to structural and/or interpersonal racism. Patient race and ethnicity was obtained from the CMS 2728 form, which is completed by the dialysis facility's attending physician, head nurse, or social worker for each patient, with instructions for providers to obtain the patient's self-reported ethnicity and race.

We categorized patient race/ethnicity as non-Hispanic White, non-Hispanic Black, or Hispanic, and restricted our analyses to these three groups given relatively small sample sizes of individuals of other races. The CMS 2728 form reports race and ethnicity separately; over 96% of Hispanic individuals in our study population reported their race as White, and survey data suggests many Hispanic individuals consider their ethnicity to be their race.[17,18] We therefore collapsed race and ethnicity into a single category for this analysis.

**Outcome**

The outcome of interest was whether the dialysis facility at which an individual initiated treatment was a high-quality facility in the calendar year during which they initiated dialysis. We used the DFC Five Star rating reports and defined high-quality facilities as those with a four or five star rating. All other facilities, whether they received three or fewer stars or were unrated, were defined as low-quality facilities. We used the DFC reports from October of each year to assign each facility as high- or low-quality for each calendar year.

**Covariates**

We included a number of person- and area-level covariates to identify potential mediators of the relationship between exposure to racism and initiating dialysis at a high-quality facility.

Person-level clinical covariates were age and sex. Person-level covariates that served as measures of access to care were insurance coverage type at dialysis initiation (Medicare, Medicaid, dually eligible for Medicare & Medicaid, employer group, other insurance type, or uninsured), whether they received nephrology care prior to dialysis initiation, and type of vascular access at dialysis initiation (catheter only, arteriovenous fistula [AVF] or graft [AVG], maturing AVF/AVG, or other).

Person-level measures of proximity to high-quality dialysis facilities were calculated using the geocoded mailing address of each individual, which is reported on the CMS 2728 form. We geocoded patient and dialysis facility addresses using ArcGIS World Geocoder (version 10.5.1). We then calculated several measures of access: the differential distance between the nearest high-quality and nearest low-quality dialysis facility for each person and the differential distances between each person's closest dialysis facility and the nearest facility of each star

rating. We capped the maximum distance to the nearest facility of each star rating at 400 miles (Supplemental Appendix). We calculated Euclidian straight-line distances between patients' mailing addresses and dialysis facilities to approximate travel distances.

We geolocated individuals in census tracts to obtain area-level measures of the percent of residents who were Black, who were Hispanic, and who lived in a household with income below the poverty line, using the 2019 American Community Survey (ACS) 5-year estimates. We also geolocated individuals in census block groups to determine neighborhood deprivation using the 2019 Area Deprivation Index (ADI).[19,20] We used the 2013 U.S. Department of Agriculture Economic Research Service's Rural-Urban Continuum Codes to classify counties as metropolitan, non-metropolitan, or rural.[21] For people living in areas missing ADI or ACS information, we used the race/ethnicity group mean value.

Finally, because the distribution of DFC Five Star ratings shifted during the study period, we included the year in which an individual initiated dialysis as a covariate in all models.[22]

**Statistical Analyses**

We used multivariable linear probability models with robust standard errors clustered at the hospital service area level to examine the association between exposure to racism and selecting a high-quality dialysis facility. To identify potential mediators, we added covariates in a stepwise manner. We included only year of dialysis initiation in our unadjusted model, to account for a secular increase in dialysis facility star rating over the study period. We added person-level clinical characteristics, person-level access to care measures, measures of proximity to high-quality dialysis facilities, neighborhood characteristics, and census tract fixed effects in subsequent models.

To quantify the association of potential mediators with selecting a high-quality dialysis facility, we used a multivariable linear probability model that included all covariates. We stratified analyses by race/ethnicity to assess whether mediators operated similarly for all racial/ethnic groups.

All analyses were performed in Stata version 17 (StataCorp) and used two-tailed hypothesis testing with a significance threshold of $p < 0.05$.

### Sensitivity Analyses

To test the robustness of our findings, we conducted several sensitivity analyses. First, we altered our definition of high-quality facility to include only facilities with a five-star rating, and considered all other facilities (one though four stars and unrated) to be low quality. Second, we stratified our analyses by geographic region, using the four Census regions. Third, we stratified our analyses by the degree of dialysis market saturation. To measure market saturation, we calculated the number of facilities that were within 14.5 miles of each patient, which is the 90$^{th}$ percentile of the distance to each patient's chosen dialysis facility. We then divided the number of facilities in that radius into quartiles to classify patients as residing in areas with low, medium low, medium high, or high dialysis market saturation.

## Results

### Characteristics of the Study Population

During the study period, 291,780 individuals initiated in-center hemodialysis and met inclusion criteria; 55.2% of patients were non-Hispanic White, 28.1% were non-Hispanic Black, and 16.7% were Hispanic (Table 1-1). Overall, 49.1% of non-Hispanic White patients selected a

high-quality dialysis facility, while 37.1% of non-Hispanic Black patients and 47.5% of Hispanic patients did so. Non-Hispanic White patients were more likely to have received pre-dialysis nephrology care (69.4% vs. 60.7% of non-Hispanic Black patients and 56.6% of Hispanic patients), and less likely to initiate dialysis with only a catheter, rather than a present or maturing AVF/AVG.

Non-Hispanic Black patients generally lived closer to both their chosen dialysis facility and their nearest facility than non-Hispanic White patients, but were less likely to have their nearest dialysis facility be high-quality (36.5% vs. 48.5%). The median non-Hispanic Black and Hispanic patient selected their third-closest dialysis facility, while the median non-Hispanic White patient selected their second-closest option. Non-Hispanic Black and Hispanic patients lived in areas with higher degrees of saturation of dialysis facilities; non-Hispanic Black patients had a median of 22 proximate facilities and Hispanic patients had 23, while non-Hispanic White patients had only 7.

**Mediators of Selecting High-Quality Dialysis Facilities**

In multivariable models, several factors were strongly associated with selecting, or with not selecting, a high-quality dialysis facility (Table 1-2). Compared to having only Medicare coverage at dialysis initiation, people with employer group insurance were 1.23 percentage points (95% CI: 0.49 to 1.98) more likely to select a high-quality facility, while those with "other" insurance (likely primarily individual market policies) were 1.45 percentage points (95% CI: -2.75 to -0.16) less likely to.

Patients were 0.91 percentage points (95% CI: -1.02 to -0.80) less likely to select a high-quality facility for each additional mile of travel to their nearest high-quality facility, relative to

their nearest low-quality facility (Table 1-2). And residents of census tracts with larger proportions of Black residents were less likely to select high-quality facilities; for every 10 percentage point increase in the proportion of their neighborhood's residents who were Black, dialysis patients were 1.79 percentage points (95% CI: -2.17 to -1.42) less likely to select a high-quality facility. The direction and magnitude of potential mediators was generally similar for each racial/ethnic group.

Figure 1-1 displays patterns of high-quality dialysis facility selection by patient proximity and neighborhood characteristics; Panel A shows how differential distance to the nearest high-quality facility is associated with selection, and Panel B displays the neighborhood decile of share of Black residents. If these factors explained the entirety of the racial/ethnic disparity, we would expect the lines to overlap. Instead, non-Hispanic Black patients selected high-quality dialysis facilities at lower rates than non-Hispanic White patients, even when their neighborhood had a similar share of Black residents, or the additional travel distance to the nearest high-quality facility was identical.

**Racial Disparities in High-Quality Dialysis Facility Selection**

In unadjusted models, non-Hispanic Black patients were 12.14 percentage points (95% CI: -14.09 to -10.19) less likely to select high-quality dialysis facilities than non-Hispanic White patients, and Hispanic patients were 1.84 percentage points (95% CI: -5.26 to 1.57) less likely to do so, though the difference was not statistically significant (Figure 1-2, Table S1-1). In stepwise models, adjusting for clinical and access to care measures left the Black-White and Hispanic-White disparities virtually unchanged. Adding measures of proximity to high-quality dialysis facilities, relative to other nearby facilities, attenuated the Black-White disparity to 8.20

percentage points (95% CI: -9.77 to -6.63), and adding neighborhood characteristics and census tract fixed effects further attenuated the disparity to 1.08 percentage points (95% CI: -1.85 to -0.32). The Hispanic-White disparity remained relatively stable throughout stepwise adjustments.

### Sensitivity Analyses

The magnitude of Black-White disparity in high-quality facility selection was slightly smaller when we classified only five-star facilities as high-quality facilities, but the relative mediation through stepwise adjustments was similar to the main analysis (Figure S1-2). When we stratified the analysis by census region, the Black-White disparity was smallest in the South and largest in the Midwest, and attenuated through stepwise adjustment as in the main analysis (Figure S1-3). The Hispanic-White disparity was larger in the Western United States, and attenuated through stepwise adjustment.

Non-Hispanic Black and Hispanic patients were more likely than non-Hispanic patients to live in areas with a high degree of dialysis market saturation (Table 1-1). However, in analyses stratified by degree of market saturation, Black-White disparities in high-quality facility selection were largest in high saturation areas. While the disparity attenuated with stepwise adjustment in high saturation areas, it did so to a lesser degree than in lower-saturation areas, where full adjustment eliminated racial/ethnic disparities.

## Discussion

In this national study of all White, Black, and Hispanic adults who initiated long-term in-center hemodialysis, we observed large racial disparities in selecting a high-quality dialysis facility that were attenuated by person-, proximity- and neighborhood-level factors. Non-

Hispanic Black and Hispanic patients lived, on average, closer to both low- and high-quality dialysis facilities than White patients, but including measures of facility proximity did not fully mitigate the disparity in high-quality facility selection. Neighborhood characteristics – and in particular, the share of a neighborhood's residents who were Black – played a large role in mediating the Black-White disparity for non-Hispanic Black patients, but did not fully eliminate it.

These findings build on other studies that have found Black hemodialysis patients have similar geographic proximity to high-quality facilities as White patients, but dialysis facilities in neighborhoods with large proportions of Black residents, and facilities with larger shares of Black patients, are generally lower-quality and perform worse in Medicare's ESRD quality incentive program (QIP).[6–8,10,11,14–16] As a result of institutionalized and systemic racism, minoritized individuals – and Black people in particular – have higher rates of kidney disease and kidney failure, less access to pre-dialysis nephrology care and dialysis preparation, delayed transplant waitlist eligibility and waitlisting rates, and lower kidney transplant rates.[2–4,23–32] Residential segregation, arising from a legacy of redlining and neighborhood disinvestment, means these outcomes operate not only at the person level but also at the neighborhood level, wherein the racial composition of a patient's neighborhood influences the quality of their kidney disease care.[6,11–16,33,34]

Disentangling a dialysis facility's inherent quality of care from the characteristics of its patients, and their neighborhoods, is difficult, and the QIP measures and star rating systems may be unable to do so. Some studies suggest that minority-serving facilities perform well on or can improve measures of care processes that are under control of the dialysis facility, such as dialysis adequacy, but struggle on outcome measures such as mortality rates.[10,35] Others find that

facilities in neighborhoods with predominantly Black populations have poorer outcomes for all patients they serve, not just Black patients.[15]

In an effort to improve health equity for people with kidney failure, CMS is considering stratifying quality measures by dual-eligibility status and race/ethnicity, and developing a facility equity score.[36] Addressing within-facility inequities is important, but this may not address underlying issues of sorting non-Hispanic Black patients to lower-quality facilities, and may even exacerbate disparities, as has been documented for nursing homes.[37] Instead, payment policies that enable and encourage dialysis facilities to actively address the social conditions of the patients and communities they serve may be more effective in improving health equity.[38]

This study has a number of limitations. Foremost, we are unable to observe all factors that may impact facility selection, such as facility capacity to accept new patients, insurance networks, provider referral patterns, and patient preferences. Second, we focused on incident in-center hemodialysis patients, and assigned them to the facility at which they initiated dialysis. Patients could subsequently change insurance type (which may affect provider networks), dialysis facility, or treatment modality, though modality switches are relatively uncommon post-initiation.[39] Third, our dichotomized high-quality outcome measure relied on the DFC star rating system, which may not be an accurate measure of quality.[40] However, it is widely available to patients and providers and presented as a measure of facility quality. Fourth, we used straight-line distances as a proxy for travel distances, but were able to calculate distances for each patient, rather than relying on neighborhood centroids. Fifth, we restricted our analyses to non-Hispanic White, non-Hispanic Black, and Hispanic patients. In doing so, we did not examine within-group heterogeneity or intersectionality,[41–45] or the experiences of individuals from other racial/ethnic groups.

Facility characteristics, such as the racial/ethnic composition of prevalent patients, may be important factors in facility selection. There is evidence of race-based sorting in nursing home selection,[46] and the same may be true for dialysis facilities. Future work should explore the role of facility characteristics as mediators of the racial disparity in high-quality dialysis facility selection. Qualitative work to elucidate the priorities and assumptions of patients and providers and the role of each party in facility selection is also critical.

In conclusion, we observed large disparities in the use of high-quality dialysis facilities among non-Hispanic Black, and to a lesser degree Hispanic, patients, compared to non-Hispanic White patients. Among Black patients, these disparities were only partially mediated by factors associated with selecting a high-quality dialysis facility; primarily by relative proximity to high-quality facilities and neighborhood proportion of residents who were Black. This study provides further evidence for the need to address geographic and neighborhood factors as structural drivers of health inequities for people with kidney failure.

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## Tables and Figures

### Table 1-1. Characteristics of the Study Population

| | Total | Non-Hispanic White | Non-Hispanic Black | Hispanic |
|---|---|---|---|---|
| **N** | 291780 | 160970 | 82029 | 48781 |
| **Selected High-Quality Facility** | 45.5% | 49.1% | 37.1% | 47.5% |
| **Age, mean (SD)** | 63.73 (14.50) | 66.63 (13.65) | 60.43 (14.63) | 59.72 (14.83) |
| **Female** | 42.2% | 40.2% | 47.1% | 40.4% |
| **Insurance Coverage Type** | | | | |
| Dual | 13.3% | 10.6% | 16.1% | 17.7% |
| Medicare | 50.7% | 61.7% | 42.1% | 28.5% |
| Medicaid | 15.0% | 9.6% | 18.7% | 26.3% |
| Employer Group | 10.2% | 9.8% | 11.7% | 9.3% |
| Other | 5.5% | 5.1% | 5.3% | 7.3% |
| Uninsured | 5.3% | 3.1% | 6.2% | 10.9% |
| **Received Pre-Dialysis Nephrology Care** | 64.8% | 69.4% | 60.7% | 56.6% |
| **Vascular Access Type** | | | | |
| Catheter | 65.5% | 64.7% | 65.3% | 68.2% |
| AVF/AVG | 18.8% | 20.0% | 18.4% | 15.6% |
| Maturing AVF/AVG | 15.6% | 15.2% | 16.3% | 16.1% |
| **Chosen Facility, median (IQR)** | | | | |
| Distance (miles) | 3.75 (1.93, 7.55) | 4.38 (2.17, 9.11) | 3.18 (1.69, 5.92) | 3.21 (1.74, 5.93) |
| Rank Order | 2 (1, 5) | 2 (1, 4) | 3 (1, 6) | 3 (1, 6) |
| Is Nearest (Rank Order 1) | 37.1% | 42.9% | 30.4% | 29.0% |
| **Nearest High-Quality Facility, median (IQR)** | | | | |
| Distance (miles) | 3.44 (1.67, 8.75) | 4.50 (2.06, 11.56) | 2.87 (1.46, 6.22) | 2.28 (1.27, 4.59) |
| Rank Order | 2 (1, 4) | 2 (1, 3) | 2 (1, 5) | 2 (1, 3) |
| **Nearest Low-Quality Facility, median (IQR)** | | | | |
| Distance (miles) | 2.84 (1.39, 7.96) | 4.20 (1.88, 11.60) | 1.90 (1.01, 3.80) | 2.14 (1.17, 4.50) |
| Rank Order | 1 (1, 2) | 1 (1, 3) | 1 (1, 2) | 1 (1, 3) |
| **Nearest Facility, median (IQR)** | | | | |
| Distance (miles) | 1.88 (1.00, 3.93) | 2.46 (1.27, 5.73) | 1.42 (0.80, 2.53) | 1.45 (0.82, 2.46) |
| Is High-Quality | 45.0% | 48.5% | 36.5% | 47.6% |
| **# Proximate Facilities*, median (IQR)** | 12 (3, 33) | 7 (2, 22) | 22 (6, 51) | 23 (7, 56) |
| **Degree of Dialysis Facility Market Saturation** | | | | |
| Low | 27.6% | 36.4% | 17.6% | 15.0% |
| Medium-Low | 24.0% | 27.0% | 20.2% | 20.7% |
| Medium-High | 23.7% | 22.2% | 25.9% | 25.1% |
| High | 24.6% | 14.3% | 36.3% | 39.2% |
| **Neighborhood Characteristics, mean (SD)** | | | | |

| | Total | Non-Hispanic White | Non-Hispanic Black | Hispanic |
|---|---|---|---|---|
| Area Deprivation Index | 56.08 (27.78) | 53.73 (26.61) | 63.95 (27.72) | 50.57 (28.92) |
| % in Poverty | 16.99 (11.66) | 13.70 (9.75) | 21.77 (13.02) | 19.83 (11.48) |
| % Black | 20.46 (26.98) | 9.94 (16.16) | 46.95 (30.99) | 10.61 (15.31) |
| % Hispanic | 21.09 (25.71) | 13.94 (18.62) | 14.89 (18.41) | 55.12 (29.14) |
| **County Metro Status** | | | | |
| Metropolitan | 84.8% | 80.1% | 89.0% | 93.7% |
| Non-metropolitan | 13.7% | 18.0% | 9.9% | 6.0% |
| Rural | 1.4% | 2.0% | 1.1% | 0.3% |

