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Research Article

COVID-19 in Haemodialysis Patients: Identifying Key Risk Factors for Adverse Outcomes

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Summary

This study highlights the heightened vulnerability of haemodialysis patients to severe COVID-19 outcomes, revealing that socio-economic deprivation significantly increases mortality risk despite uniform healthcare access in dialysis settings. The findings underscore the need for targeted care, especially during surges of more virulent virus variants, to better protect this high-risk population.

Keywords: *Haemodialysis (HD); COVID-19; Mortality; Deprivation*

Abstract :

Background: *Haemodialysis (HD) patients are particularly vulnerable to SARS-CoV-2 due to frequent healthcare exposure and multiple comorbidities. This study examines outcomes of HD patients infected with SARS-CoV-2 and evaluates risk factors for hospital admission, Intensive Care Unit (ITU) admission, length of stay, and 30-day mortality.*

Methods: *A retrospective cohort study was conducted in four HD centres at a major London hospital, including 249 SARS-CoV-2-positive HD patients from March 2020 to August 2021. Data on demographics, comorbidities, deprivation, and COVID-19 wave were collected. PCR was used for nasopharyngeal swabs, with genotypic analysis in waves 2 and 3. Logistic regression models assessed risk of hospital and ITU admissions, while a Cox proportional hazards model was applied for 30-day mortality.*

Results: *Of the HD population, 28.9% contracted SARS-CoV-2, 96% had at least one comorbidity, 40% required hospital admission, 11% needed ITU care, and 11% died within 30 days (median time-to-death: 14 days). Mortality was significantly higher in the second wave (p = 0.038), coinciding with the Alpha variant. Age was the only factor associated with hospital admission (OR 1.03, 95% CI 1.01–1.06, p = 0.008). In multivariate analysis, age, comorbidities, deprivation, and wave 2 infection were linked to increased mortality hazard, with lower deprivation significantly reducing risk (HR 0.50, 95% CI 0.26–0.95, p = 0.036).*

Discussion: *The findings underscore the increased vulnerability of HD patients to COVID-19, particularly with emerging variants. Although age was the main predictor of hospital admission, mortality was also influenced by comorbidities and deprivation, indicating socio-economic disparities despite uniform healthcare access.*

BACKGROUND

Nearly 25,000 patients with Chronic Kidney Disease (CKD) are treated with Haemodialysis (HD) in the UK [1]. For these patients, haemodialysis represents a lifeline. However, patients on haemodialysis were disproportionally affected during the recent COVID-19 pandemic. HD patients are recognised to be more susceptible, and more vulnerable, to SARS-CoV-2 [2]. Compared to other vulnerable groups, HD patients were largely unable to reduce social contact due to their requirement to attend a healthcare facility several times a week for dialysis treatments. Indeed, 93% dialyse thrice weekly with 71% spending 4-5 hours in the dialysis centre [1]. This led to a high rate of nosocomial transmission between HD patients and between healthcare workers and patients.

In the UK, there were three major 'waves' of SARS-CoV-19 infection during 2020 and 2021 [3]. These waves represented both peaks in transmission, and changes in the dominant circulating variant. The first wave (March–May 2020) involved the wild-type virus. The Alpha variant, which was more transmissible, emerged during wave 2 (September 2020–April 2021), while the Delta variant dominated wave 3 (June–August 2021), known for its higher virulence and reduced vaccine protection.

Stringent lockdown measures, including mask-wearing, social distancing, and travel restrictions, were imposed in the first wave, followed by a relaxation between waves and an increase in cases and subsequent reinstatement [4]. Vaccinations began in December 2020, with HD patients starting to receive vaccines in early 2021. By June 2021 half of UK adults had been received two doses of the vaccination against SARS-CoV-2 [5].

In this study we aimed to describe the characteristics of our HD cohort of patients who tested positive for SARS-CoV-2 from March 2020 to August 2021. We aimed to determine risk factors that predict hospital admission, hospital stay length, intensive treatment unit admission and death within 30 days from a positive SARS-CoV-2 swab.

METHODS

Patient Cohort

This retrospective cohort study reviewed HD patients from four centres at a London university hospital. All HD patients with a positive Nasopharyngeal Swab (NPS) for SARS-CoV-2 between March 2020 and August 2021 were included. Socio-economic deprivation was assessed using the UK's Index of Multiple Deprivation (IMD) based on patient postcodes, ranking areas into deciles (Decile 1 = most deprived, Decile

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10 = least deprived). Ethnicity was classified as White, Afro-Caribbean, Asian, Mixed, or Other, with "Other" representing those not identifying with listed groups.

Clinical details for positive patients were obtained from electronic records, including demographics, co-morbidities, vaccination status, and adverse outcomes (hospital admission, length of stay, ITU admission, and death within 30 days). Length of stay was calculated only for patients who survived beyond 30 days post-positive NPS.

SARS-CoV-2 Testing

RT-PCR was used for NPS testing. Initially, only symptomatic or suspected cases were tested, but routine screening every two weeks began in June 2020. Positive patients were isolated for at least 14 days, with re-testing for contacts. Swabs taken outside the hospital were excluded due to lack of access to data.

Wave Classification

Cases were grouped by transmission surges in the UK: Wave 1 (March-May 2020), Wave 2 (September 2020-April 2021), and Wave 3 (June-August 2021).

Genotype Analysis

All NPS after wave 1 underwent genotypic analysis by whole genome sequencing carried out at the central reference lab, UK Health Security Agency.

Vaccination Status

Vaccination status was classified as: unvaccinated; between two vaccine doses; and vaccinated. Our cohort received Pfizer-BioNTech, AstraZeneca or both vaccinations. During the study period no booster vaccinations were given. The cohort described in Wave 1 consisted entirely of unvaccinated patients.

Statistical Analysis

Descriptive statistics were calculated, stratified by wave, with comparisons between waves using chi-square, Fisher's exact, and Kruskal-Wallis tests. Multiple logistic regression models assessed predictors of hospital and ITU admission, including age, sex, ethnicity, comorbidities, deprivation index, and wave.