* Proximate facilities are those that are within 14.5 miles of a patient's address; which is the 90$^{th}$ percentile of distance to chosen facility

**Table 1-2. Characteristics Associated with Selecting a High-Quality Dialysis Facility**

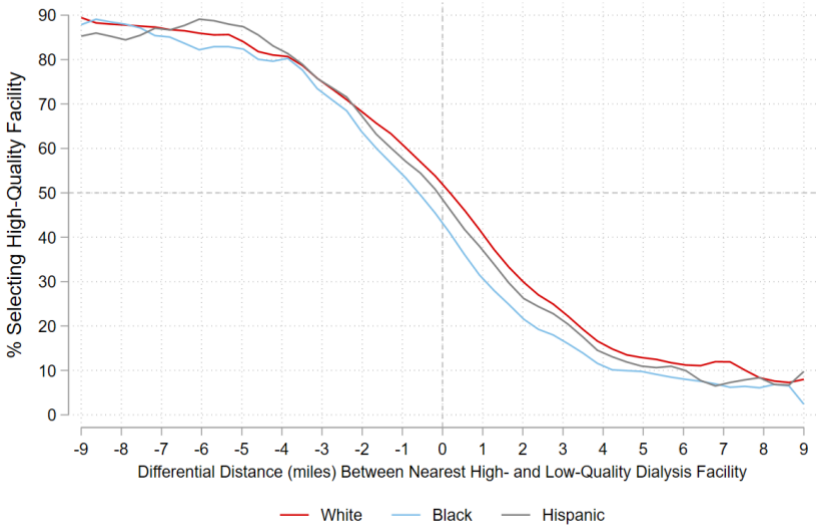
| | Overall | Non-Hispanic White | Non-Hispanic Black | Hispanic |
|---|---|---|---|---|
| | Change in Probability (Percentage Points) of Selecting High-Quality Facility (95% CI) | | | |
| **Insurance Coverage Type (vs. Medicare)** | | | | |
| Dual | 0.22 (-0.74 to 1.17) | 1.02 (0.06 to 1.97) | -0.20 (-1.43 to 1.03) | 0.16 (-1.84 to 2.15) |
| Medicaid | 0.67 (-0.56 to 1.90) | 1.08 (-0.09 to 2.25) | 0.30 (-1.04 to 1.63) | 1.89 (-0.50 to 4.28) |
| Employer Group | 1.23 (0.49 to 1.98) | 1.27 (0.40 to 2.14) | 0.81 (-0.43 to 2.05) | 2.88 (0.83 to 4.92) |
| Other | -1.45 (-2.75 to -0.16) | -0.63 (-1.90 to 0.64) | -2.58 (-4.43 to -0.73) | -1.62 (-4.83 to 1.59) |
| Uninsured | -0.13 (-1.75 to 1.48) | -0.86 (-2.8 to 1.09) | -1.42 (-3.17 to 0.34) | 1.97 (-0.18 to 4.11) |
| **Received Pre-Dialysis Nephrology Care** | 2.70 (1.82 to 3.57) | 2.82 (1.94 to 3.70) | 2.28 (0.98 to 3.58) | 2.17 (0.57 to 3.77) |
| **Vascular Access (vs. Catheter)** | | | | |
| AVF/AVG | 4.12 (3.32 to 4.92) | 3.81 (3.02 to 4.60) | 4.48 (3.20 to 5.76) | 4.22 (2.40 to 6.03) |
| Maturing AVF/AVG | 4.55 (3.68 to 5.42) | 3.80 (2.96 to 4.64) | 5.00 (3.54 to 6.47) | 5.89 (4.06 to 7.73) |
| **Differential Distance to High-Quality Facility (1 mile increase)** | -0.91 (-1.02 to -0.80) | -0.91 (-1.03 to -0.78) | -1.19 (-1.40 to -0.98) | -0.77 (-0.95 to -0.58) |
| **Neighborhood Characteristics (10 unit increase)** | | | | |
| Area Deprivation Index | -0.39 (-0.8 to 0.03) | -0.63 (-0.96 to -0.29) | -0.54 (-1.11 to 0.03) | -0.20 (-1.03 to 0.62) |
| % in Poverty | 0.09 (-0.55 to 0.73) | 0.11 (-0.52 to 0.74) | -0.07 (-0.73 to 0.59) | 0.00 (-1.19 to 1.18) |
| % Black | -1.79 (-2.17 to -1.42) | -1.60 (-2.03 to -1.17) | -1.01 (-1.47 to -0.54) | -2.38 (-3.09 to -1.68) |
| % Hispanic | -0.48 (-1.05 to 0.08) | -0.35 (-0.97 to 0.27) | -0.11 (-0.94 to 0.71) | -0.37 (-1.01 to 0.26) |
| **County Metropolitan Status (vs. Metro)** | | | | |
| Non-metro | 7.84 (5.63 to 10.05) | 7.51 (5.24 to 9.78) | 7.11 (3.34 to 10.87) | 2.68 (-1.69 to 7.04) |
| Rural | 6.87 (4.01 to 9.72) | 5.45 (2.60 to 8.30) | 7.52 (2.62 to 12.42) | 5.34 (-4.01 to 14.69) |

Differential distance coefficient represents one additional mile traveled to nearest high-quality facility vs. nearest low-quality facility. Coefficients for neighborhood characteristics represent a 10-unit increase.

Each column is from a separate linear probability model adjusting for the characteristics in the table, as well as age, sex, differential distances between each person's closest dialysis facility and the nearest facility of each star rating, and year of dialysis initiation. Models include robust standard errors clustered at the hospital service area level.

**Figure 1-1. Unadjusted Probability of High-Quality Dialysis Facility Selection, by Race/Ethnicity**

**A.** By Differential Distance to Nearest High-Quality Facility




**B.** By Decile of Neighborhood Percent Black

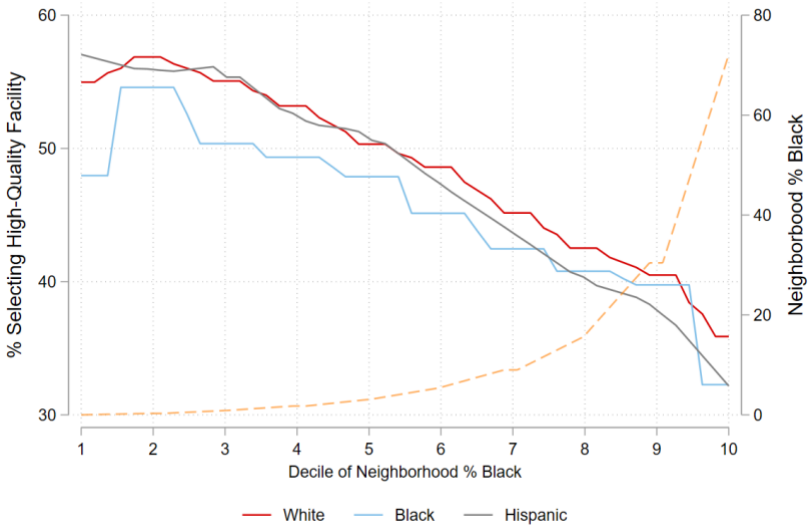
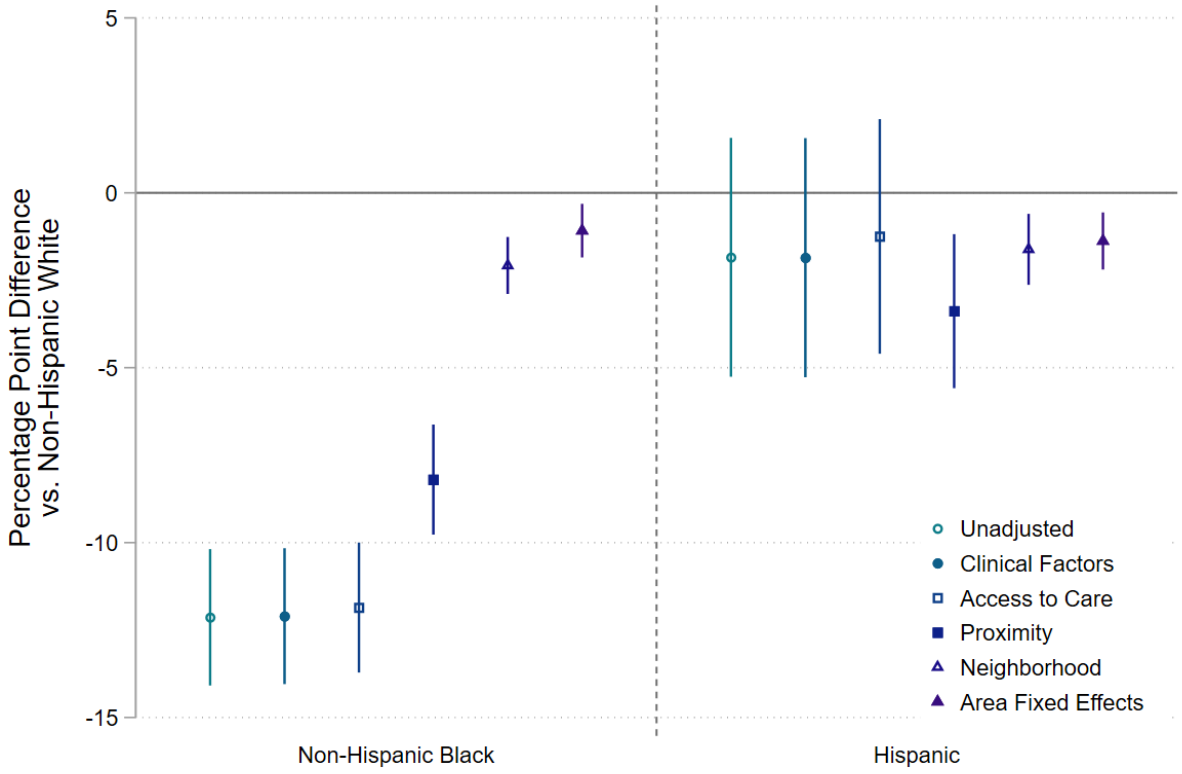


**Figure 1-2. Adjusted Difference in Probability of Selecting a High-Quality Dialysis Facility by Race/Ethnicity, with Stepwise Adjustment**




**Unadjusted:** year of dialysis initiation
**Clinical Factors:** + age, sex
**Access to Care:** + insurance coverage type, receipt of pre-dialysis nephrology care, vascular access
**Proximity Characteristics:** + differential distance between nearest high-quality and low-quality facility; differential distances between closest facility and nearest unrated, 1-star, 2-star, 3-star, 4-star, and 5-star facility (capped at 400 miles)
**Neighborhood Characteristics:** + census block group level area deprivation index; census tract level % poverty, % Black, % Hispanic; county metropolitan status
**Area Fixed Effects: +** census tract fixed effects
Models include robust standard errors clustered at the hospital service area level.

## Supplemental Appendix

### Study Population Details

The final study cohort included adults with incident kidney failure who initiated in-center hemodialysis as their initial treatment modality from January 2017 through December 2019. We excluded people who met any of the following criteria (also see Supplemental Figure 1)

- Reported Veterans Administration (VA) health insurance, as they have access to dialysis facilities in the VA health system
- Selected a facility that was not in the Dialysis Facility Compare datasets in the year in which they initiated dialysis
- Selected a dialysis facility ≥200 miles from their mailing address
- Selected a dialysis facility that was greater than the 95$^{th}$ percentile in distance (22.8 miles) and greater than the 95$^{th}$ percentile in number of facilities bypassed (20 facilities)

### Covariate Details

To calculate distances between patients and dialysis facilities, we geocoded patient and facility addresses using ArcGIS World Geocoder (version 10.5.1). All facilities and the majority of people geocoded successfully; 4.3% of people were geolocated using their zip code centroid rather than their address.

We then calculated several measures of access: the differential distance between the nearest high-quality and nearest low-quality dialysis facility for each person and the differential distances between each person's closest dialysis facility and the nearest facility of each star rating. We capped the maximum distance to the nearest facility of each star rating at 400 miles. This affected the distance to: 136 people's nearest unrated facility; 4,737 people's nearest one-

star facility, 533 people's nearest two-star facility; 3 people's nearest three-star facility; 5 people's nearest four-star facility; and 4 people's nearest five-star facility.

For people who resided in a census block group with missing Area Deprivation Index (ADI), or in a census tract with missing race/ethnicity or poverty information, we used the race/ethnicity group mean value. Overall 1.19% of the sample was missing ADI information, and 0.03% of the sample was missing census tract composition.

**Statistical Analysis**

We used a multivariable linear probability model with robust standard errors clustered at the hospital service area level *h* for person *i* who lives in neighborhood *z* initiating dialysis at facility *j* during year *y*

$$highqual_{ijy} = \beta_1 raceeth_i + \gamma_{iy} + \theta_i + \delta_i + \mu_i + \rho_{iz} + \varphi_z + \varepsilon_{ih}$$

We added covariates in a stepwise manner:

1. **Unadjusted** model only includes $\gamma_{iy}$, year of treatment initiation
2. **Clinical Factors** $\theta_i$ (age and sex)
3. **Access to Care Measures** $\delta_i$ (insurance coverage type at dialysis initiation, receipt of pre-dialysis nephrology care, and vascular access type)
4. **Proximity Characteristics** $\mu_i$ (differential distance between nearest high-quality and low-quality facility; differential distances between closest facility and nearest unrated, 1-star, 2-star, 3-star, 4-star, and 5-star facilities [distances capped at 400 miles])
5. **Neighborhood Characteristics** $\rho_i$ (census block group level Area Deprivation Index; census tract level poverty rate, proportion of residents who are Black, and proportion of residents who are Hispanic; county metropolitan status)

6. **Area (Census Tract) Fixed Effects** $\varphi_z$. In this model, the neighborhood characteristics drop out due to collinearity. Additionally, in the main analysis, 10,547 individuals (3.6% of the sample) were excluded as they were the only resident of their census tract.

The coefficient of interest was $\beta_1$, which provided the difference in probability of a given racial/ethnic group (here, non-Hispanic Black patients or Hispanic patients) in selecting a high-quality dialysis facility compared to the reference group (here, non-Hispanic White patients).

The outcome, $highqual_{ijy}$ was a binary indicator of whether facility *j* selected by patient *i* during year *y* was a high quality facility (rated 4 or 5 stars, in the main analysis) or not.

**Table S1-1. Adjusted Difference in Probability of Selecting a High-Quality Dialysis Facility by Race/Ethnicity, with Stepwise Adjustment**

| Model | Non-Hispanic White | Non-Hispanic Black | Hispanic |
|---|---|---|---|
| Unadjusted | [reference] | -12.14<br>(-14.09 to -10.19) | -1.84<br>(-5.26 to 1.57) |
| Clinical Factors | [reference] | -12.15<br>(-14.10 to -10.21) | -1.86<br>(-5.28 to 1.55) |
| Access to Care | [reference] | -11.86<br>(-13.72 to -10.00) | -1.25<br>(-4.60 to 2.11) |
| Proximity Characteristics | [reference] | -8.20<br>(-9.77 to -6.63) | -3.38<br>(-5.58 to -1.18) |
| Neighborhood Characteristics | [reference] | -2.08<br>(-2.89 to -1.26) | -1.61<br>(-2.63 to -0.60) |
| Area Fixed Effects | [reference] | -1.08<br>(-1.85 to -0.32) | -1.38<br>(-2.19 to -0.56) |

**Unadjusted:** year of dialysis initiation
**Clinical Factors:** + age, sex
**Access to Care:** + insurance coverage type, receipt of pre-dialysis nephrology care, vascular access
**Proximity Characteristics:** + differential distance between nearest high-quality and low-quality facility; differential distances between closest facility and nearest unrated, 1-star, 2-star, 3-star, 4-star, and 5-star facility (capped at 400 miles)
**Neighborhood Characteristics:** + census block group level area deprivation index; census tract level % poverty, % Black, % Hispanic; county metropolitan status
**Area Fixed Effects: +** census tract fixed effects
Models include robust standard errors clustered at the hospital service area level.