Penalized regression was used for ITU admission due to sparse data. Odds Ratios (OR) and 95% Confidence Intervals (CI) were reported, with model fit assessed by the Hosmer-Lemeshow test and Variance Inflation Factors (VIF) for multicollinearity. Linear regression predicted log-transformed hospital stay lengths, with model fit checked via residual plots and VIF. Kaplan-Meier curves and Cox proportional hazards models examined 30-day mortality, using penalized splines for non-linear age effects and Schoenfeld residuals for proportional hazards. Analyses were conducted in R 4.4.1, with significance at $P < 0.05$.

RESULTS

Number of Patients

Data were collected on 544 SARS-CoV-2 positive NPS samples from 249 patients from 11/02/2020 to 14/09/2021. Three patients with two distinct infections were analyzed only once to maintain statistical independence. Among 765 HD patients, 28.9% tested positive for SARS-CoV-2 over the three waves, with an infection prevalence of 17.4% in the first wave (April 2020) when there were 649 patients (Figure 1)

Patient Demographics

The HD cohort's mean age was 61.9 years; 58.6% were male. Ethnicity distribution was 34.1% White, 27.7% Afro-Caribbean, 19.3% Asian, 3.6% Mixed, and 15.3% Other. Ethnicity and deprivation levels did not significantly differ between infected and non-infected patients in wave 1 (Wilcoxon rank sum test: $W = 27915$, $p = 0.233$; Fisher's exact test: $p = 0.345$).

Patients had a mean of 2.6 comorbidities, with 96.2% having at least one. The most common were hypertension (78.9%), diabetes (56%), and ischemic heart disease (30%) (Figure 2). Demographics remained consistent across waves, except for the number of patients in each dialysis unit (Table 1 & Supplementary Figure 1,2).

Genotype

No genotypic data was available for wave 1. During wave 2, 84 patients

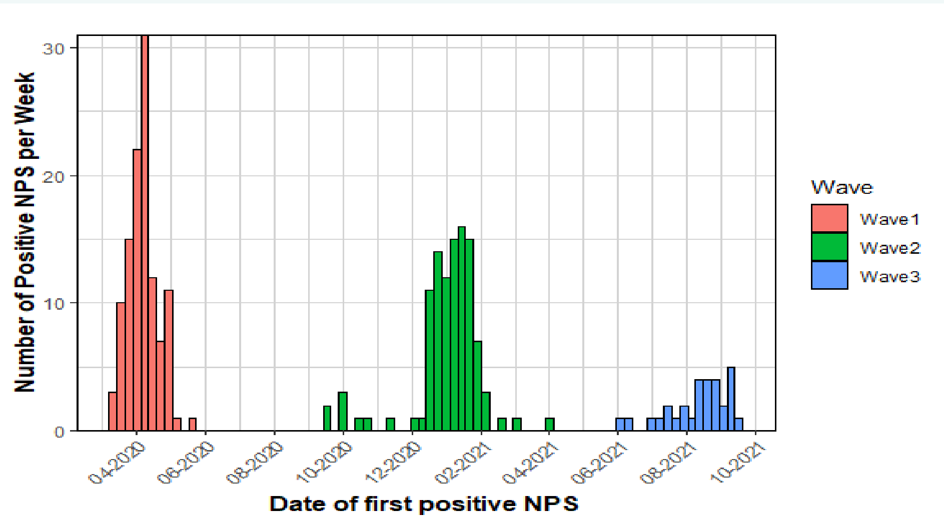


Figure 1: Number of weekly positive SARS-CoV-2 NPS per wave.
The number of positive NPS cases per week is represented on the y-axis, with the date of first positive NPS on the x-axis. Wave 1 (red) peaked in early 2020, Wave 2 (green) occurred primarily during late 2020 and early 2021, while Wave 3 (blue) peaked later in 2021. The colours represent the different waves, indicating the timing and intensity of infection spread among haemodialysis patients.

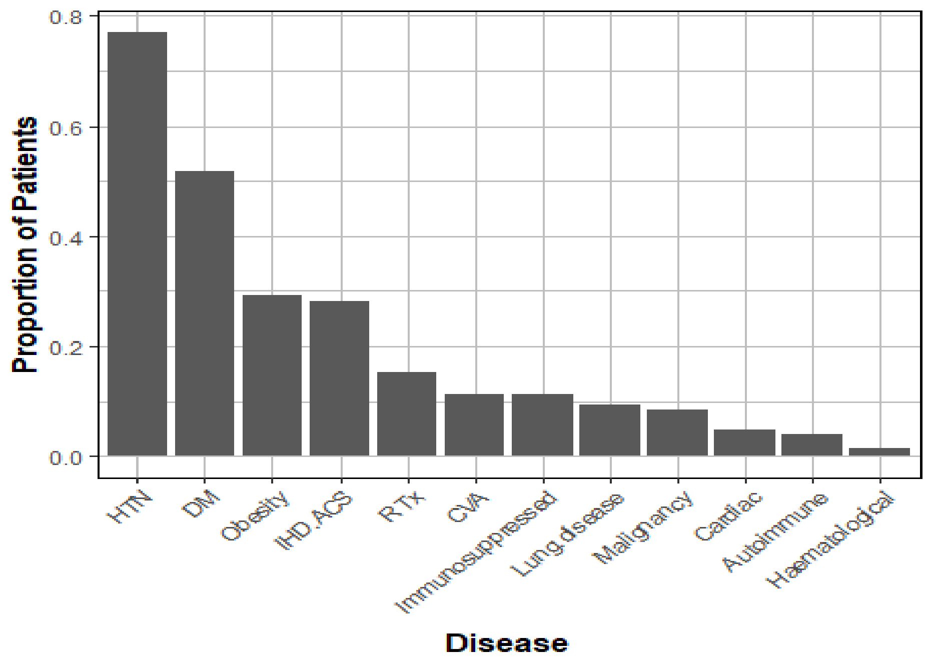


Figure 2: Proportion of comorbidities for total cohort.
HTN: Hypertension; DM: Diabetes Mellitus; IHD ACS: Ischaemic Heart Disease or Acute Coronary Syndrome; CVA: Cerebrovascular Accident; RTx: Renal Transplant.

had genotypic data available; With 92% of NPS identified to be B.1.1.7, 3.6% B.177.54, and 1.2% each for B.1, B.177, B.177.1, B.177.11, B.1.258.4, B.1.525. In wave 3, 22 patients had genotypic data available; 64% were B.1.617.2, 27% AY.4, and 4.5% each for AY.10, AY.12 (Supplementary Figure 3).