**Figure S1-1. Study Cohort Identification**

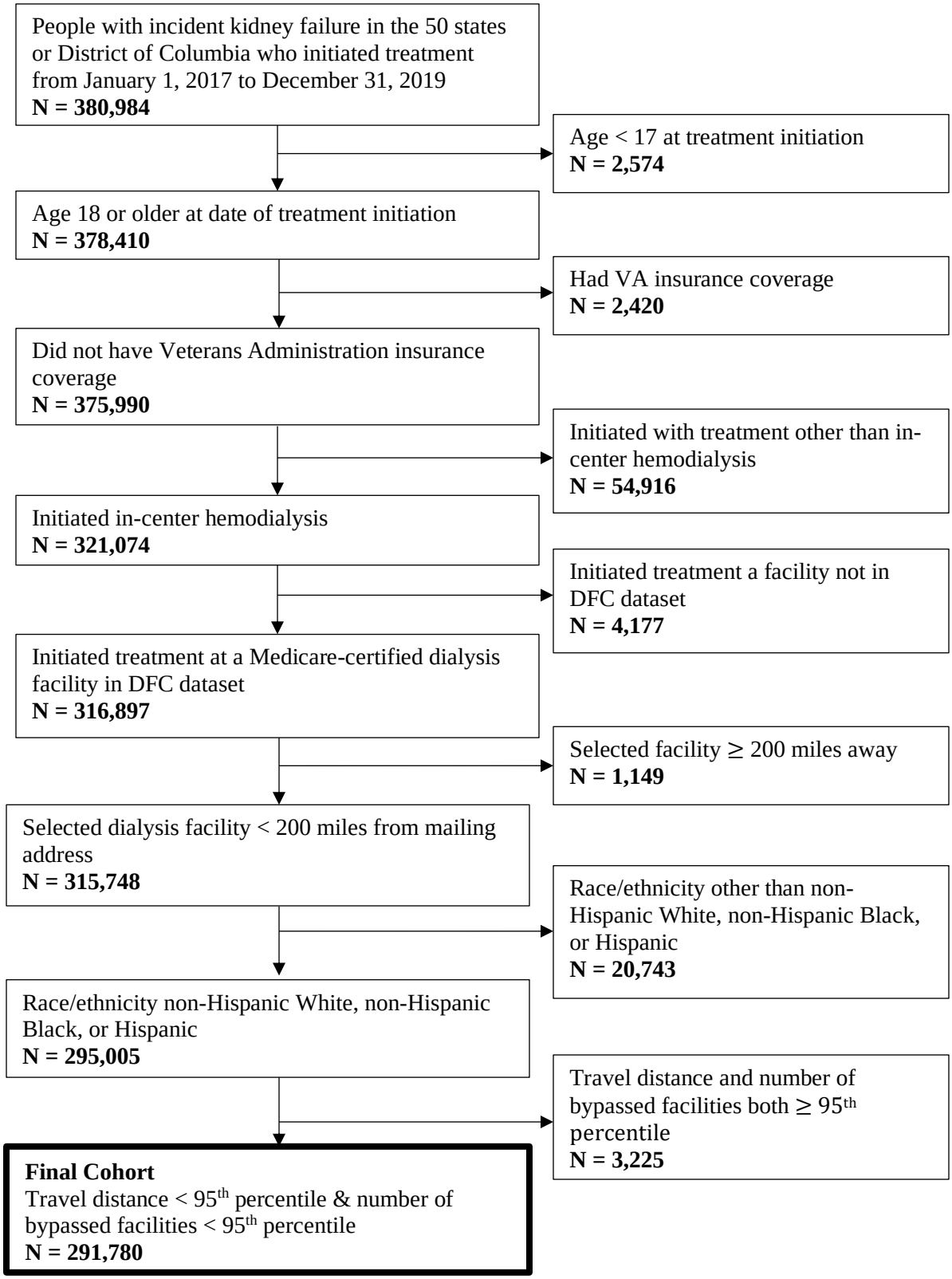
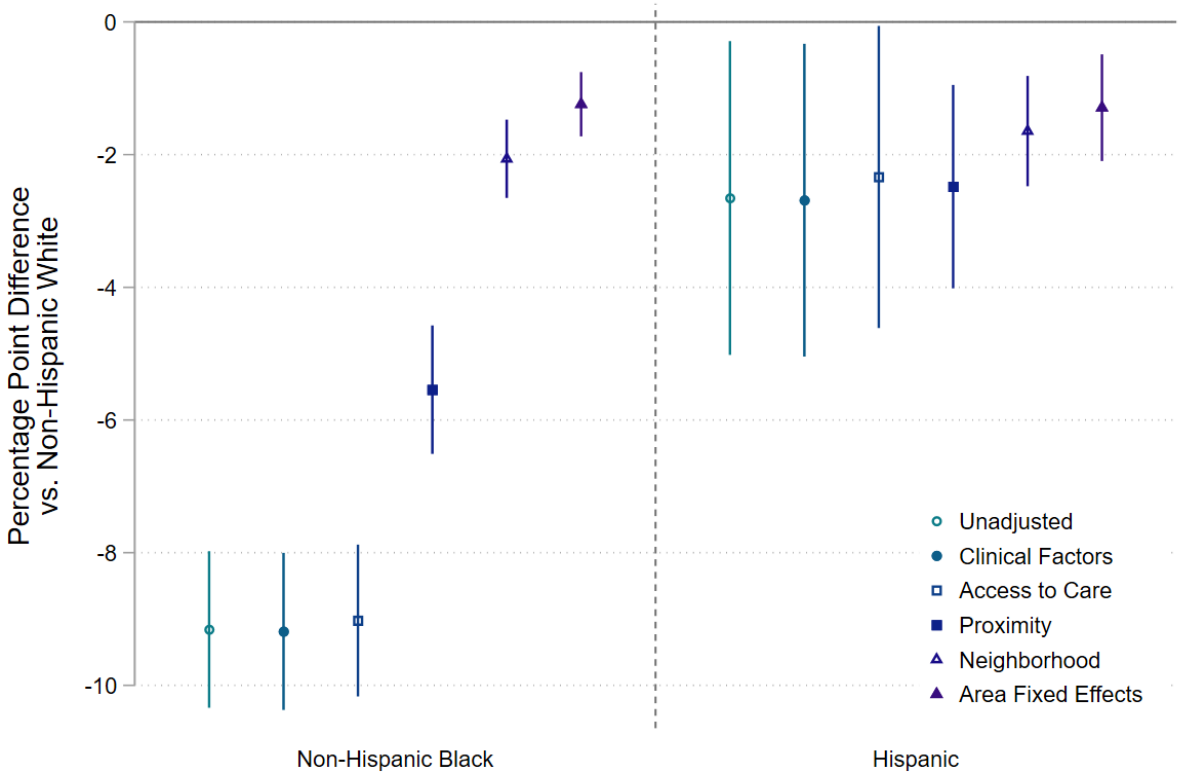


**Figure S1-2. Sensitivity Analysis: Adjusted Difference in Probability of Selecting a High-Quality Dialysis Facility by Race/Ethnicity, Alternative Definition of High-Quality Facility**




In this sensitivity analysis, high-quality facilities were defined as five-star facilities.

**Figure S1-3. Sensitivity Analysis: Adjusted Difference in Probability of Selecting a High-Quality Dialysis Facility by Race/Ethnicity, Stratified by Census Region**

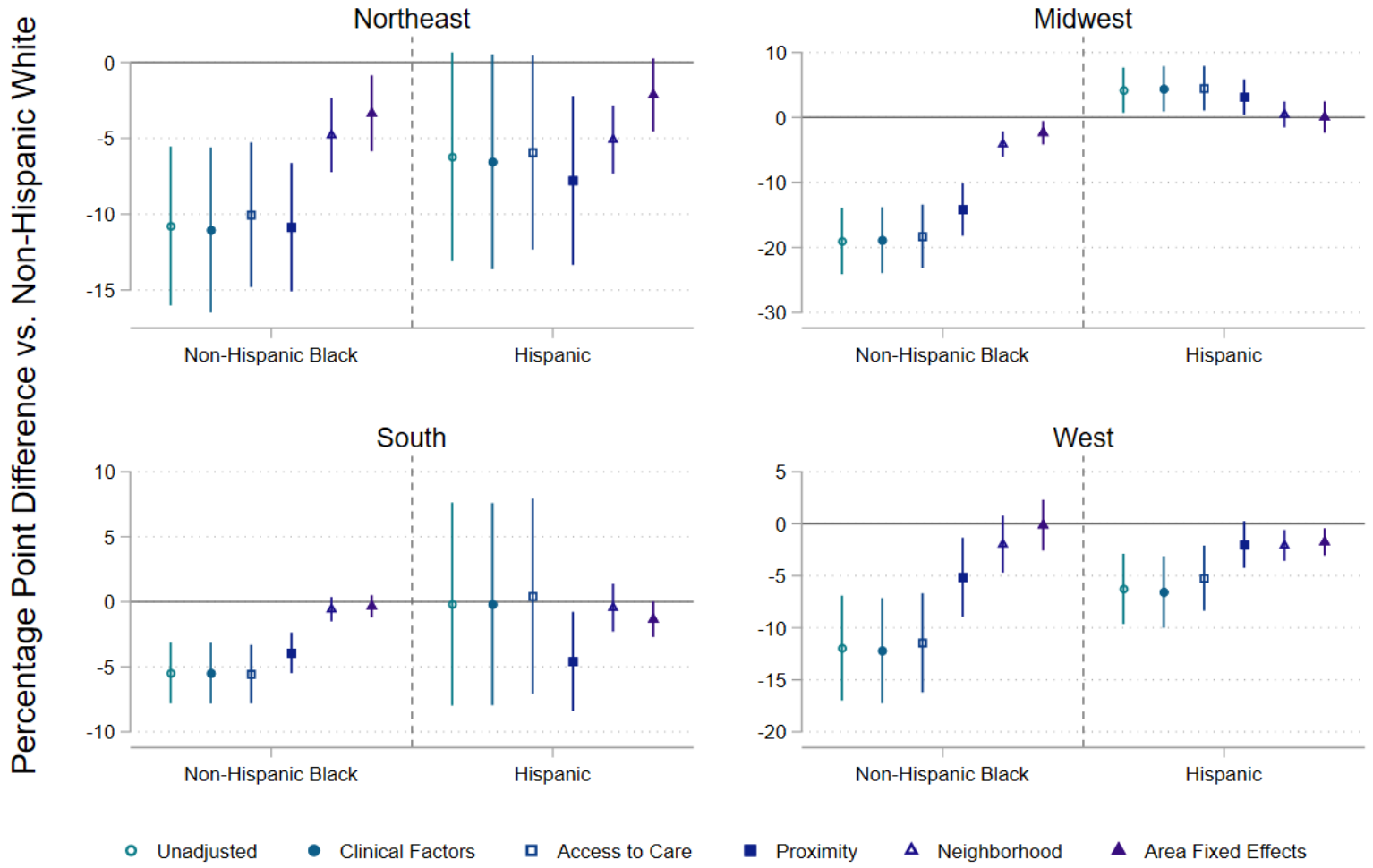
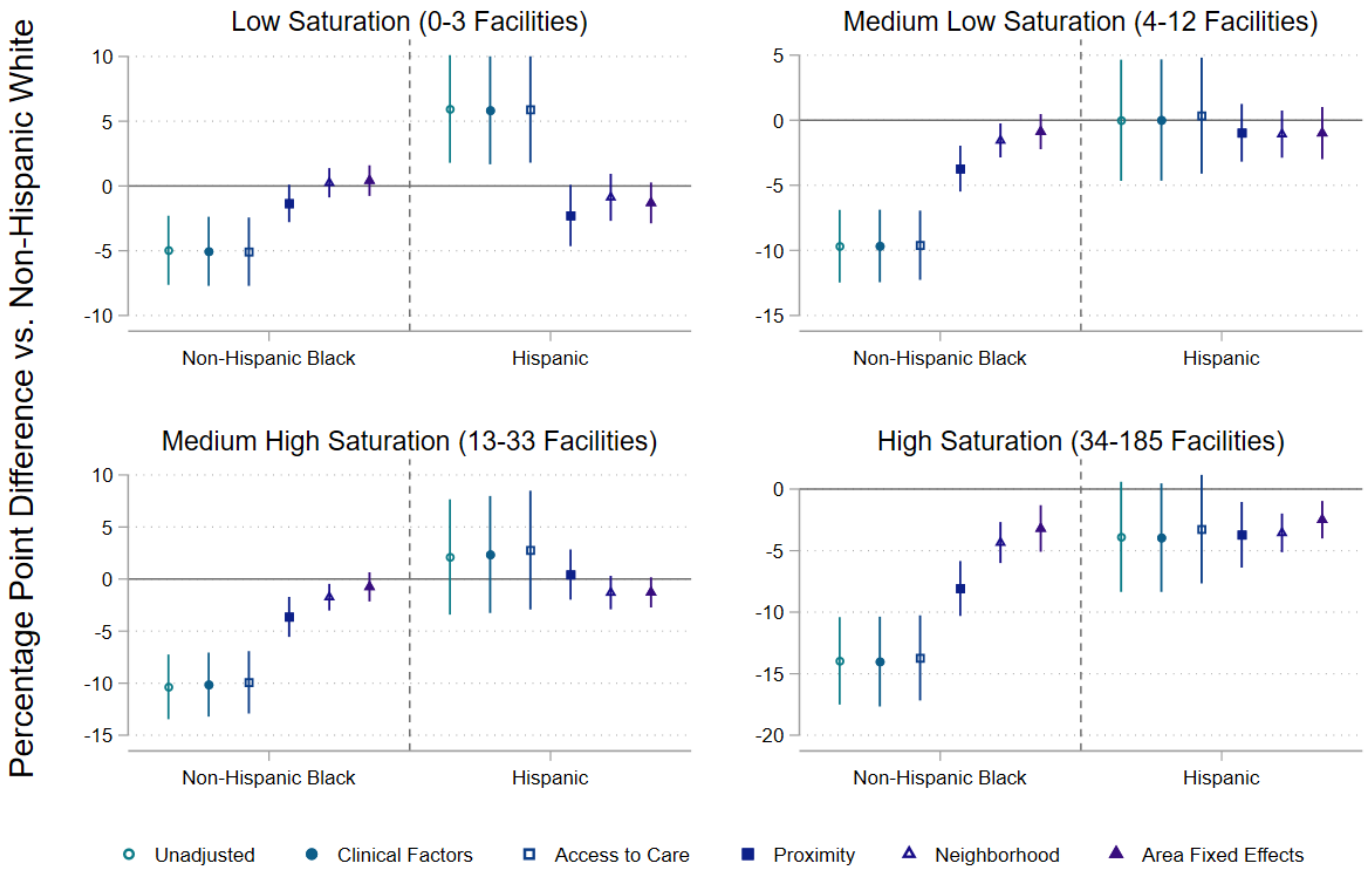


**Figure S1-4. Sensitivity Analysis: Adjusted Difference in Probability of Selecting a High-Quality Dialysis Facility by Race/Ethnicity, Stratified by Degree of Dialysis Facility Market Saturation**




Degree of dialysis facility market saturation was calculated by counting the number of dialysis facilities within 14.5 miles of each patient (which is the 90$^{th}$ percentile of distance to each patient's chosen dialysis facility). We then divided the number of facilities in that radius into quartiles to classify patients as residing in areas with low, medium low, medium high, or high dialysis market saturation.

# CHAPTER 2: ASSOCIATION OF SOCIAL RISK FACTORS WITH PERFORMANCE MEASURES IN THE ESRD TREATMENT CHOICES MODEL

## Introduction

In 2021 the Centers for Medicare and Medicaid Services (CMS) launched the mandatory End-Stage Renal Disease (ESRD) Treatment Choices (ETC) Model, which randomly assigned 30% of dialysis facilities to financial incentives to increase home dialysis and transplantation for people with kidney failure. Social risk factors, such as exposure to poverty and racism, are associated with less access to home dialysis and kidney transplantation.[1–3] However, the ETC model does not adjust performance for any characteristic other than age. CMS has proposed revising the model to stratify performance measures by facilities' share of low-income patients but has not reached a final decision. We assessed rates of home dialysis and transplantation among dialysis facilities that serve patients with high social risk to estimate whether these facilities may disproportionately face payment penalties beginning July 2022.