Adverse Outcomes per Wave

For HD patients with a positive NPS, 40.3% were admitted to hospital, with 11.2% of these admissions then transferred to the Intensive Care Unit (ITU). Mean hospital stay was 13.4 days with a median stay of 7

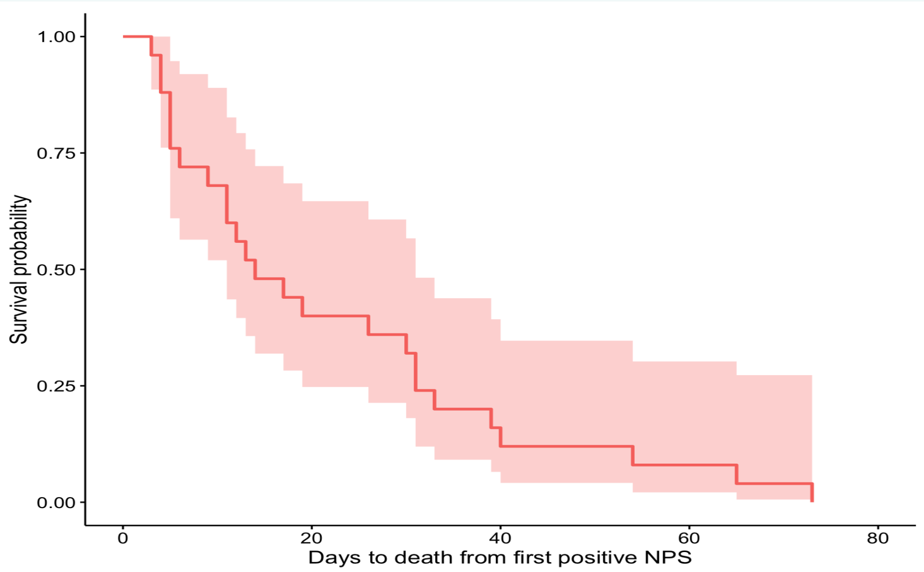


Figure 3: Survival curve for all deaths within 30 days of a positive NPS.
Kaplan-Meier survival curve depicting the probability of survival for HD patients from the date of first positive nasopharyngeal swab (NPS) for SARS-CoV-2. The red line represents the survival probability over time, with the shaded area indicating the 95% confidence interval. The X-axis represents the number of days from the first positive NPS to death, and the Y-axis represents the probability of survival.

Table 1: Patient demographics and adverse outcomes in total and per wave.

This table presents the demographics and adverse outcomes of patients across three COVID-19 waves. Statistical significance was determined using Chi-square, Fisher, and Wilcoxon tests, with p-values indicated. A *P*-value less than 0.05 is marked with an asterisk (*) to denote statistical significance.

	Across all waves	Wave 1	Wave 2	Wave 3	*P*-value
Number of patients	249	113	106	30	
Mean age (range)	64 (18-91)	63 (19-91)	61 (18-87)	69 (22-85)	0.21
Sex					0.53
Male	145 (58.6%)	62 (54.9%)	64 (61.3%)	19 (63.3%)	
Female	103 (41.4%)	51 (45.1%)	41 (38.7%)	11 (36.7%)	
Ethnicity					0.24
White	85 (34.1%)	39 (34.5%)	36 (24.5%)	10 (33.3%)	
Afro-Caribbean	69 (27.7%)	36 (31.9%)	22 (20.8%)	11 (36.7%)	
Asian	48 (19.3%)	20 (17.7%)	26 (24.5%)	2 (6.7%)	
Mixed	9 (3.6%)	3 (2.7%)	4 (3.8%)	2 (6.7%)	
Other	38 (15.2%)	15 (12.3%)	18 (17.0%)	5 (16.7%)	
Vaccination status at time of infection					**< 0.001***
Unvaccinated	123 (89.6%)	113 (100%)	103 (97.1%)	7 (23.3%)	
One dose	3 (1.2%)	0 (0%)	3 (2.8%)	0 (0%)	
Two doses	23 (9.2%)	0 (0%)	0 (0%)	23 (76.7%)	
Mean number of co-morbidities (median)	2.9 (3)	2.9 (3)	3.0 (3)	3.1 (3)	0.65
Mean Multiple Deprivation Rank (median)	4.1 (4)	3.9 (4)	4.1 (4)	5.6 (6)	0.11
Adverse Outcomes					
Hospital Admission					0.084
Admitted	101 (40.6%)	54 (47.8%)	35 (33.0%)	12 (40%)	
Not Admitted	148 (59.4%)	59 (52.2%)	71 (67.0%)	18 (60%)	
Mean Admission Length (median) / days	15.5 (8)	16.8 (9)	12.5 (7)	18.8 (7)	0.61
Admitted to ITU					0.23
Admitted	10 (9.9%)	4 (7.4%)	6 (17.1%)	0 (0%)	
Not Admitted	91 (90.1%)	50 (92.6%)	29 (82.9%)	12 (100%)	
Death within 30 days					**0.023***
Deaths	25 (10.0%)	7 (6.2%)	17 (16.0%)	1 (3.3%)	
Recovered	224 (90.0%)	106 (93.8%)	89 (84.0%)	29 (96.7%)	

days. There were 25 deaths within 30 days of a positive NPS throughout all waves, representing 11.3% of the cohort. Only the number of deaths differed significantly between waves, with a statistically higher number of patients dying within 30 days in wave 2 (6.2% of HD patients with a positive NPS died in wave 2, 16.0% in wave 2, 3.3% in wave 3, p = 0.038) (Supplementary Figure 4).

Risk Factors for Adverse Outcomes

Univariate analysis (Table 2) found that age was significantly associated with hospital admission (p = 0.035) and death within 30 days (p=0.00533), with older patients more likely to be admitted and experience mortality. Comorbidities, Index of Multiple Deprivation decile, and vaccination status were not significantly linked to adverse outcomes. Dialysis unit was associated with 30-day mortality (p = 0.0434), while ethnicity was linked to mortality (p = 0.0030), with White and Afro-Caribbean patients showing higher death rates. There was no significant association between vaccination status and outcomes, but the test was likely underpowered due to the small number of vaccinated patients with adverse outcomes.