## Methods

We attributed incident adult kidney failure patients from January 2017 through June 2020 to dialysis facilities using the Renal Management Information System (Supplemental Appendix). Consistent with CMS' rules, we aggregated facilities with common ownership within the same hospital referral region (hereafter, 'facility groups'), and excluded those with fewer than 11 patients.

We identified facility groups in the highest quintile of proportion of incident patients who were: non-Hispanic Black, Hispanic, uninsured or Medicaid-covered at dialysis initiation, or

residents of the most socially disadvantaged neighborhoods (Supplemental Appendix). A composite score assigned groups as bearing zero, one, or two or more of these characteristics.

We approximated ETC performance measures by calculating rates of home dialysis initiation and one-year overall and living donor age-standardized kidney transplantation. T-tests compared performance by facility groups' social risk scores (Supplemental Appendix).

## Results

We attributed 433,831 incident patients at 7,570 dialysis facilities to 1,713 dialysis facility groups, of which 479 (28%) met criteria for one social risk characteristic and 410 (24%) did so for two or more (Table 2-1). Compared to facility groups with a composite score of zero, groups with two or more social risk features were less likely to offer peritoneal dialysis (62% vs. 80%), had lower proportions of patients initiating home dialysis (9.3% vs. 15.6%) or receiving a transplant within one year (1.7% vs 3.6%), and were more likely to have no incident patients initiate home dialysis (45.1% vs. 24.4%) or receive a transplant within one year (51.5% vs. 33.3%; $p < 0.001$ for all comparisons).

For facility groups in the highest quintile of Medicaid-covered or uninsured patients the home dialysis initiation rate was 7.7% (vs. 15.6% for other quintiles) (Figure 2-1). One-year living-donor transplant rates were lower for facility groups with large proportions of non-Hispanic Black patients (1.0% vs. 1.6%) and patients from disadvantaged neighborhoods (0.7% vs. 1.7%).

## Discussion

Dialysis facility groups serving higher proportions of patients with social risk factors performed worse on measures similar to those in the ETC Model, compared to groups serving patients with less social risk. The lower use of home dialysis and transplantation has the potential to disproportionately penalize these providers, consistent with other CMS alternative payment models.[4,5]

Study limitations include using incident rather than prevalent patients, and not restricting to traditional Medicare beneficiaries. Outcomes were similar but not identical to ETC performance measures, and did not assess transplant waitlisting.

The ETC model includes both achievement and improvement pathways, so low performing facilities may avoid penalties if they can improve home dialysis and transplant rates. However, socioeconomic and insurance-related barriers to home dialysis and transplant may persist, and the findings suggest that facilities that serve these populations are less likely to even offer home dialysis services. These findings support monitoring adverse impacts of the ETC model on facilities that serve vulnerable populations, and considering social risk factors in performance measurement.[6]

## References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3. Shen JI, Chen L, Vangala S, et al. Socioeconomic Factors and Racial and Ethnic Differences in the Initiation of Home Dialysis. *Kidney Medicine*. 2020;2(2):105-115. doi:10.1016/j.xkme.2019.11.006
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## Tables and Figures

**Table 2-1. Dialysis Facility Group Characteristics, by Composite Social Risk Score, January 2017 through June 2020**

| | Composite Social Risk Score[a] | | |
|---|---|---|---|
| | **0** | **1** | **2+** |
| Facility Groups, No. (%)[b] | 824 (48.1%) | 479 (28.0%) | 410 (23.9%) |
| Facilities per Group, mean (SD) | 4.6 (7.3) | 4.7 (9.5) | 3.7 (7.7) |
| N, Incident Patients per Facility Group, median (IQR) | 90.0 (35.0, 276.0) | 79.0 (31.0, 270.0) | 68.0 (32.0, 159.0) |
| **Incident Patient Composition, mean (SD)** | | | |
| % Non-Hispanic Black | 14.0 (12.3) | 29.0 (24.8) | 39.1 (30.3) |
| % Hispanic | 7.0 (6.7) | 16.5 (18.5) | 29.4 (29.1) |
| % with Medicaid/Uninsured | 23.7 (9.3) | 31.3 (12.2) | 52.3 (17.8) |
| % from High-Disadvantage Neighborhood[c] | 15.9 (13.7) | 27.5 (22.8) | 34.0 (29.6) |
| **Facility Group Characteristics, No. (%)** | | | |
| For-Profit | 547 (70.4%) | 359 (78.7%) | 270 (71.6%) |
| Chain | 472 (60.7%) | 271 (59.4%) | 159 (42.2%) |
| 1+ Facility w/ Late Shift | 324 (41.7%) | 164 (36.0%) | 128 (34.0%) |
| 1+ Facility Offers Hemodialysis | 742 (95.5%) | 428 (93.9%) | 367 (97.3%) |
| 1+ Facility Offers Peritoneal Dialysis | 618 (79.5%) | 351 (77.0%) | 234 (62.1%) |
| 1+ Facility Offers Home Hemodialysis | 461 (59.3%) | 234 (51.3%) | 139 (36.9%) |
| Assigned to ETC Model | 272 (33.0%) | 140 (29.2%) | 109 (26.6%) |
| Dialysis Stations per Facility, mean (SD) | 14.8 (7.4) | 16.3 (9.3) | 18.2 (9.8) |
| **Incident Patient Outcomes, mean (SD)[d]** | | | |
| % Initiating with Home Dialysis | 15.6 (23.1) | 15.4 (24.4) | 9.3 (18.2)*** |
| % with Kidney Transplant by 1 Year[e] | 3.6 (4.6) | 2.3 (3.1)*** | 1.7 (3.3)*** |
| % with Living-Donor Kidney Transplant by 1 Year[e] | 1.9 (2.9) | 1.3 (2.4)*** | 0.9 (2.1)*** |
| **Facility Groups With Performance Measure Rates of 0%, No. (%)[d]** | | | |
| Home Dialysis Rate of 0% | 201 (24.4%) | 126 (26.3%) | 185 (45.1%)*** |
| 1-Year Transplant Rate of 0%[e] | 274 (33.3%) | 189 (39.5%)* | 211 (51.5%)*** |
| 1-Year Living Donor Transplant Rate of 0%[e] | 366 (44.4%) | 244 (50.9%)* | 269 (65.6%)*** |

[a] Composite social risk score is the number of categories of social risk per facility group. Categories of social risk were facility groups in the highest quintile of proportion of incident patients who were: non-Hispanic Black, Hispanic, uninsured or Medicaid-covered at dialysis initiation (including those dually eligible for Medicaid & Medicare), and residents of neighborhoods with high social disadvantage.

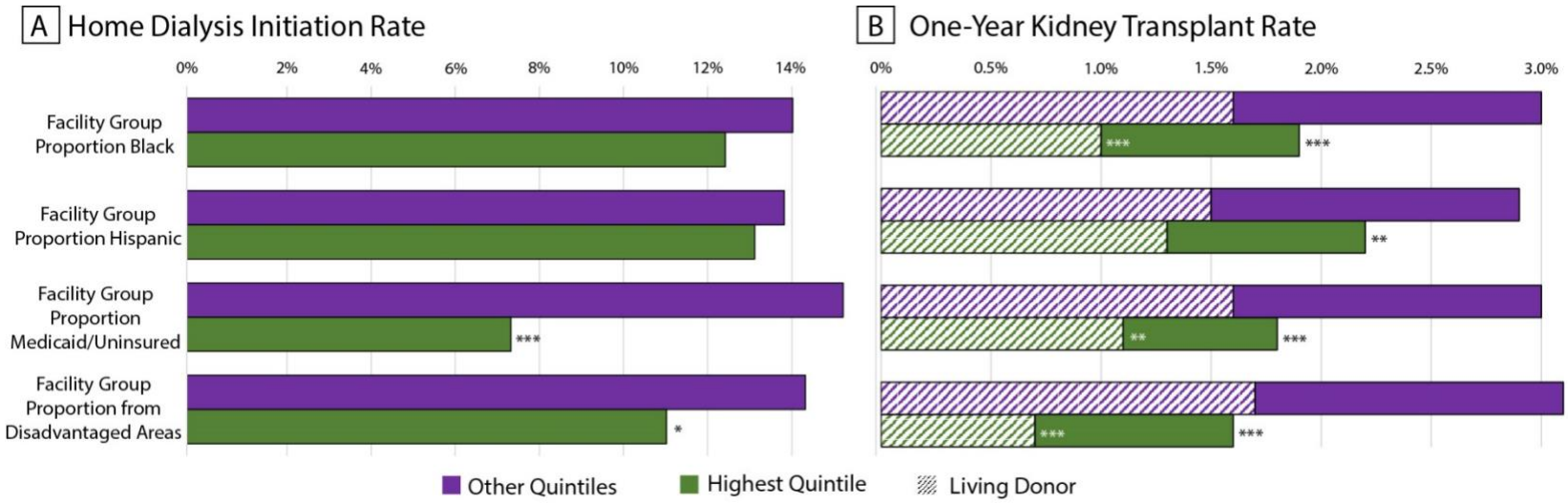
[b] Facility groups are composed of all dialysis facilities with common ownership in a given hospital referral region.

[c] High social disadvantage neighborhoods were defined as those in the highest quintile of area deprivation, using the 2018 Area Deprivation Index.

[d] We used two-sample t-tests to compare outcomes of facility groups with 1 or 2+ social risk characteristics to facility groups with 0 social risk characteristics.
* $p < 0.05$; ** $p < 0.01$; *** $p < 0.001$

[e] Transplant rate includes only incident patients aged 18-74 who initiated dialysis from January 2017 through June 2019. Transplant rates were age-standardized to the overall distribution of attributed patients, using age groups 18-55, 56-70, and 71-74, consistent with the ETC model and national standardized transplantation ratio metrics.

**Figure 2-1. Incident Patient Outcomes for Dialysis Facility Groups, By Dimension of Social Risk, January 2017 through June 2020**




Proportion of incident dialysis patients who (A) initiated dialysis at home (vs. in-facility) and (B) received a kidney transplant within one year of dialysis initiation. Compares facility groups in the highest quintile of incident patients with a given dimension of social risk to facilities in the other four quintiles.

Facility groups are composed of all dialysis facilities with common ownership in a given hospital referral region. The characteristics of adult incident dialysis patients from January 2017 through June 2020 were used to identify facility groups in the highest quintile of proportion of patients who were: non-Hispanic Black, Hispanic, uninsured or Medicaid-covered at dialysis initiation (including those dually eligible for Medicaid & Medicare), and residents of the most socially disadvantaged neighborhoods.

Age-standardized transplant rates only include incident patients aged 18-74 who initiated dialysis from January 2017 through June 2019. We used two-sample t-tests to compare outcomes of facility groups in the highest quintile to those in the other quintiles for each dimension of social risk.

* $p < 0.05$; ** $p < 0.01$; *** $p < 0.001$

## Supplemental Appendix

### Item S2-1. Detailed Methods

*Patient Attribution*

Incident kidney failure patients were identified using the ESRD Medical Evidence Report (CMS 2728), which is completed for all incident kidney failure patients initiating treatment. The form collects patient sociodemographic and clinical information at the time of treatment initiation, including insurance type, patient-reported race and ethnicity, and patient mailing address. Incident patients who met the following criteria were attributed to the dialysis facility at which they initiated treatment:

1. Initiated treatment with dialysis between January 1, 2017 and June 30, 2020
2. Age ≥18 years old at treatment initiation (consistent with the ETC model methodology, 42 CFR §512.360(b)(4))[1]
3. Primary dialysis setting was not a SNF/Long Term Care Facility (consistent with the ETC model methodology, 42 CFR §512.360(b)(8)) [1]
4. Initiated treatment at a dialysis facility that:
    a. Was located in the 50 states or District of Columbia
    b. Was Medicare-certified and included in the publicly-available CMS Dialysis Facility Compare or ESRD Quality Incentive Program in at least one year 2017-2020
    c. Was part of an facility group that had 11 or more incident patients in total from January 2017 through June 2020 (similar to ETC model methodology that excludes facility groups with fewer than 11 incident patients in a given measurement year, 42 CFR §512.385(a)) [1]

Brown University's Institutional Review Board and the Centers for Medicare and Medicaid Services (CMS) Privacy Board approved the study and waived the requirement for informed consent.

*Facility Group Social Risk*

Dialysis facilities were aggregated at the hospital referral region by common ownership to form facility groups (consistent with the ETC model methodology, 42 CFR §512.365(e)(1)).[1] Ownership was determined using publicly available CMS Dialysis Facility Compare data, which reports whether a dialysis facility is part of a chain, and if so, which chain organization. Facility groups were then categorized by their incident patient composition (using patient characteristics from the CMS 2728) to identify groups in the highest quintile of proportion of incident patients who were:

1. Non-Hispanic Black (highest quintile: ≥ 44.4% of incident patients)
2. Hispanic (highest quintile: ≥ 25.3% of incident patients)
3. Uninsured or covered by Medicaid (including Medicare-Medicaid dual eligibles) at dialysis initiation (highest quintile: ≥ 43.7% of incident patients)
4. Residents of a census block group with high social disadvantage (highest quintile: ≥ 44.5% of incident patients). Incident patient mailing addresses were geocoded using ArcGIS World Geocoder (version 10.5.1) and geolocated within census block groups. We used the 2018 Area Deprivation Index[2,3] to identify census block groups (neighborhoods) with a deprivation score of >80 (the highest quintile of area deprivation), which we classified as the most socially disadvantaged neighborhoods.

We then developed a composite score of social risk that measured whether a facility group was in zero, one, or two or more of these categories. These patient-level characteristics have been used in other analyses to identify dialysis facilities that serve patients with high social risk.[4]

*Patient Outcomes*

The ETC model performance measures[1] focus on home dialysis and kidney transplantation waitlisting and living-donor transplant rates. To approximate these measures in the incident population, we assessed three outcomes of interest:

1. The proportion of incident patients initiating home (vs. in-center) dialysis. Overall, 29.8% of facility groups had no incident patients initiating home dialysis during the study period.
2. The proportion of incident patients aged 18-74 who received a kidney transplant within one year of initiating dialysis. Overall, 39.4% of facility groups had no incident patients receive a kidney transplant within one year of dialysis initiation during the study period.
3. The proportion of incident patients aged 18-74 who received a living donor kidney transplant within one year of initiating dialysis. Overall, 51.3% of facility groups had no incident patients receive a living-donor kidney transplant within one year of dialysis initiation during the study period.

To ensure one year of follow up, only patients who initiated dialysis from January 1, 2017 through June 30, 2019 were included in the transplant measure outcomes. Consistent with the ETC model methodology (42 CFR §512.365(d)),[1] we age-standardized transplant rates to the overall distribution of attributed patients aged 18-74, using age groups 18-55 (36.1% of eligible

incident patients), 56-70 (50.3%), and 71-74 (13.6%). Facility groups with no incident patients in a given age group were given a rate of zero for that age group in calculations.[5]

We used two-sample t-tests to compare outcomes of facility groups with 1 or 2+ social risk characteristics to facility groups with 0 social risk characteristics, and to compare facility groups in the highest quintile to those in the other quintiles for each dimension of social risk.

**Supplemental Appendix References**


1. Centers for Medicare and Medicaid Services. Final Rule: Medicare Program; Specialty Care Models To Improve Quality of Care and Reduce Expenditures. Fed Regist. 2020;85:61114-61381. Codified at 42 CFR §512.
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# CHAPTER 3: ASSOCIATION OF CHRONIC KIDNEY DISEASE WITH 30-DAY SARS-COV-2 MORTALITY IN NURSING HOME RESIDENTS: A RETROSPECTIVE COHORT STUDY

## Introduction

Since the beginning of the Coronavirus Disease 2019 (COVID-19) pandemic caused by Severe Acute Respiratory Syndrome Coronavirus 2 (SARS-CoV-2), researchers and clinicians have sought to identify which individuals were at highest risk for worse outcomes. Nursing home residents quickly emerged as a particularly high risk group due to advanced age and frailty, and their need for hours of hands-on care in a congregate care setting.[1–7]

Aside from age and functional impairment, chronic kidney disease (CKD) has been identified as a significant independent predictor of mortality in nursing home residents with SARS-CoV-2,[3,6] and in the general population.[7–12] Some but not all studies have shown that individuals on long-term dialysis are at increased risk for death.[8,11–15] However, the relationship between CKD stage, based on Kidney Disease Improving Global Outcomes (KDIGO) criteria,[16] and SARS-CoV-2 mortality has not been fully explored among nursing home residents, a particularly vulnerable population.