Multivariate analysis (Table 3) confirmed age as a significant predictor of hospital admission, with each year increasing the odds by 3% (OR: 1.03, 95% CI: 1.01–1.06, p = 0.008), though it was not associated with ITU admission or admission length. No significant associations were found for comorbidities, deprivation level, sex or COVID-19 wave. 'Other' ethnicity showed reduced odds of hospital admission (OR: 0.236, 95% CI: 0.059–0.777, p = 0.026). Model diagnostics revealed that the assumptions were met, and all variance inflation factors were below 5 (Supplementary Figure 5). Vaccination status and dialysis unit was not included in any multivariate analysis due to sparsity of data.

Survival analysis for deaths within 30 days of a positive NPS showed a median time to death of 14 days (Figure 3). In the Cox regression (Table 3), age had a significant non-linear effect on 30-day mortality (p = 0.021), while the linear term was not significant (p = 0.940). Comorbidities were a strong predictor of mortality (HR 4.08, 95% CI 1.48–11.27, p = 0.0066). Wave 2 was associated with increased mortality risk compared to Wave 1 (HR 128.8, 95% CI 4.16–3982.73, p = 0.0055), but Wave 3 showed no difference. Lower deprivation (i.e., a higher Index of Multiple Deprivation decile), which was not significant in the univariate analysis when mortality was treated as a binary variable, was associated with reduced mortality risk in the Cox proportional hazards model (HR 0.50, 95% CI 0.26–0.95, p = 0.036). Ethnicity was excluded due to insufficient events, and model diagnostics confirmed no violations of the proportional hazards assumption (global p = 0.11).

DISCUSSION

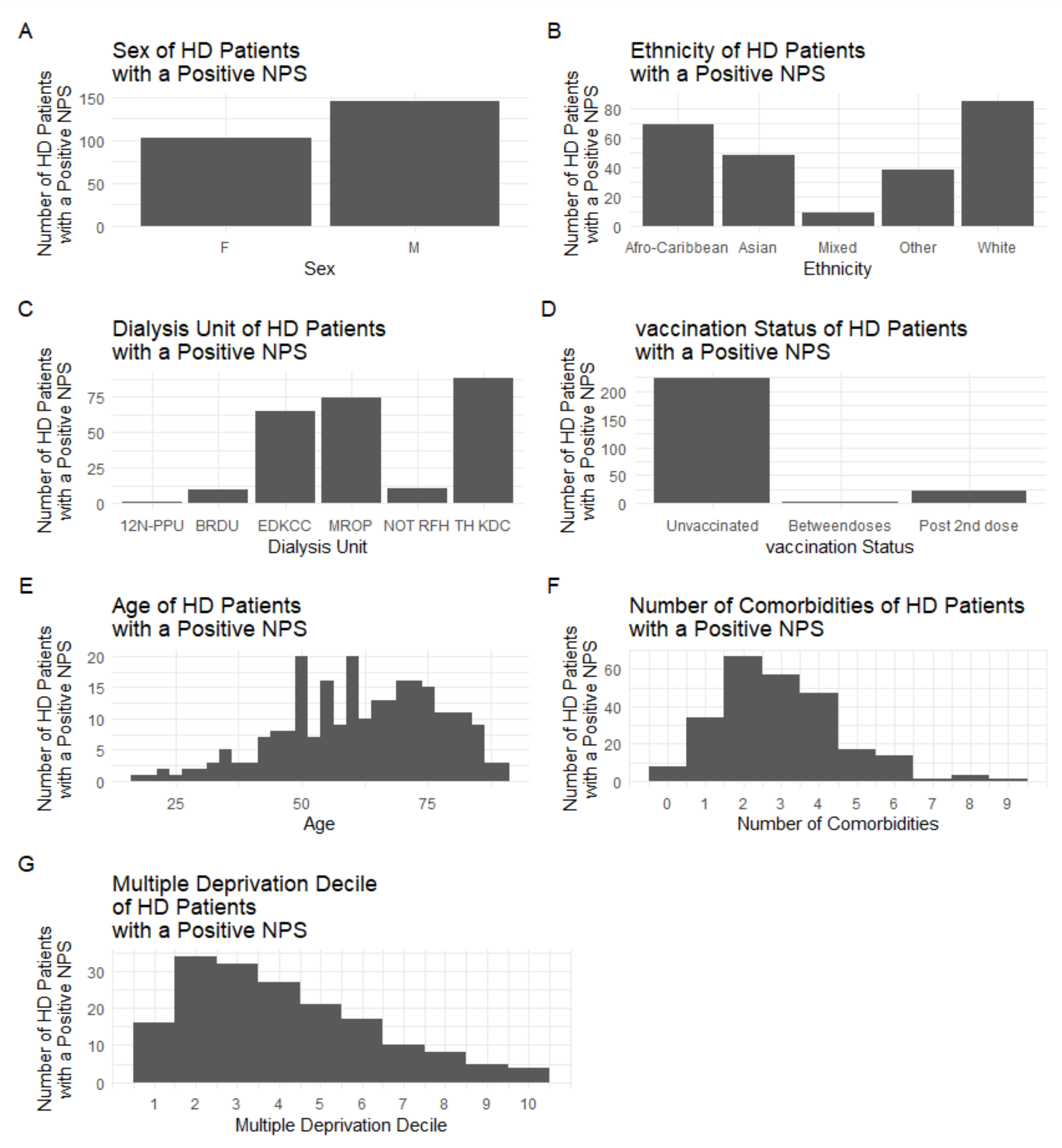
This study characterizes HD patients in a major London hospital during the first three UK SARS-CoV-2 waves. Over a quarter of HD patients were infected with SARS-CoV-2, with 96% having at least one additional comorbidity. Of the patients infected, 10% died within 30 days of testing positive for SARS-CoV-2, with a median time-to-death of 14 days. Mortality was significantly higher in wave 2. Risk factors for adverse outcomes included age, ethnicity, the number of comorbidities, and deprivation levels. The SARS-CoV-2 infection rate in HD patients was 28.6%, much higher than the general population [6]. This high prevalence likely results from increased virus transmissibility, communal transport to dialysis centres, prolonged time spent in poorly ventilated centres, and the cohort's heightened susceptibility. Routine testing in waves 2 and 3 may have increased asymptomatic case detection, despite new infection control measures. Fewer infections in waves 2 and 3 likely reflect early immunity within the cohort from high initial infection rates.