Over one in three people over age 65 in the United States have CKD,[17–19] and prevalence is even higher among nursing home residents.[20,21] Despite the increasing availability of SARS-CoV-2 vaccines to older adults, factors such as vaccine hesitancy[22] and uncertainty as to how well vaccines will protect against emerging variants[23] mean that SARS-CoV-2 remains a risk in this population. A more nuanced understanding of the relationship between CKD stage and risk for death from SARS-CoV-2 in frail older adults can aid in risk stratification and mitigation. We

described the association between CKD stage and all-cause 30-day mortality following SARS-CoV-2 diagnosis among nursing home residents. We hypothesized that mortality would be lowest among nursing home residents with SARS-CoV-2 who did not have pre-existing CKD, and would increase progressively with increasing CKD severity.

## Methods

### Study Design and Data Sources

Our retrospective cohort study used a unique dataset of real-time electronic health record (EHR) and other clinical data from Genesis HealthCare, one of the largest long-term care providers in the US, linked to several other datasets (Table S3-1). Genesis transferred data nightly to Brown University under an IRB-approved data use agreement. The EHR data included SARS-CoV-2 test dates and results, diagnoses, medication administration records, a daily resident census, nursing documentation, and laboratory test records. All residents underwent at least daily nursing assessments to screen for new symptoms of SARS-CoV-2. Testing was triggered by a number of factors, which included new symptoms, potential exposure, admission to the facility, or for surveillance when there was a confirmed outbreak. The EHR data were linked to the Minimum Data Set (MDS), a standardized health assessment tool completed upon admission, discharge, and at regular intervals for all nursing home residents. Brown University's Institutional Review Board approved the study and waived the requirement for informed consent.

### Study Population

We identified all nursing home residents with an incident SARS-CoV-2 infection confirmed by reverse transcriptase polymerase chain reaction or antigen testing between March 1, 2020 and December 31, 2020. Clinical information was extracted during the time period

beginning January 1, 2020 through January 31, 2021. Other inclusion criteria were (1) resided in their nursing home for at least 7 days prior to their first positive test to prevent inclusion of individuals who were discharged to the nursing home after hospitalization for SARS-CoV-2, (2) had complete laboratory, medication, and baseline MDS comorbidity information data available, and (3) had known baseline kidney function.

**Exposure**

The main exposure of interest was CKD stage, categorized using baseline kidney function. Baseline kidney function was defined as the estimated glomerular filtration rate (eGFR, measured in mL/min/1.73m$^2$) derived from serum creatinine values measured during the baseline period, which spanned from January 1, 2020 or date of admission to the nursing home (whichever was later) to the day prior to SARS-CoV-2 diagnosis for each individual. eGFR was calculated using the CKD-EPI formula.[24] For residents with multiple serum creatinine measurements during the baseline period we used the median value (Item S3-1).

We categorized kidney function by eGFR according to the 2012 KDIGO Guidelines:[16] G1 for eGFR $\geq$ 90; G2 for eGFR 60-89; G3a for eGFR 45-59; G3b for eGFR 30-44; G4 for eGFR 15-29; and G5 for eGFR <15 or an MDS indicator for dialysis treatment. All residents with a dialysis indicator were included in G5 because dialysis patients frequently have bloodwork performed at the dialysis facility rather than at the nursing home, and therefore are less likely to have all laboratory results included in the nursing home's EHR. Because urine microalbumin and albumin were not measured consistently across residents, CKD manifesting only as proteinuria was not accounted for in this analysis.

**Outcome and Follow-up**

Our outcome was death due to any cause within 30 days of the resident's SARS-CoV-2 diagnosis. Follow-up for mortality began on the date of each resident's first positive SARS-CoV-2 test. The date of death was ascertained from the daily census and MDS. These data have been used in prior studies to identify deaths in this population.[3,25]

We additionally used MDS records to identify any acute care hospitalizations that occurred in the 30 days following a resident's SARS-CoV-2 diagnosis, and the status of each resident at 30 days after diagnosis (deceased, alive and in the nursing home, discharged to a hospital, discharged to the community). Deaths are reliably recorded for all residents who die in the nursing home; in some but not all cases death information is available for recently-discharged residents who die in other settings.

**Covariates**

We included a number of baseline person-level characteristics associated with SARS-CoV-2 mortality to better isolate the independent association between kidney function and all-cause mortality following SARS-CoV-2 infection.

Resident characteristics ascertained from MDS assessments included age, sex, long-stay status (admission date ≥100 days earlier than SARS-CoV-2 diagnosis date), cognitive and functional impairment,[26,27] comorbidities (coronary artery disease, heart failure, hypertension, chronic obstructive pulmonary disease [COPD]/asthma, diabetes, active cancer diagnosis, BMI category, and depression category) (Table S3-2). We used information from the most recent MDS assessment prior to a resident's SARS-CoV-2 diagnosis to ascertain covariate information. The MDS assessment was incomplete at the time of SARS-CoV-2 diagnosis for less than 5% of

residents; in these cases, we included MDS assessment information obtained during the seven days following their positive test.

We identified medication use using medication administration records within the EHR data and identified whether a medication was administered within the seven days prior to a resident's SARS-CoV-2 diagnosis date, excluding the day of diagnosis. We categorized medications into the following classes: anticoagulants, antiplatelets, non-steroidal anti-inflammatories (NSAIDs), renin-angiotensin-aldosterone system (RAAS) inhibitors (angiotensin converting enzyme inhibitors [ACEIs] and angiotensin receptor blockers [ARBs]), beta blockers, loop diuretics, thiazide diuretics, hydroxymethylglutaryl-coenzyme A (HMG-CoA) reductase inhibitors, and oral corticosteroids (Table S3-3).

Because SARS-CoV-2 mortality risk has varied temporally in this population due to factors such as testing and treatment availability, and potentially also due to virus and disease characteristics that changed over time, we included indicators for the calendar month in which the positive test occurred.[6,25]

**Statistical Analysis**

To model the association between kidney function and death following SARS-CoV-2 infection, we used multivariable logistic regression models with Huber-White robust standard errors clustered at the facility level (Item S3-2) to estimates odds ratios and used postestimation commands to calculate adjusted probabilities and risk ratios with 95% confidence intervals (CIs).[28] We chose adjusted risk ratios because odds ratios exaggerate risk ratios when the outcome is common,[29] and death following SARS-CoV-2 infection is a common outcome in the nursing home population.

**Stability Analyses**

We conducted several stability analyses to examine the robustness of our findings. First, we explored whether the association between CKD stage and SARS-CoV-2 mortality differed by other known risk factors for SARS-CoV-2 mortality. Prior studies have found diabetes status and glycemic control,[8,30,31] age group,[3,6,8,32] and degree of functional and cognitive impairment[3] are all important predictors for death following SARS-CoV-2. For each of these risk factors, we specified a regression model that included an interaction term between CKD stage and the subgroups of that risk factor to estimate the joint probabilities of mortality for each CKD stage within each risk factor subgroup (Item S3-2).

Second, 30% of residents of nursing homes that reported electronic laboratory and medication information had no baseline information about kidney function, so were excluded from the main analysis. We constructed inverse probability of non-missingness weights to estimate how our findings may have differed had those individuals with missing laboratory information been included in the analysis. We then re-estimated our main model, using the weights to approximate the results for the entire cohort of residents with confirmed SARS-CoV-2 infection who met the other inclusion criteria (Item S3-2).

Third, we estimated a multivariable logistic regression model with random intercepts for each nursing home to account for any clustering of residents with similar characteristics at certain facilities (Item S3-2). Fourth, we also used three alternative approaches to characterize baseline kidney function: each resident's highest baseline recorded eGFR value, each resident's most recent baseline value, and each resident's median baseline eGFR calculated using the CKD-EPI equation but omitting the race coefficient (Item S3-1).[33]

### Software

All analyses were performed in Stata version 17 (StataCorp) and used two-tailed hypothesis testing with a significance threshold of $p < 0.05$.

## Results

### Characteristics of the Study Population

During calendar year 2020, 6,798 residents had a confirmed new SARS-CoV-2 infection and met the cohort inclusion requirements (Figure S3-1). Over half of residents had baseline kidney function consistent with groups G1 and G2, with progressively lower numbers in more advanced stages (Table 3-1). The majority of residents were non-Hispanic White (overall, 75.0% non-Hispanic White, 15.2% non-Hispanic Black, 6.1% Hispanic), though the G4 and G5 groups were composed of a larger share of non-Hispanic Black and Hispanic residents than the other kidney function groups. The G5 group had less cognitive and functional impairment than residents in the G1-G4 groups. The G5 group otherwise had higher rates of other comorbidities (diabetes: 74.5% in G5 vs 37.0% in G1; heart failure: 41.3% vs 13.9%; hypertension 90.7% vs 68.6%; coronary artery disease 38.2% vs 17.0%; cancer 11.5% vs 9.0%). G5 individuals were more likely to use certain classes of medications than G1 individuals, notably anticoagulants (12.7% vs 8.9%), antiplatelet agents (29.2% vs 20.5%), and HMG-CoA reductase inhibitors (28.9% vs 20.3%) (Table 3-1). In the 30 days following SARS-CoV-2 diagnosis, 18.8% of residents were hospitalized, and G5 residents were more likely to be hospitalized than G1 residents (45.3% vs. 17.2%).

### Mortality in Residents with SARS-CoV-2

Overall, 15.3% of nursing home residents died within 30 days of their SARS-CoV-2 diagnosis. In unadjusted analyses, G1 residents had the lowest mortality rate at 7.3% (95% CI: 5.9% to 8.7%), and G4 residents had the highest rate at 24.7% (95% CI: 20.4% to 29.1%) (Table 3-2). In adjusted analyses that accounted for resident characteristics, mortality risk increased progressively with higher CKD stages from 10.1% (95% CI: 8.3% to 11.9%) for G1 residents to 16.4% (95% CI: 14.3% to 18.4%) for G3a residents to 23.2% (95% CI: 18.6% to 27.7%) for G5 residents. Compared with residents with kidney function in group G1, the risk of death ranged from 1.4 (95% CI: 1.12 to 1.7) times higher for G2 residents to 2.3 (95% CI: 1.8 to 3.0) times higher for G5 residents.

### Stability Analyses

In the first stability analysis, adjusted mortality generally increased with increasing CKD severity among subgroups with known risk factors for SARS-CoV-2 mortality such as older age, degree of cognitive and functional impairment, and diabetes status and glycemic control (Figure 1). Stability analyses that used alternative model specifications (Tables S3-4 to S3-6) or methods of categorizing kidney function (Tables S3-7 to S3-9) were consistent with the main analysis.

## Discussion

In this large multi-state cohort of nursing home residents with SARS-CoV-2, the risk of all-cause 30-day mortality increased progressively with higher CKD stages. The increased risk of mortality was evident even for residents with mildly reduced kidney function versus those with normal eGFR. Compared with G1 nursing home residents, G2 residents were 1.4 (95% CI: 1.2 to

1.7) times more likely to die following SARS-CoV-2 infection and G5 residents were 2.3 (95% CI: 1.8 to 3.0) times more likely.

Prior studies have shown higher SARS-CoV-2 mortality among hospitalized older adults with CKD, and among nursing home residents with kidney failure or renal insufficiency documented in the MDS.[3,9,12] Our study corroborates and expands upon these findings by using creatinine-based determination of CKD stage, allowing a more granular assessment of how CKD at different stages is associated with mortality. Large population-based studies have found moderately or severely reduced kidney function is associated with higher mortality following SARS-CoV-2 infection, but have generally not identified modestly reduced eGFR or earlier-stage CKD as an independent risk factor.[8,10–12]

Increased mortality in this vulnerable older adult population with increasing CKD severity may be driven by increased susceptibility to the inflammatory response, endothelial dysfunction, and coagulopathy which contribute to SARS-CoV-2 pathophysiology.[34,35] Prior studies in older adults with CKD have shown a greater degree of endothelial dysfunction,[36] coagulopathy,[37] and inflammatory response.[37] Additionally, frailty tends to increase with higher CKD stage in older adults,[38] and frailty appears to be an important risk factor for death following SARS-CoV-2 infection.[39,40] This study and others have demonstrated that cognitive and functional impairment are significant predictors of SARS-CoV-2 mortality among nursing home residents,[3,6] but even adjusting for and stratifying by cognitive and functional impairment we find a large association between CKD and mortality that increases with worsening kidney function. This association is even observed within subgroups of age and degree of cognitive and functional impairment, suggesting that kidney function, which is closely related to age and frailty, is independently associated with death following SARS-CoV-2.

**Limitations**

Our study has a number of limitations. We identified factors associated with SARS-CoV-2 mortality, and the observed associations should not be considered causal effects. We aimed to make descriptive inferences only. Other factors may have influenced mortality, though there is limited evidence that frail older adults with SARS-CoV-2 benefit from intubation and intensive care unit admission.[39,41] Our outcome measure was all-cause mortality rather than cause-specific SARS-CoV-2 mortality, which may be of separate interest. However, ascertaining cause of death is difficult for multimorbid older nursing home residents, and all-cause mortality may be more meaningful because residents may die from multiple joint causes. Our method for classifying kidney function of nursing home residents may have misclassified some residents. Because we had to rely on baseline laboratory data, residents had different amounts of information available, and the period between serum creatinine values and SARS-CoV-2 diagnosis varied. We classified CKD based only on serum creatinine and eGFR as we had limited data on albuminuria and microalbuminuria. We also may have incomplete information about deaths among residents who were discharged from and not readmitted to the nursing home. However, hospitalization rates were higher for residents with more advanced CKD, who already had higher mortality, suggesting that our estimates would, if anything, underestimate deaths for these residents.

In conclusion, mortality risk among our cohort of US nursing home residents with SARS-CoV-2 increased progressively with more advanced CKD stages. While other studies have identified CKD as a risk factor for death following SARS-CoV-2, we expand upon this using creatinine-based determination of CKD stage, which provides a more granular assessment of how CKD stage is associated with mortality among nursing home residents. Despite widespread

availability of vaccines to nursing home residents, SARS-CoV-2 remains a threat. Understanding which individuals are particularly vulnerable will remain important for risk mitigation strategies.

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## Tables and Figures

**Table 3-1. Characteristics of Nursing Home Residents Who Tested Positive for SARS-CoV-2**

| Characteristic | Total | CKD Stage | | | | | |
|---|---|---|---|---|---|---|---|
| | | G1 | G2 | G3a | G3b | G4 | G5 |
| N | 6798 | 1422 | 2692 | 1127 | 899 | 336 | 322 |
| Age, mean (SD) | 76.7 (12.8) | 65.2 (11.7) | 79.3 (10.6) | 81.4 (10.7) | 82.1 (11.2) | 81.7 (12.0) | 69.3 (12.0) |
| Age Group, (%) | | | | | | | |
| <70 | 28.2 | 65.0 | 17.6 | 15.3 | 14.3 | 15.5 | 50.9 |
| 70-79 | 27.1 | 24.4 | 31.6 | 24.5 | 21.2 | 25.3 | 28.6 |
| 80-89 | 28.1 | 9.9 | 33.6 | 34.9 | 36.0 | 28.3 | 17.4 |
| 90+ | 16.6 | 0.7 | 17.2 | 25.4 | 28.4 | 31.0 | 3.1 |
| Female, (%) | 60.8 | 43.6 | 63.3 | 67.4 | 74.1 | 68.8 | 47.2 |
| Race/Ethnicity (%) | | | | | | | |
| Non-Hispanic White | 75.0 | 63.2 | 81.1 | 78.7 | 80.1 | 73.5 | 51.6 |
| Non-Hispanic Black | 15.2 | 26.4 | 9.7 | 11.9 | 10.8 | 17.3 | 32.9 |
| Hispanic/Latino | 6.1 | 7.0 | 5.6 | 6.1 | 5.1 | 6.3 | 10.2 |
| Other/Unknown | 3.6 | 3.5 | 3.6 | 3.3 | 4.0 | 3.0 | 5.3 |
| Long Stay Resident | 77.7 | 73.7 | 80.4 | 81.0 | 77.8 | 71.4 | 68.3 |
| ADL Score, mean (SD) | 16.5 (6.6) | 17.3 (7.0) | 16.6 (6.5) | 15.9 (6.5) | 16.0 (6.2) | 16.8 (6.0) | 15.9 (6.3) |
| ADL Category, (%) | | | | | | | |
| 0-13 | 27.5 | 25.7 | 26.8 | 31.1 | 28.5 | 25.0 | 29.2 |
| 14-18 | 22.7 | 18.8 | 22.3 | 23.6 | 27.3 | 23.5 | 27.0 |
| 19-20 | 20.4 | 17.3 | 20.8 | 20.9 | 21.5 | 24.4 | 22.7 |
| 21-28 | 29.3 | 38.2 | 30.1 | 24.3 | 22.8 | 27.1 | 21.1 |
| Cognitive Function Category, (%) | | | | | | | |
| Cognitively Intact | 40.4 | 46.7 | 36.1 | 36.6 | 41.3 | 40.5 | 59.9 |
| Mild Impairment | 23.3 | 22.1 | 23.8 | 23.2 | 23.0 | 28.6 | 20.5 |
| Moderate Impairment | 27.5 | 18.7 | 30.9 | 33.1 | 28.6 | 25.9 | 16.5 |
| Severe Impairment | 8.7 | 12.5 | 9.1 | 7.0 | 7.1 | 5.1 | 3.1 |
| BMI, $kg/m^2$, mean (SD) | 28.3 (9.3) | 28.7 (11.1) | 27.6 (8.2) | 28.6 (10.0) | 29.2 (8.9) | 29.1 (8.0) | 28.7 (8.5) |
| BMI Category, (%) | | | | | | | |
| Normal Weight | 33.4 | 32.3 | 35.6 | 33.7 | 30.9 | 25.6 | 33.9 |
| Underweight | 6.5 | 7.4 | 7.2 | 6.4 | 4.2 | 5.7 | 4.0 |
| Overweight | 25.8 | 25.0 | 26.0 | 24.2 | 26.6 | 28.6 | 28.3 |
| Obesity I | 15.6 | 14.8 | 14.7 | 17.3 | 16.0 | 20.5 | 15.2 |
| Obesity II or III | 16.6 | 17.9 | 14.4 | 16.7 | 19.8 | 17.9 | 18.0 |
| Unknown | 2.1 | 2.5 | 2.1 | 1.7 | 2.4 | 1.8 | 0.6 |
| Depression, (%) | | | | | | | |
| None | 22.2 | 21.9 | 21.6 | 22.2 | 22.8 | 22.6 | 26.1 |