While univariate analysis highlights potential associations, only multivariate results are discussed here, as they account for confounding factors and provide a more accurate assessment of the relationships between variables and outcomes. Deprivation and ethnicity did not significantly differ between infected and non-infected HD patients, contrasting with findings in the general population [7]. However, in the HD setting, universal exposure to dialysis facilities and strict infection control measures likely minimized disparities, leading to similar infection risks across socio-economic and ethnic groups. This highlights the success of infection control measures in eliminating socio-economic disparities associated with infection. From our cohort of patients with a positive NPS, 40% were admitted to hospital, with a median admission length of 7 days. This figure is much higher than that observed in the general population over the same time period [8,9]. There are several potential reasons for this, firstly, HD patients are more vulnerable to severe disease. Secondly, patients admitted to hospital for reasons other than COVID disease would have been swabbed on admission. This figure likely includes incidental cases, which we could not distinguish in the data. Nevertheless, even if were to assume a proportion of incidental cases, the number of admissions with SARS-CoV-2 infection still remains high.

Age was associated with hospital admission, consistent with existing research [10]. Only 'Other' ethnicity increased risk of admission this cohort. In the general population, Afro-Caribbean ethnicities have been shown to increase the risk of some adverse outcomes [11]. Only five categories of ethnicity could be extracted from electronic patient records, which may limit the granularity of our data, thereby overlooking true effects of ethnicity. No factors were significantly associated with ITU admission or hospital stay length in our analysis. The small number of ITU admissions, driven in part by the scarcity of ITU beds in the UK during the pandemic, likely resulted in our model being underpowered to detect meaningful associations. Additionally, the lack of correlation between risk factors and hospital stay duration may be due to the influence of non-clinical factors, such as variations in hospital discharge protocols and differing levels of access to post-hospital rehabilitation services.

11.8% of our cohort died within 30 days of a positive NPS, reflecting a much higher mortality rate than in the general population [12]. This supports the results of several studies noting a higher mortality rate in HD patients compared to the general population [13-16]. Median time from the first positive NPS to death was 14 days. This is in agreement with data from previous observations showing a shorter time from infection to death in HD patients [17,18]. Indeed, HD patients are more vulnerable to severe disease once infection has occurred. Not only are patients with CKD more likely to be older and have a greater number of comorbidities, HD and CKD has been reported to be an independent risk factor for developing severe disease [19,20]. One major driver thought to contribute to the deleterious effects of CKD on SARS-CoV-2 outcomes is that of immunosenescence. This causes an upregulation of inflammation and chronic activation, and hence, dysfunction of immune cells. Indeed, HD patients have been shown to have slower viral clearance [21,22]. After vaccination, the humoral response has also been shown to be reduced in HD patients compared to the general population [23,24].

Survival analysis revealed that a higher number of comorbidities, infection in wave 2, and living in a more deprived area were all associated with mortality risk. Interestingly, comorbidities and deprivation index were not significantly associated with 30-day mortality in univariate analysis, likely due to confounding factors and the binary outcome used, which doesn't account for time-to-event data. In survival analysis, age was significantly associated with mortality risk when modelled non-linearly, indicating that the relationship between age and 30-day mortality is more complex than a simple linear increase in risk. Older HD patients may receive medical interventions that prolong life temporarily without necessarily leading to full recovery, which could explain the lack of a direct relationship between age and time-to-death in this cohort. The number of comorbidities has previously been shown to increase the risk of severe disease [25], consistent with our findings comorbidities was associated with mortality risk. This is due to the direct effect of SARS-CoV-2 on previously damaged organs, but also due to higher levels of inflammation



Supplementary Figure 1: Characteristics of HD Patients with a Positive NPS across all COVID-19 Waves.

(A) Sex of HD Patients with a Positive NPS: The number of HD patients with a positive nasopharyngeal swab (NPS) categorized by sex (F = Female, M = Male).

(B) Ethnicity of HD Patients with a Positive NPS: The number of HD patients with a positive NPS categorized by recorded ethnicity (Afro-Caribbean, Asian, Mixed, Other, White).