| Characteristic | Total | CKD Stage | | | | | |
|---|---|---|---|---|---|---|---|
| | | G1 | G2 | G3a | G3b | G4 | G5 |
| Minimal/Mild | 53.1 | 51.2 | 53.2 | 54.4 | 54.3 | 55.4 | 51.6 |
| Moderate/Severe | 8.5 | 9.2 | 8.6 | 7.6 | 7.7 | 7.1 | 10.9 |
| Unknown | 16.2 | 17.7 | 16.6 | 15.8 | 15.2 | 14.9 | 11.5 |
| Comorbidities, (%) | | | | | | | |
| Coronary Artery Disease | 41.4 | 37.0 | 36.8 | 41.3 | 45.9 | 53.3 | 74.5 |
| Heart Failure | 25.1 | 17.0 | 24.2 | 27.9 | 29.7 | 33.0 | 38.2 |
| Hypertension | 25.0 | 13.9 | 21.1 | 27.9 | 37.5 | 44.9 | 41.30 |
| Asthma/COPD | 80.6 | 68.6 | 79.5 | 85.4 | 88.2 | 93.2 | 90.7 |
| Diabetes Mellitus | 27.4 | 27.1 | 26.8 | 28.0 | 29.8 | 26.2 | 25.8 |
| Cancer | 9.8 | 9.0 | 10.1 | 9.0 | 10.6 | 10.4 | 11.5 |
| Medication Use, (%) | | | | | | | |
| Anticoagulants | 7.3 | 8.9 | 6.1 | 6.9 | 7.2 | 5.7 | 12.7 |
| Antiplatelets | 22.7 | 20.5 | 23.4 | 21.7 | 21.2 | 27.1 | 29.2 |
| NSAIDs | 2.2 | 2.7 | 2.0 | 2.4 | 2.2 | 2.4 | 0.6 |
| RAAS Inhibitors | 15.2 | 12.4 | 15.9 | 17.4 | 16.0 | 13.7 | 14.0 |
| Beta Blockers | 26.1 | 21.3 | 24.1 | 26.1 | 30.0 | 41.7 | 37.6 |
| Loop Diuretics | 10.1 | 6.0 | 8.5 | 10.7 | 17.8 | 16.4 | 11.8 |
| Thiazide Diuretics | 2.3 | 2.3 | 2.2 | 2.7 | 2.3 | 2.7 | 0.6 |
| HMG-CoA Reductase Inhibitors | 20.9 | 20.3 | 20.7 | 18.9 | 21.4 | 22.6 | 28.9 |
| Oral Corticosteroids | 2.8 | 3.6 | 2.7 | 3.0 | 2.4 | 0.9 | 3.4 |
| Hospitalized (%) | 18.8 | 17.2 | 15.3 | 17.8 | 22.5 | 21.7 | 45.3 |
| Status 30 Days after SARS-COV-2 Diagnosis (%) | | | | | | | |
| Deceased | 15.3 | 7.3 | 15.6 | 17.9 | 18.9 | 24.7 | 18.3 |
| Alive, in Nursing Home | 72.6 | 80.0 | 73.8 | 71.7 | 67.1 | 61.0 | 60.6 |
| Discharged to Hospital | 7.8 | 7.6 | 6.6 | 6.2 | 9.9 | 11.6 | 14.6 |
| Discharged to Community | 4.2 | 5.0 | 3.9 | 3.9 | 4.1 | 2.7 | 6.2 |

Notes: CKD stage was determined using the median baseline serum creatinine value to calculate eGFR (in mL/min/1.73m$^2$) and categorized according to the KDIGO 2012 guidelines; all residents on dialysis were assigned to G5.

Medication use is during the 7 days prior to infection, clinical characteristics obtained during baseline period.

**Table 3-2. 30-Day All-Cause Mortality Among Nursing Home Residents Who Tested Positive for SARS-CoV-2, by CKD Stage**

| Model | | G1 (eGFR >90) | G2 (eGFR 60-89) | G3a (eGFR 45-59) | G3b (eGFR 30-44) | G4 (eGFR 15-29) | G5 (eGFR <15 or dialysis) |
|---|---|---|---|---|---|---|---|
| **Unadjusted** (95% CI) | Probability | 7.31% (5.90% to 8.72%) | 15.56% (13.79% to 17.34%) | 17.92% (15.57% to 20.28%) | 18.91% (15.82% to 22.00%) | 24.70% (20.36% to 29.05%) | 18.32% (14.00% to 22.64%) |
| | Risk Ratio | [ref] | 2.13 (1.77 to 2.55) | 2.45 (2.00 to 3.01) | 2.59 (2.08 to 3.21) | 3.38 (2.60 to 4.39) | 2.51 (1.85 to 3.39) |
| **Adjusted** (95% CI) | Probability | 10.09% (8.33% to 11.85%) | 14.46% (12.98% to 15.94%) | 16.35% (14.31% to 18.39%) | 17.42% (14.78% to 20.06%) | 21.76% (17.75% to 25.78%) | 23.16% (18.62% to 27.70%) |
| | Risk Ratio | [ref] | 1.43 (1.19 to 1.72) | 1.62 (1.34 to 1.96) | 1.73 (1.41 to 2.12) | 2.16 (1.69 to 2.75) | 2.30 (1.77 to 2.97) |

Notes: CKD stage was determined using the median baseline serum creatinine value to calculate eGFR (in mL/min/1.73m$^2$) and categorized according to the KDIGO 2012 guidelines.

Adjusted model adjusts for resident characteristics including: age, sex, long stay status, degree of cognitive and functional impairment, comorbidities, medication use during the 7 days prior to SARS-CoV-2 infection, and calendar month of SARS-CoV-2 diagnosis.

Predicted probabilities and risk ratios were calculated following logistic regression. Models clustered robust standard errors at the nursing home facility level.

**Figure 3-1. Adjusted 30-Day All-Cause Mortality Following SARS-CoV-2 Infection by CKD Stage and SARS-CoV-2 Risk Factors**

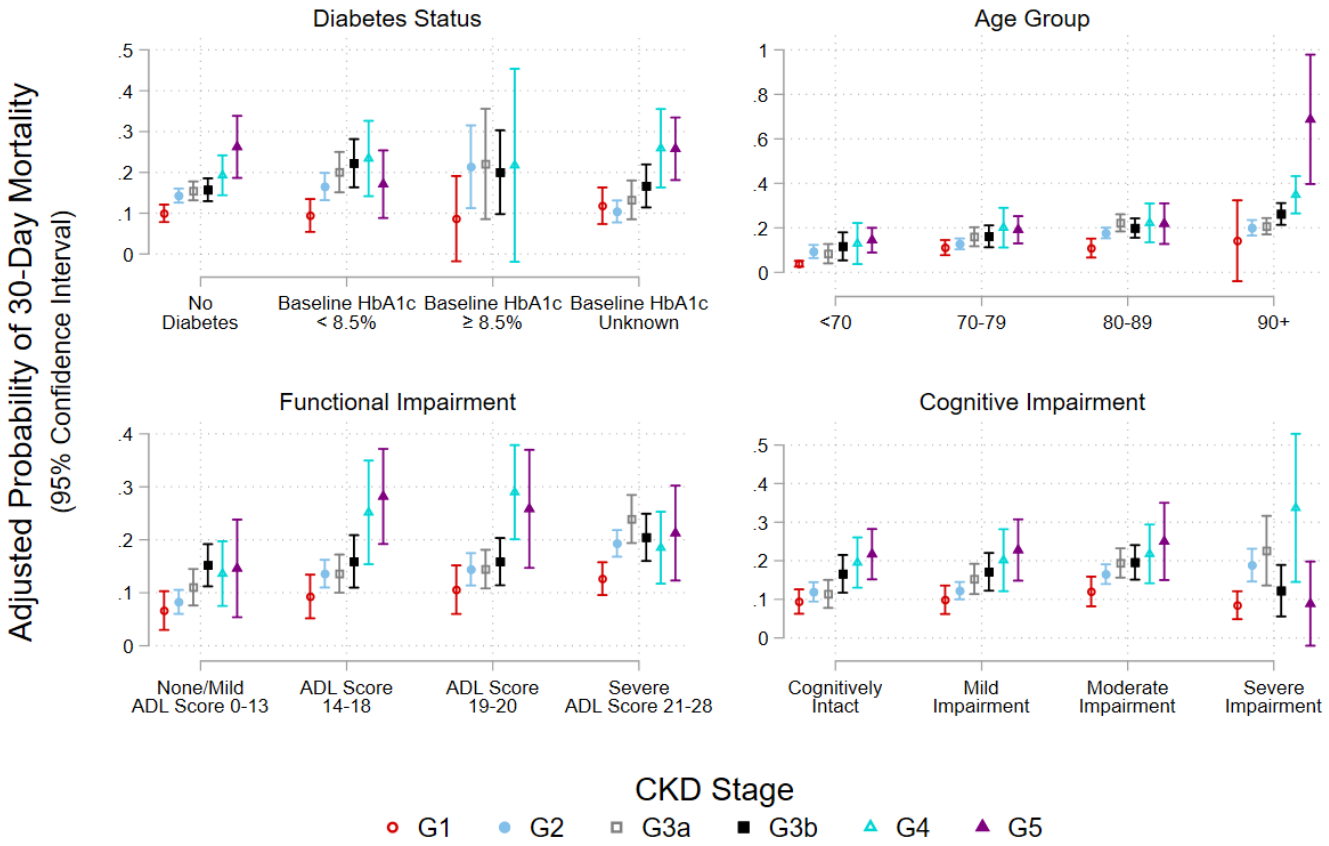



Figure panels show the adjusted probability of 30-day mortality by chronic kidney disease (CKD) stage within subgroups of other risk factors. In nearly all subgroups, mortality increases with advancing CKD stage, suggesting kidney function is associated with SARS-CoV-2 mortality independent of these risk factors.

Models adjust for all resident characteristics other than the risk factor under investigation, including: age, sex, long stay status, degree of cognitive and functional impairment, comorbidities, medication use during the 7 days prior to SARS-CoV-2 infection, and calendar month of SARS-CoV-2 diagnosis.

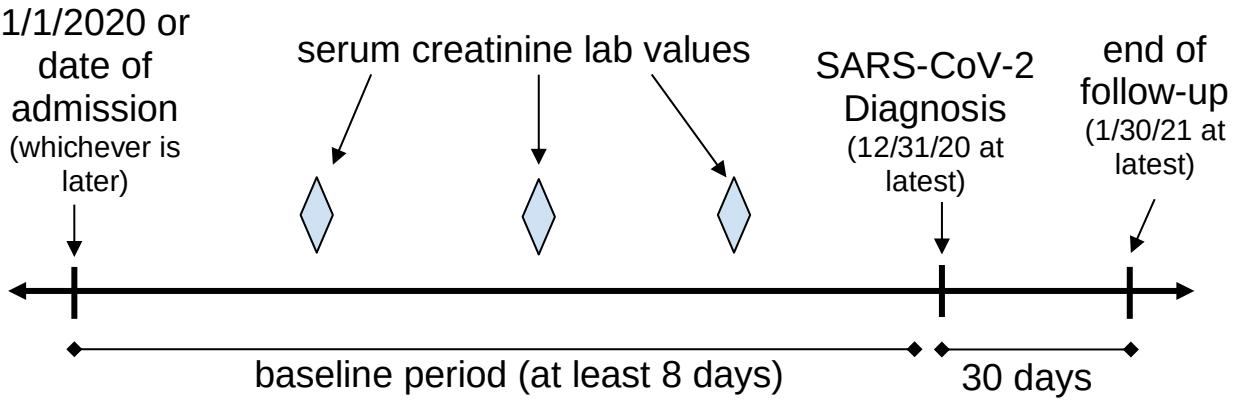
Predicted probabilities were calculated following logistic regression. Models clustered robust standard errors at the nursing home facility level. Due to collinearity, adjusted probability of mortality was not estimable for residents in the G5 group with HbA1c ≥ 8.5%.

## Supplemental Appendix

### Item S3-1. CKD Staging Details

We used information from the time period before a resident was diagnosed with SARS-CoV-2 to determine baseline kidney function. Laboratory data was available for all nursing home residents beginning January 1, 2020 or upon admission to the nursing home for residents admitted after that date. We considered the baseline period as the time between January 1, 2020/date of admission and the date of a resident's first positive SARS-CoV-2 test, which we considered to be the date of SARS-CoV-2 diagnosis.

We used laboratory data to identify all serum creatinine measurements during the baseline period, and calculated eGFR using the CKD-EPI formula.[1] For residents with multiple serum creatinine measurements during the baseline period we used the median value to determine kidney function in the main analysis.




For residents who lacked any baseline serum creatinine information, we used reported eGFR laboratory values, and again used the median value for residents with multiple reported values. We then classified kidney function by eGFR using the 2012 KDIGO guidelines:[2]

- G1 for eGFR $\geq$ 90 mL/min/1.73m$^2$;

- G2 for eGFR 60-89 mL/min/1.73m$^2$;
- G3a for eGFR 45-59 mL/min/1.73m$^2$;
- G3b for eGFR 30-44 mL/min/1.73m$^2$;
- G4 for eGFR 15-29 mL/min/1.73m$^2$; and
- G5 for eGFR <15 mL/min/1.73m$^2$ or a Minimum Data Set (MDS indicator for dialysis treatment.

All residents who had an MDS indicator for dialysis treatment at the most proximate baseline MDS assessment were assigned to G5 because dialysis patients frequently have bloodwork performed at the dialysis facility rather than at the nursing home, and therefore are less likely to have all laboratory results included in the nursing home's electronic health record (EHR). Of the G5 group, 86.7% were treated with dialysis according to the MDS, though there are concerns that the MDS may underreport comorbidities.[3]

We were able to determine baseline kidney function for 6,798 residents who were subsequently diagnosed with SARS-CoV-2. Of those, 6,613 were classified using serum creatinine to calculate eGFR, 35 were classified using reported eGFR values, and 150 were classified based on an MDS dialysis indicator (see Figure S3-1). Residents were classified using a median of 2 serum creatinine values (mean 3.2, range 1-57), and 64.8% of residents had two or more baseline serum creatinine measurements. The baseline period had a median length of 124 days (mean 164 days, range 8-365 days).

*Stability Analyses: Alternate Methods of Categorizing Kidney Function*

In stability analyses, we tested whether our results were robust to different methods of categorizing kidney function by:

- Using the most proximate baseline serum creatinine or eGFR value (rather than the median value) to classify kidney function (Table S3-7). In this stability analysis 11.95% of the sample was assigned to a different kidney function group than in the main analysis, and the period between the lab draw and SARS-CoV-2 diagnosis was a median of 37 days (mean 56 days, range 1-355 days).
- Using the highest baseline eGFR value (rather than the median value) to classify kidney function (Table S3-8). In this stability analysis, 15.71% of the sample was assigned to a different kidney function group than in the main analysis.
- Calculating eGFR using the CKD-EPI equation but omitting the race coefficient,[4] and using the median value to categorize kidney function (Table S3-9). In this stability analysis 4.66% of the sample was assigned to a different kidney function group than in the main analysis.

**Item S2. Statistical Analysis Details**

*Main Analyses*

To model the association between CKD stage and mortality following SARS-CoV-2 infection, we estimated multivariable logistic regression models for resident *i* at facility *j* during calendar month *m*

$$logit\left(died30_{ij}\right) = \beta_1 CKDstage_i + \theta_i + \delta_i + \gamma_{im} + \varepsilon_{ij}$$

with Huber-White robust standard errors clustered at the facility level.

- $\theta_i$ represents resident characteristics measured using MDS assessments (Table S3-2).
- $\delta_i$ represents medication use in the seven days prior to the first positive SARS-CoV-2 test date, not including the day of the test (Table S3-3).
- $\gamma_{im}$ represent indicators for the calendar month in which the resident's positive test occurred. We included this because SARS-CoV-2 mortality risk has varied temporally in this population due to factors such as testing and treatment availability, and potentially also due to virus and disease characteristics that changed over time.[5]
- $died30_{ij}$ is a binary indicator of whether resident *i* at facility *j* died within 30 days of their SARS-CoV-2 diagnosis. Follow-up for mortality began on the date of each resident's first positive SARS-CoV-2 test. The date of death was ascertained from the daily census and MDS. These data have been used in prior studies to identify deaths in this population.[5,6]

$\beta_1$ is the coefficient of interest; we used the `margins` post-estimation command in Stata to calculate the adjusted probability of all-cause 30-day mortality for each CKD stage. This post-estimation command estimates the adjusted predicted outcome (30-day all-cause mortality) for a certain independent variable (CKD stage) under the same distribution of covariates, providing

estimates which would be equivalent to those obtained by standardizing to the total population.[7] We also used the `adjrr` post-estimation command in Stata to calculate adjusted risk ratios.[8] We chose adjusted risk ratios because odds ratios exaggerate risk ratios when the outcome is common,[9] and death following SARS-CoV-2 infection is a common outcome in the nursing home population.

All analyses were performed in Stata version 17 (StataCorp) and used two-tailed hypothesis testing with a significance threshold of $p < 0.05$.

*Stability Analysis: By Resident Characteristics/Comorbidities*

To explore whether the association between CKD stage and mortality following SARS-CoV-2 infection differed by certain resident characteristics and comorbidities, we re-specified our statistical models to interact CKD stage and these characteristics (Figure 3-1). The characteristics of interest were:

- Diabetes status (no diabetes, median baseline HbA1c < 8.5%, median baseline HbA1c ≥ 8.5%, or no baseline HbA1c information).[10] We obtained information about diabetes from MDS records, and used baseline laboratory data to determine each resident's median baseline hemoglobin A1c level, using the same baseline period as we did to categorize kidney function.
- Age group (< 70 years old, 70-79 years old, 80-89 years old, ≥ 90 years old)
- Functional impairment, as measured by the Activities of Daily Living (ADL) functional score (broken into 4 quartiles, where higher scores are associated with greater dependency in ADLs), ascertained from MDS records

- Cognitive impairment (cognitively intact, mild impairment, moderate impairment, severe impairment), ascertained from MDS records

In separate models for each characteristic, we estimated the probability of mortality for each CKD stage within characteristic subgroup, adjusting for all the other covariates.

$$logit\left(died30_{ij}\right) = \beta_1(CKDstage_i \times characteristic_i) + \theta_i + \delta_i + \gamma_{im} + \varepsilon_{ij}$$

$\beta_1$ is the coefficient of interest; we used the `margins` post-estimation command in Stata to calculate the adjusted probability of all-cause 30-day mortality for each combination of CKD stage and characteristic subgroup.

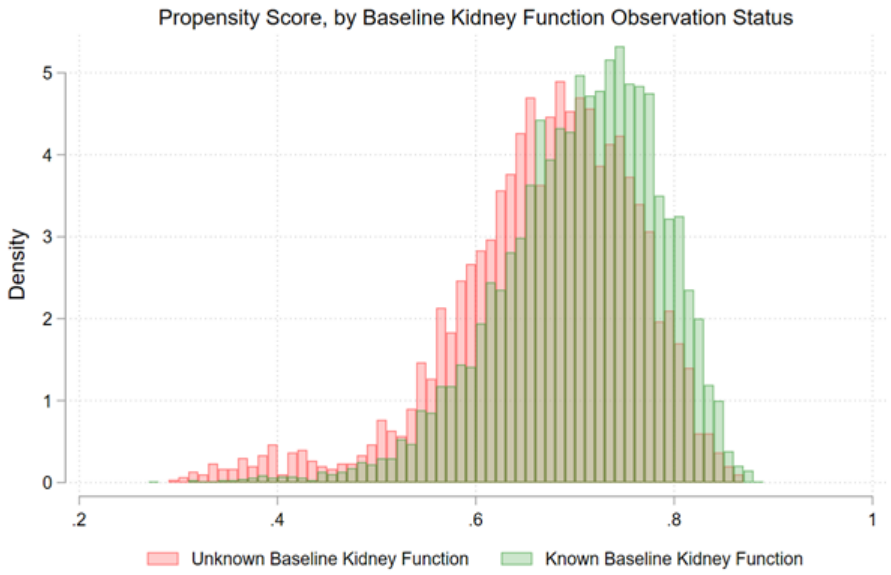
*Stability Analysis: Unknown Baseline Kidney Function*

Thirty percent of residents of nursing homes that reported electronic laboratory and medication information had no baseline information about kidney function, so were excluded from the main analysis (Figure S3-1). To address this, we constructed inverse probability of non-missingness weights (IPW) to estimate how our findings may have differed had those individuals with missing baseline eGFR information been included in the analysis.

To construct the weights, we created a binary indicator where individuals were assigned a value of 1 if they had no missing information about baseline kidney function (reported serum creatinine or eGFR test result or MDS dialysis indicator; $knownKF_i$ in the model below) and a value of 0 if they had missing information. We then used a multivariable logistic regression model to estimate the probability (i.e., propensity score) of having no missing laboratory information (versus having missing information) conditional on baseline covariates, including demographic characteristics and comorbidities (listed below and in Table S3-5).

$$logit\ (knownKF_i) = \theta_i + \delta_i + \gamma_{im} + \varepsilon_i$$

- $\theta_i$ represents resident characteristics drawn from MDS assessments (items in Table S3-2, as well as race/ethnicity and Alzheimer's diagnosis).
- $\delta_i$ represents medication use in the seven days prior to the first positive SARS-CoV-2 test date, not including the day of the test (medication classes in Table S3-3)
- $\gamma_m$ represent binary indicators for the calendar month in which the positive test occurred
- The distribution of propensity scores overlapped well for residents with known and unknown kidney function.




These probabilities were used to construct unstabilized inverse probability of non-missingness (i.e., selection) weights; residents with known kidney function received a weight of 1/P, and residents with unknown kidney function received a weight of 1/(1-P). The weights for the entire sample had the following characteristics:

| Mean | Median | Interquartile Range | Range |
|---|---|---|---|
| 2.00 | 1.51 | 1.35 to 2.49 | 1.13 to 7.69 |

After reweighting, characteristics between those with known and unknown kidney function were very similar (Table S3-5), with nearly all standardized differences less than 1 percent.

We then re-estimated our main statistical model for the cohort with known kidney function using the inverse probability of non-missingness weights to approximate the results for the entire cohort of residents with a positive SARS-CoV-2 test who met the other inclusion criteria (Table S3-6).

*Stability Analysis: Nursing Home Random Effects*

Though we saw no evidence of clustering of patients by CKD stage by nursing home, we estimated a multivariable logistic regression model with random intercepts for each nursing home to account for any clustering of residents with similar characteristics at certain facilities (Table S3-7).

**Table S3-1. Data Source Information**

| Data Source | Variables Used | Details |
|---|---|---|
| Minimum Data Set (MDS) 3.0[11(p0)] | • Date of assessment<br>• Date of birth<br>• Date of death<br>• Date of admission to the nursing home<br>• Sex<br>• Race/ethnicity<br>• Comorbidity indicators<br>• Dialysis treatment indicator<br>• Activities of Daily Living (ADL) functional score<br>• Cognitive function<br>• Height and weight (to calculate BMI)<br>• PHQ-9 Symptom Severity Score<br>• Discharges from and (re)admissions to the nursing home (date and type) | A comprehensive and standardized health assessment tool completed upon admission, discharge, and at regular intervals for all nursing home residents. We used information from the most recent MDS assessment prior to a resident's SARS-CoV-2 diagnosis to ascertain covariate information. The MDS assessment was incomplete at the time of SARS-CoV-2 diagnosis for less than 5% of residents; in these cases, we included MDS assessment information obtained during the seven days following their positive test. |
| **Electronic Health Record (available to researchers beginning 1/1/2020)** | | |
| Resident Census | • Date of death | Person-day file that includes transfers, discharges, and deaths |
| SARS-CoV-2 Testing and Results | • SARS-CoV-2 test results<br>• SARS-CoV-2 test dates | Used to identify first positive SARS-CoV-2 polymerase chain reaction or antigen test date and result. Inclusive of testing conducted in the nursing home and by outside laboratories. All residents underwent at least daily nursing assessments to screen for new symptoms of SARS-CoV-2. Testing was triggered by a number of factors, which included new symptoms, potential exposure, admission to the facility, or for surveillance when there was a confirmed outbreak. |
| Electronic Medication Administration Records | • Medications administered and date of administration | Used to identify use of medications in certain classes (see Supplemental Table 2) in the 7 days prior to SARS-CoV-2 diagnosis. |
| Electronic Laboratory Test Records | • Serum creatinine, eGFR, and HbA1c laboratory test dates and results | Used to determine baseline kidney function, baseline HbA1c. |

Note: All data sources were supplied to the researchers by Genesis Healthcare under an IRB-approved data use agreement. Nursing home residents had common identifiers in all datasets which allowed datasets to be linked.

**Table S3-2. Covariate Details**

| Covariate | Details |
|---|---|
| Age | continuous variable, from MDS<br>Calculated age at time of SARS-CoV-2 infection |
| Sex | binary variable (male or female), from MDS |
| Long Stay Status | binary variable, from MDS<br>defined as admission date ≥100 days earlier than first SARS-CoV-2 positive test date |
| Cognitive Function Category[12] | categorical variable, from MDS<br>• Cognitively Intact<br>• Mild Impairment<br>• Moderate Impairment<br>• Severe Impairment |
| Activities of Daily Living Score[13] | broken into 4 quartiles, from MDS<br>• 0-13, None/Mild Impairment<br>• 14-18<br>• 19-20<br>• 21-28, Severe Impairment |
| Coronary Artery Disease | binary variable, from MDS |
| Heart Failure | binary variable, from MDS |
| Hypertension | binary variable, from MDS |
| COPD/Asthma | binary variable, from MDS |
| Diabetes | binary variable, from MDS |
| BMI Category | calculated BMI using height and weight, from MDS, and categorized<br>• <18.5, Underweight<br>• 18.5-24.9, Normal Weight<br>• 25-29.9, Overweight<br>• 30-34.9, Obesity I<br>• ≥35, Obesity II or III<br>• Unknown (missing data) |
| Depression Category | PHQ-9 Symptom Severity Score, from MDS, and categorized<br>• None, 0<br>• Minimal/Mild, 1-10<br>• Moderate/Severe, 10-27<br>• Unknown (missing data) |

We used information from the most recent MDS assessment prior to a resident's SARS-CoV-2 diagnosis to ascertain covariate information. The MDS assessment was incomplete at the time of SARS-CoV-2 diagnosis for less than 5% of residents; in these cases, we included MDS assessment information obtained during the seven days following their positive test.

**Table S3-3. Medication Class Details**

| Medication Class | Included Medications |
|---|---|
| Anticoagulants | Warfarin, Apixaban, Dabigatran, Rivaroxaban, Edoxaban, Betrixaban, Fondaparinux, Enoxaparin, Dalteparin, Heparin |
| Antiplatelets | Aspirin, Clopidogrel, Prasugrel, Ticagrelor, Ticlopidine, Vorapaxar, Cilostazol |
| Non-Steroidal Anti-inflammatories (NSAIDs) | Celecoxib, Diclofenac, Etodolac, Diflunisal, Fenoprofen, Flurbiprofen, Ibuprofen, Indomethacin, Ketoprofen, Ketorolac, Mefenamic acid, Meloxicam, Nabumetone, Naproxen, Oxaprozin, Phenylbutazone, Piroxicam, Sulindac, Salsalate |
| Renin-Angiotensin-Aldosterone System (RAAS) Inhibitors | **ACEIs**: Benazepril, Captopril, Enalapril, Fosinopril, Lisinopril, Moexipril, Perindopril, Quinapril, Ramipril, Trandolapril<br>**ARBs**: Azilsartan, Candesartan, Eprosartan, Irbesartan, Losartan, Olmesartan, Telmisartan, Valsartan |
| Beta Blockers | Acebutolol, Atenolol, Betaxolol, Bisoprolol, Carvedilol, Labetalol, Metoprolol, Nadolol, Nebivolol, Propranolol, Pindolol |
| Loop Diuretics | Bumetanide, Ethacrynic acid, Furosemide, Torsemide |
| Thiazide Diuretics | Hydrochlorothiazide Chlorothiazide, Chlorthalidone, Indapamide, Metolazone, Methyclothiazide, Trichlormethiazide |
| Hydroxymethylglutaryl-Coenzyme A (HMG-CoA) Reductase Inhibitors | Atorvastatin, Fluvastatin, Lovastatin, Pitavastatin, Pravastatin, Rosuvastatin, Simvastatin |
| Oral Corticosteroids | Dexamethasone, Hydrocortisone, Methylprednisolone, Prednisone, Prednisolone |

We identified medication use using medication administration records within the EHR data and identified whether a medication was administered within the seven days prior to a resident's SARS-CoV-2 diagnosis date, excluding the day of diagnosis.

**Table S3-4 Differences in Control Variables for Residents with Known and Unknown CKD Stage Pre- and Post-Weighting**

| Variable | Pre-Weighting | | | Post-Weighting | | |
|---|---|---|---|---|---|---|
| | Known Kidney Function | Unknown Kidney Function | Standardized Difference (%) | Known Kidney Function | Unknown Kidney Function | Standardized Difference (%) |
| Age (mean) | 76.70 | 78.51 | -14.08 | 77.23 | 77.22 | 0.13 |
| Female (%) | 60.81 | 63.11 | -4.74 | 61.44 | 61.22 | 0.46 |
| Long Stay (%) | 77.74 | 77.54 | 0.49 | 77.53 | 77.10 | 1.01 |
| Race/Ethnicity (%) | | | | | | |
| Non-Hispanic White | 75.02 | 73.84 | 2.70 | 74.64 | 74.70 | -0.13 |
| Non-Hispanic Black | 15.18 | 14.56 | 1.74 | 14.97 | 14.87 | 0.28 |
| Hispanic/Latino | 6.15 | 7.40 | -4.97 | 6.56 | 6.55 | 0.03 |
| Other/Unknown | 3.65 | 4.20 | -2.84 | 3.83 | 3.88 | -0.26 |
| ADL Score Quartile (%) | | | | | | |
| 0-13 | 27.52 | 23.86 | 8.39 | 26.42 | 26.29 | 0.29 |
| 14-18 | 22.74 | 21.89 | 2.04 | 22.45 | 22.18 | 0.66 |
| 19-20 | 20.45 | 20.56 | -0.28 | 20.53 | 20.69 | -0.38 |
| 21-28 | 29.29 | 33.69 | -9.48 | 30.60 | 30.85 | -0.54 |
| Comorbidities (%) | | | | | | |
| Alzheimer's | 11.02 | 13.73 | -8.24 | 11.89 | 11.77 | 0.38 |
| Coronary Artery Disease | 25.14 | 23.06 | 4.87 | 24.46 | 24.29 | 0.40 |
| Heart Failure | 25.02 | 19.13 | 14.25 | 23.26 | 23.44 | -0.43 |
| Asthma/COPD | 27.38 | 23.89 | 7.98 | 26.34 | 26.44 | -0.23 |
| Dementia | 45.91 | 51.92 | -12.03 | 47.65 | 47.35 | 0.61 |
| Diabetes | 41.38 | 32.49 | 18.50 | 38.65 | 38.60 | 0.10 |
| Hypertension | 80.55 | 75.51 | 12.21 | 79.02 | 78.95 | 0.17 |
| Cancer | 9.81 | 9.16 | 2.21 | 9.57 | 9.50 | 0.23 |
| Cognitive Function Category (%) | | | | | | |
| Cognitively Intact | 40.44 | 31.59 | 18.51 | 37.76 | 37.79 | -0.06 |
| Mild Impairment | 23.35 | 21.76 | 3.79 | 22.88 | 22.91 | -0.08 |
| Moderate Impairment | 27.48 | 33.72 | -13.58 | 29.37 | 29.39 | -0.03 |
| Severe Impairment | 8.74 | 12.93 | -13.51 | 9.99 | 9.91 | 0.26 |
| BMI Category (%) | | | | | | |
| Normal Weight | 33.39 | 36.99 | -7.53 | 34.52 | 34.55 | -0.06 |
| Underweight | 6.50 | 8.86 | -8.88 | 7.22 | 7.22 | -0.03 |
| Overweight | 25.83 | 22.69 | 7.33 | 24.87 | 24.75 | 0.29 |