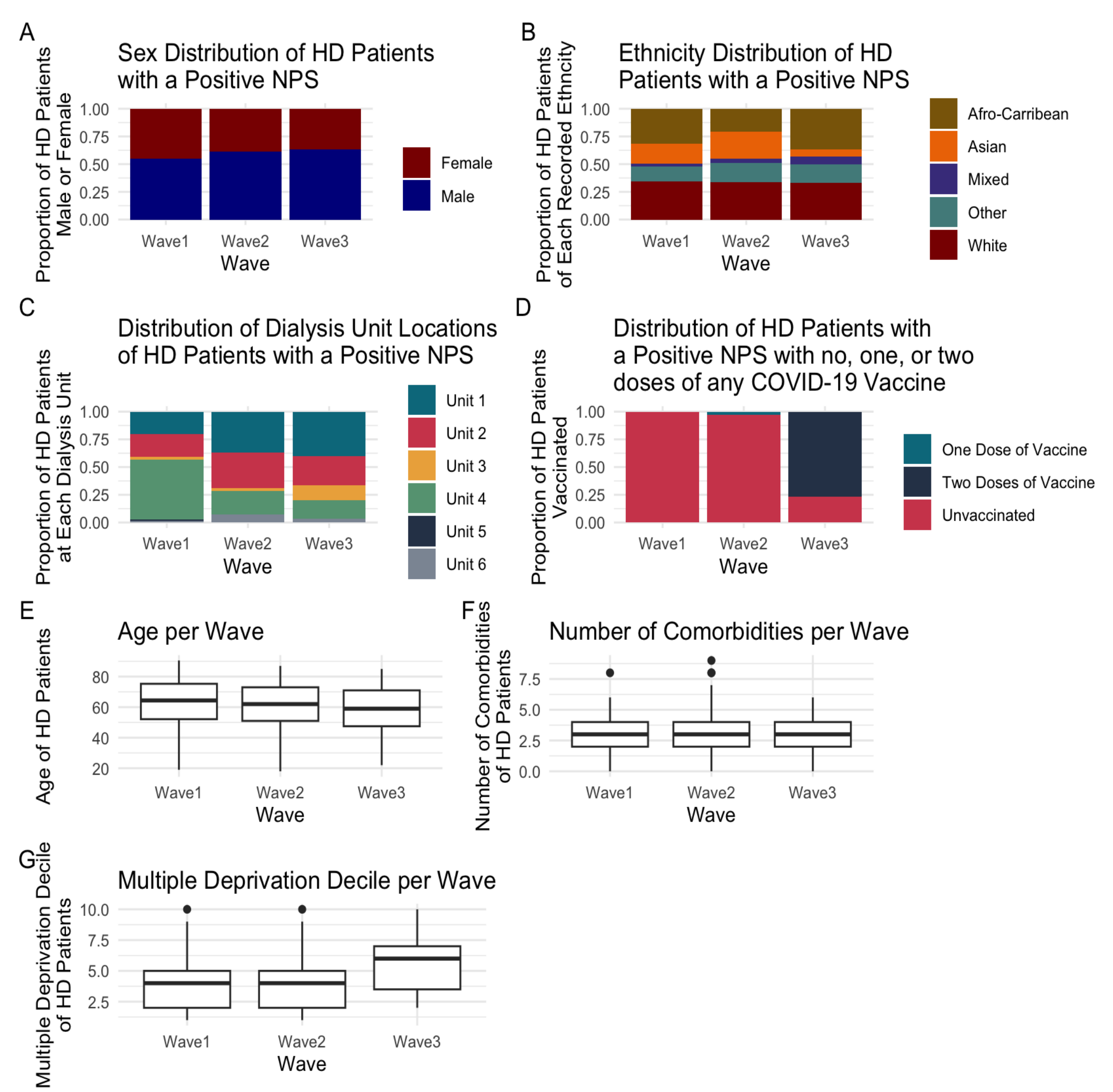
(C) Dialysis Unit of HD Patients with a Positive NPS: The number of HD patients with a positive NPS categorized by dialysis unit location (12N-PPU, BRDU, EDKCC, MROP, NOT RFH, TH KDC).

(D) Vaccination Status of HD Patients with a Positive NPS: The number of HD patients with a positive NPS categorized by vaccination status at the time of infection (Unvaccinated, between doses, Post 2nd dose).

(E) Age of HD Patients with a Positive NPS: Histogram showing the age distribution of HD patients with a positive NPS.

(F) Number of Comorbidities of HD Patients with a Positive NPS: Histogram showing the number of comorbidities among HD patients with a positive NPS.

(G) Index of Multiple Deprivation Decile of HD Patients with a Positive NPS: Histogram showing the distribution of Index of Multiple Deprivation Deciles among HD patients with a positive NPS, where 1 represents the most deprived and 10 the least deprived.



Supplementary Figure 2: Characteristics of HD Patients with a Positive NPS across COVID-19 Waves. This figure summarises key demographic and clinical data of HD patients with a positive COVID-19 test across three waves.

(A) Sex Distribution: Proportion of male (blue) and female (red) patients.

(B) Ethnicity Distribution: Proportion of patients by ethnicity (Afro-Caribbean, Asian, Mixed, Other, White).

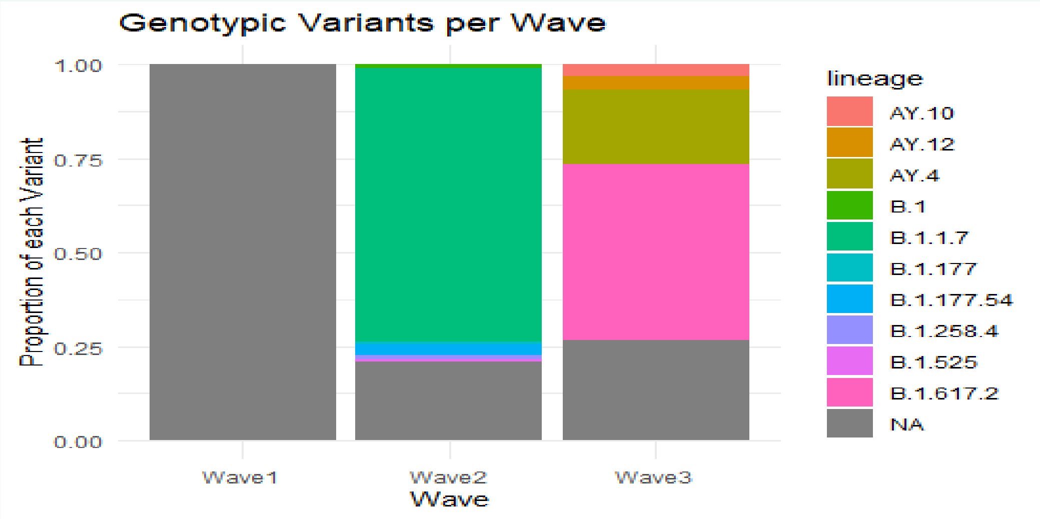
(C) Dialysis Unit Locations: Proportion of patients at different dialysis units (anonymised from 1-6).

(D) Vaccination Status: Proportion of unvaccinated (red), one dose (light blue), and two doses (dark blue) patients.

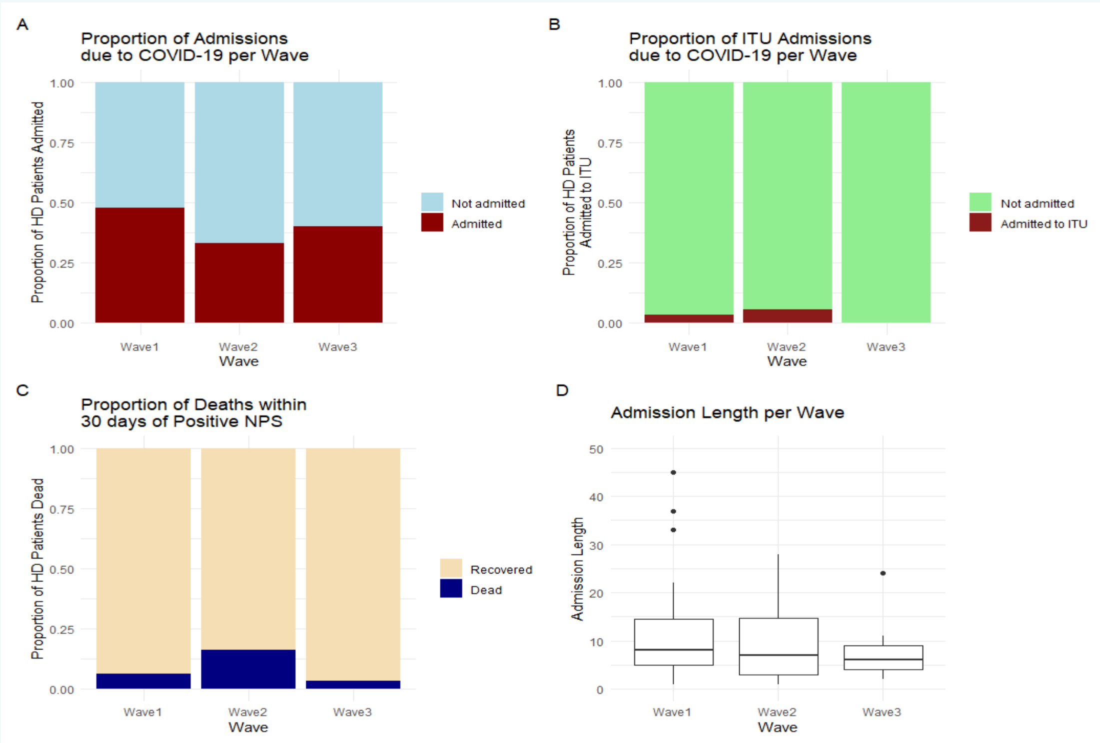
(E) Age per Wave: Boxplot of patient age distribution.

(F) Number of Comorbidities per Wave: Boxplot of the number of comorbidities, with outliers indicated.

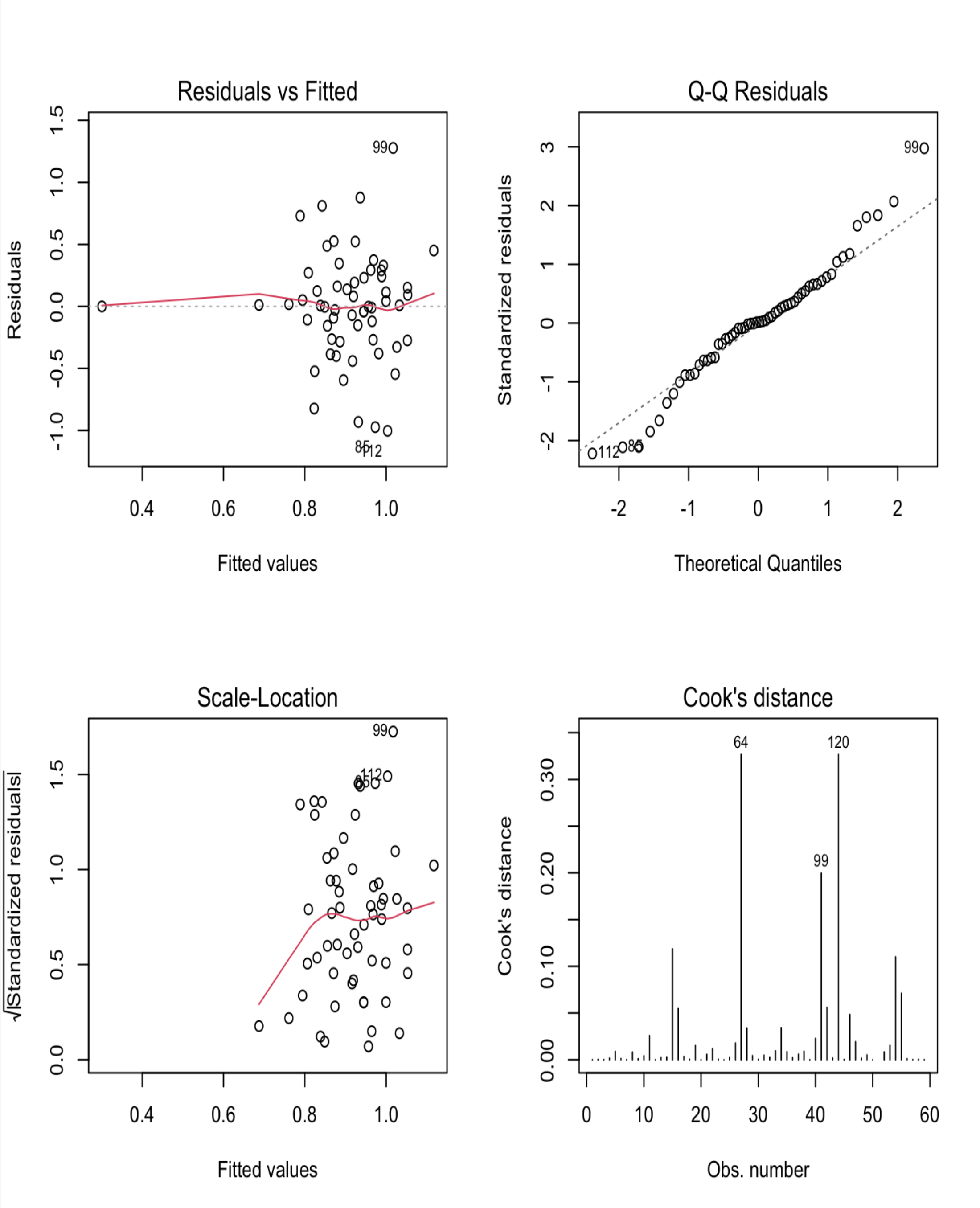
(G) Index of Multiple Deprivation Decile per Wave: Boxplot of the Multiple Deprivation Index, with 1 being the most deprived, and 10 the least deprived.



Supplementary Figure 3: Genotypic Variants per Wave.
Distribution of genotypic variants of the COVID-19 virus across three waves. Each bar represents a different wave, with the height of the segments within each bar indicating the proportion of each genotypic variant. Where genotypic information was no available it has been labelled as NA.