| Variable | Pre-Weighting | | | Post-Weighting | | |
|---|---|---|---|---|---|---|
| | Known Kidney Function | Unknown Kidney Function | Standardized Difference (%) | Known Kidney Function | Unknown Kidney Function | Standardized Difference (%) |
| Obesity I | 15.64 | 12.76 | 8.24 | 14.77 | 14.79 | -0.05 |
| Obesity II or III | 16.56 | 13.13 | 9.67 | 15.53 | 15.59 | -0.16 |
| Unknown | 2.07 | 5.56 | -18.29 | 3.09 | 3.10 | -0.07 |
| Depression Category (%) | | | | | | |
| None | 22.18 | 25.66 | -8.15 | 23.28 | 23.26 | 0.03 |
| Minimal/Mild | 53.15 | 47.05 | 12.22 | 51.31 | 51.35 | -0.09 |
| Moderate/Severe | 8.47 | 6.63 | 6.97 | 7.94 | 8.06 | -0.44 |
| Unknown | 16.20 | 20.66 | -11.53 | 17.48 | 17.33 | 0.40 |
| Month of SARS-CoV-2 Infection (%) | | | | | | |
| March | 1.60 | 1.57 | 0.30 | 1.60 | 1.57 | 0.24 |
| April | 29.73 | 32.76 | -6.53 | 30.59 | 30.40 | 0.40 |
| May | 14.62 | 13.63 | 2.85 | 14.25 | 13.98 | 0.78 |
| June | 4.02 | 4.77 | -3.66 | 4.28 | 4.45 | -0.84 |
| July | 6.19 | 5.16 | 4.44 | 5.86 | 5.83 | 0.13 |
| August | 4.15 | 4.83 | -3.30 | 4.44 | 4.74 | -1.42 |
| September | 3.30 | 2.97 | 1.89 | 3.21 | 3.32 | -0.58 |
| October | 4.97 | 5.36 | -1.77 | 5.08 | 5.13 | -0.23 |
| November | 11.61 | 10.63 | 3.11 | 11.35 | 11.45 | -0.29 |
| December | 19.81 | 18.33 | 3.79 | 19.33 | 19.13 | 0.52 |
| Medication Use (%) | | | | | | |
| RAAS Inhibitors | 15.24 | 14.16 | 3.04 | 14.98 | 15.24 | -0.72 |
| Anticoagulents | 7.25 | 6.10 | 4.62 | 6.91 | 6.92 | -0.04 |
| Antiplatelets | 22.68 | 21.63 | 2.55 | 22.34 | 22.32 | 0.06 |
| Beta Blockers | 26.13 | 22.33 | 8.88 | 25.05 | 25.26 | -0.48 |
| Loop Diuretics | 10.14 | 8.50 | 5.64 | 9.67 | 9.78 | -0.37 |
| NSAIDs | 2.21 | 2.60 | -2.56 | 2.35 | 2.35 | 0.00 |
| Oral Corticosteroids | 2.84 | 2.10 | 4.77 | 2.61 | 2.61 | 0.00 |
| HMG-CoA Reductase Inhibitors | 20.86 | 18.96 | 4.76 | 20.38 | 20.56 | -0.46 |
| Thiazide Diuretics | 2.25 | 2.20 | 0.35 | 2.24 | 2.28 | -0.31 |

**Table S3-5. Stability Analysis: Probability of 30-Day All-Cause Mortality Among Nursing Home Residents Who Tested Positive for SARS-CoV-2, by CKD Stage, Weighted by Inverse Probability of Non-Missingness Weights**

| Model | G1 (eGFR >90) | G2 (eGFR 60-89) | G3a (eGFR 45-59) | G3b (eGFR 30-44) | G4 (eGFR 15-29) | G5 (eGFR <15 or chronic dialysis) |
|---|---|---|---|---|---|---|
| **Unadjusted** | 7.68% (6.21% to 9.16%) | 16.48% (14.64% to 18.32%) | 18.79% (16.32% to 21.25%) | 19.64% (16.49% to 22.79%) | 26.05% (21.65% to 30.45%) | 18.91% (14.53% to 23.29%) |
| **Adjusted** | 10.57% (8.72% to 12.42%) | 15.32% (13.78% to 16.86%) | 17.20% (15.06% to 19.34%) | 18.17% (15.46% to 20.88%) | 23.01% (18.88% to 27.14%) | 24.15% (19.52% to 28.78%) |

Notes: CKD stage was determined using the median baseline serum creatinine value to calculate eGFR (in mL/min/1.73m$^2$) and categorized according to the KDIGO 2012 guidelines.

Adjusted model adjusts for resident age, sex, long stay indicator (≥100 days), cognitive function, activities of daily living (ADL) score (broken into 4 quartiles), comorbidities, medication use during the 7 days prior to SARS-CoV-2 infection, and calendar month of SARS-CoV-2 infection.

Predicted probabilities were calculated following logistic regression; 95% confidence intervals in parentheses. Models clustered robust standard errors at the facility level.

Models were weighted by the inverse likelihood of having known baseline kidney function (reported serum creatinine or eGFR test result or an MDS dialysis indicator) to approximate results for the entire cohort of residents who met the other inclusion criteria.

**Table S3-6. Stability Analysis: Probability of 30-Day All-Cause Mortality Among Nursing Home Residents Who Tested Positive for SARS-CoV-2, by CKD Stage, with Nursing Home Random Effects**

| Model | G1 (eGFR >90) | G2 (eGFR 60-89) | G3a (eGFR 45-59) | G3b (eGFR 30-44) | G4 (eGFR 15-29) | G5 (eGFR <15 or chronic dialysis) |
|---|---|---|---|---|---|---|
| **Unadjusted** | 6.71% (5.36% to 8.06%) | 13.69% (11.93% to 15.45%) | 15.81% (13.54% to 18.09%) | 16.77% (13.95% to 19.59%) | 22.04% (17.45% to 26.64%) | 16.56% (12.17% to 20.95%) |
| **Adjusted** | 9.71% (7.95% to 11.47%) | 13.39% (11.9% to 14.87%) | 15.20% (13.22% to 17.18%) | 16.39% (13.95% to 18.84%) | 20.84% (16.82% to 24.86%) | 22.54% (17.93% to 27.15%) |

Notes: CKD stage was determined using the median baseline serum creatinine value to calculate eGFR (in mL/min/1.73m$^2$) and categorized according to the KDIGO 2012 guidelines.

Adjusted model adjusts for resident age, sex, long stay indicator (≥100 days), cognitive function, activities of daily living (ADL) score (broken into 4 quartiles), comorbidities, medication use during the 7 days prior to SARS-CoV-2 infection, and calendar month of SARS-CoV-2 infection.

Predicted probabilities were calculated following logistic regression; 95% confidence intervals in parentheses. Models included nursing home random effects.

**Table S3-7. Stability Analysis: Probability of 30-Day All-Cause Mortality Among Nursing Home Residents Who Tested Positive for SARS-CoV-2, by CKD Stage, Characterized by Most Recent Pre-COVID Measurement**

| Model | G1 (eGFR >90) | G2 (eGFR 60-89) | G3a (eGFR 45-59) | G3b (eGFR 30-44) | G4 (eGFR 15-29) | G5 (eGFR <15 or chronic dialysis) |
|---|---|---|---|---|---|---|
| **N** | 1,441 | 2,662 | 1,106 | 910 | 353 | 326 |
| **Unadjusted** | 7.43% (6.06% to 8.79%) | 15.59% (13.81% to 17.37%) | 17.18% (14.72% to 19.64%) | 19.67% (16.41% to 22.93%) | 24.08% (19.75% to 28.41%) | 18.71% (14.44% to 22.98%) |
| **Adjusted** | 10.16% (8.35% to 11.96%) | 14.49% (13.03% to 15.95%) | 15.56% (13.41% to 17.70%) | 17.91% (15.16% to 20.66%) | 22.31% (18.37% to 26.26%) | 23.51% (18.93% to 28.08%) |

Notes: CKD stage was determined using the baseline serum creatinine value most proximate to the SARS-CoV-2 test date to calculate eGFR (in mL/min/1.73m$^2$) and categorized according to the KDIGO 2012 guidelines.

Adjusted model adjusts for resident age, sex, long stay indicator (≥100 days), cognitive function, activities of daily living (ADL) score (broken into 4 quartiles), comorbidities, medication use during the 7 days prior to SARS-CoV-2 infection, and calendar month of SARS-CoV-2 infection.

Predicted probabilities were calculated following logistic regression; 95% confidence intervals in parentheses. Models clustered robust standard errors at the facility level.

**Table S3-8. Stability Analysis: Probability of 30-Day All-Cause Mortality Among Nursing Home Residents Who Tested Positive for SARS-CoV-2, by CKD Stage, Characterized by Highest Baseline eGFR Measurement**

| Model | G1 (eGFR >90) | G2 (eGFR 60-89) | G3a (eGFR 45-59) | G3b (eGFR 30-44) | G4 (eGFR 15-29) | G5 (eGFR <15 or chronic dialysis) |
|---|---|---|---|---|---|---|
| **N** | 1,746 | 2,775 | 1,011 | 709 | 253 | 304 |
| **Unadjusted** | 7.90% (6.63% to 9.18%) | 16.58% (14.78% to 18.37%) | 18.20% (15.45% to 20.95%) | 19.46% (15.93% to 23.00%) | 25.30% (20.42% to 30.17%) | 17.43% (13.17% to 21.69%) |
| **Adjusted** | 10.95% (9.26% to 12.64%) | 15.11% (13.62% to 16.61%) | 16.07% (13.80% to 18.34%) | 17.45% (14.48% to 20.41%) | 21.85% (17.28% to 26.42%) | 22.23% (17.50% to 26.97%) |

Notes: CKD stage was determined based using the lowest baseline serum creatinine value (highest baseline eGFR value) to calculate eGFR (in mL/min/1.73m$^2$) and categorized according to the KDIGO 2012 guidelines.

Adjusted model adjusts for resident age, sex, long stay indicator (≥100 days), cognitive function, activities of daily living (ADL) score (broken into 4 quartiles), comorbidities, medication use during the 7 days prior to SARS-CoV-2 infection, and calendar month of SARS-CoV-2 infection.

Predicted probabilities were calculated following logistic regression; 95% confidence intervals in parentheses. Models clustered robust standard errors at the facility level.

**Table S3-9. Stability Analysis: Probability of 30-Day All-Cause Mortality Among Nursing Home Residents Who Tested Positive for SARS-CoV-2, by CKD Stage, Characterized by Median eGFR Measurement Calculated without Race Coefficient**

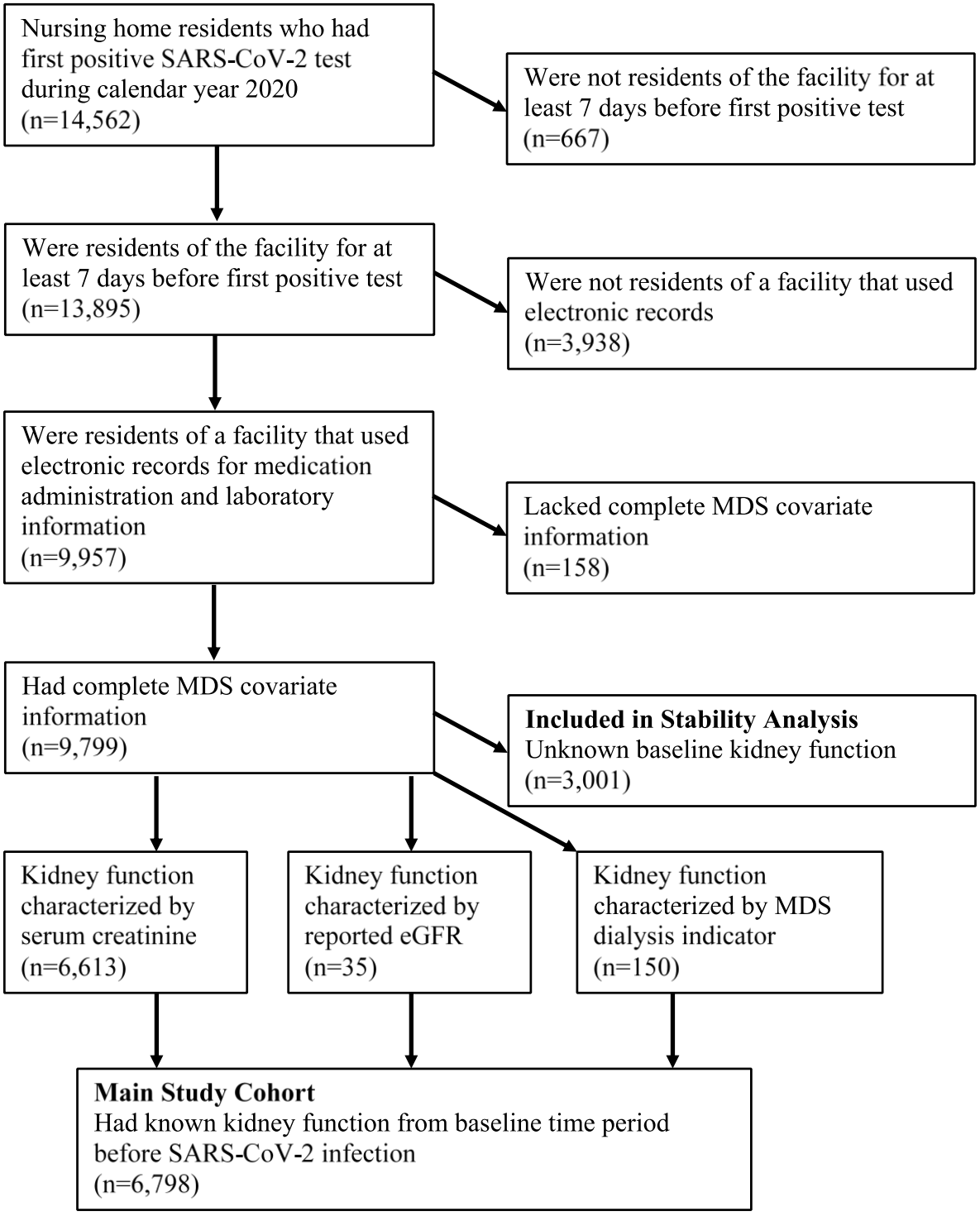
| Model | G1 (eGFR >90) | G2 (eGFR 60-89) | G3a (eGFR 45-59) | G3b (eGFR 30-44) | G4 (eGFR 15-29) | G5 (eGFR <15 or chronic dialysis) |
|---|---|---|---|---|---|---|
| **N** | 1,270 | 2,764 | 1,146 | 941 | 350 | 327 |
| **Unadjusted** | 6.93% (5.47% to 8.39%) | 15.27% (13.49% to 17.05%) | 17.45% (15.00% to 19.90%) | 18.81% (15.74% to 21.88%) | 26.00% (21.57% to 30.43%) | 18.04% (13.76% to 22.33%) |
| **Adjusted** | 10.17% (8.23% to 12.11%) | 14.20% (12.73% to 15.68%) | 16.04% (13.91% to 18.17%) | 17.04% (14.48% to 19.59%) | 23.22% (19.07% to 27.37%) | 22.57% (17.98% to 27.16%) |

Notes: CKD stage was determined using the median serum creatinine value to calculate eGFR (in mL/min/1.73m$^2$), using the CKD-EPI equation without the race coefficient, and categorized according to the KDIGO 2012 guidelines.

Adjusted model adjusts for resident age, sex, long stay indicator (≥100 days), cognitive function, activities of daily living (ADL) score (broken into 4 quartiles), comorbidities, medication use during the 7 days prior to SARS-CoV-2 infection, and calendar month of SARS-CoV-2 infection.

Predicted probabilities were calculated following logistic regression; 95% confidence intervals in parentheses. Models clustered robust standard errors at the facility level.

**Figure S3-1. Study Cohort Identification**




Flowchart of the study cohort selection; 14,562 nursing home residents tested positive for SARS-CoV-2 during calendar year 2020 and after exclusions, 6,798 residents were included in the main analysis.

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