Supplementary Figure 4: Distribution of Health Outcomes per Wave due to COVID-19.
(A) Admissions: Proportion of HD patients admitted due to COVID-19 per wave. «Not admitted» (light blue), «Admitted» (dark red).
(B) ITU Admissions: Proportion of HD patients admitted to ITU due to COVID-19 per wave. «Not admitted» (light green), «Admitted to ITU» (dark red).
(C) Deaths within 30 Days: Proportion of HD patients who died within 30 days of a positive NPS per wave. «Recovered» (light yellow), «Dead» (dark blue).
(D) Admission length: Time spent in hospital for those who were admitted, but who did not die within 30 days of an NPS swab. Three outliers are not plotted on the graph, ranging between 60-200 days.



Supplementary Figure 5: Diagnostic Plots for Linear Model of Log-transformed Admission Length.

The figure presents four diagnostic plots for the linear regression model of log-transformed admission length. The Residuals vs fitted plot shows residuals plotted against fitted values. The Q-Q plot compares the distribution of standardized residuals to a normal distribution. The Scale-Location plot checks for homoscedasticity by plotting the square root of standardized residuals against fitted values. The Cook's Distance plot highlights observations with higher influence on the model.

Table 2: Univariate analysis for adverse outcomes.

Univariate analysis of age, number of comorbidities, Index of Multiple Deprivation decile, sex, ethnicity, dialysis unit, and vaccination status across four outcomes: hospital admission, ITU admission, admission length, and death within 30 days of a positive Nasopharyngeal Swab (NPS) for SARS-CoV-2. The *P*-values for each covariate are shown alongside the respective outcome, with significant values ($P < 0.05$) indicated by an asterisk (*). Descriptive statistics, such as means or counts, are provided where applicable.

	Hospital Admission		**ITU Admission**		**Admission Length**	**Death within 30 days of a positive NPS**	
	No	**Yes**	**No**	**Yes**	**(Days)**	**No**	**Yes**
Age (years)	*P*-value = **0.035***		*P*-value = 0.225		*P*-value = 0.197	*P*-value = **0.00533***	
	60.2	64.5	62.1	56.8	Pearson's correlation coefficient = -0.14	71.0	70.2
Number of Comorbidities	*P*-value = 0.246		*P*-value = 0.707		*P*-value = 0.737	*P*-value = 0.996	
	2.88	3.07	2.95	3.20	Pearson's correlation coefficient = -0.037	2.96	2.96
Index of Multiple Deprivation Decile (1-10; 1 = most deprived, 10 = least deprived)	*P*-value = 0.511		*P*-value = 0.753		*P*-value = 0.372	*P*-value = 0.497	
	4.06	4.17	4.10	4.29	Pearson's correlation coefficient = -0.11	4.08	4.31
Sex	*P*-value = 0.550		*P*-value = 1.00		*P*-value = 0.625	*P*-value = 0.233	
Male	84	62	140	6	-	128	18
Female	64	39	99	4	-	96	7
Ethnicity	*P*-value = 0.503		*P*-value = 0.178		*P*-value = 0.361	*P*-value = **0.0030***	
White	46	39	81	4	-	73	12
Afro-Caribbean	40	29	67	2	-	68	1
Asian	29	19	48	0	-	44	4
Mixed	6	3	8	1	-	9	0
Other	27	11	35	3		30	8
Dialysis Unit	*P*-value = 0.169		*P*-value = 0.149		*P*-value = 0.317	*P*-value = **0.0434***	
Unit 1	51	23	73	1	-	71	3
Unit 2	37	28	61	4	-	54	11
Unit 3	5	5	10	0	-	10	0
Unit 4	51	37	85	3	-	80	8
Unit 5	0	1	1	0	-	1	0
Unit 6	4	7	9	2	-	8	3
Vaccination status	*P*-value = 1.00		*P*-value = 0.623		*P*-value = 0.499	*P*-value = 0.269	
Unvaccinated	132	91	213	10	-	198	25
One dose	2	1	3	0	-	3	0
Two doses	14	9	23	0	-	23	0

Table 3: Multivariate analysis for adverse outcomes.

Multivariate analyses examining the associations between various covariates and three outcomes in hemodialysis patients with COVID-19: hospital admission, ITU admission within 30 days of a positive NPS (Nasopharyngeal Swab), and log-transformed admission length (in days). The Odds Ratio (OR), coefficients, 95% Confidence Intervals (CI), and *P*-values are reported. *P*-values < 0.05 are in bold.

	Hospital Admission		**ITU Admission**		**Admission Length (Days)**		**Time to death within 30 days of a positive NPS**	
Covariate	Odds Ratio (95% CI)	*P*-value	Odds Ratio (95% CI)	*P*-value	Coefficient (95% CI)	*P*-value	Hazard Ratio (95% CI)	*P*-value
Age	1.03 (1.01–1.06)	**0.008***	0.98 (0.94–1.03)	0.474	1.00 (0.98–1.02)	0.95	HR not linear	(Non-linear effect, ***p*=0.021***)
Number of Comorbidities	1.19 (0.95–1.51)	0.132	1.14 (0.68–1.82)	0.605	0.94 (0.76–1.17)	0.564	4.08 (1.48–11.27)	**0.0066***
Index of Multiple Deprivation Decile	1.03 (0.88–1.20)	0.72	1.06 (0.75–1.47)	0.721	0.94 (0.82–1.09)	0.407	0.50 (0.26–0.95)	**0.036***
Sex (Reference: Male)								
Female	0.88 (0.43–1.79)	0.734	1.43 (0.30–7.11)	0.651	0.99 (0.53–1.83)	0.965	0.06 (0.002–1.62)	0.093
Ethnicity (Reference: White)								
Afro-Caribbean	0.90 (0.40–2.03)	0.796	0.60 (0.10–2.89)	0.529	0.93 (0.45–1.91)	0.835	-	-
Asian	0.80 (0.32–1.97)	0.634	0.16 (0.001–1.52)	0.124	0.81 (0.36–1.80)	0.592	-	-
Mixed	0.949 (0.116-6)	0.957	1.71 (0.112-14.2	0.657	0.84 (0.16–4.58)	0.84	-	-
Other	0.24 (0.059–0.777)	**0.026***	0.26 (0.002–2.49)	0.283	0.24 (0.02–2.62)	0.239	-	-
Wave (Reference: Wave 1)								
Wave 2	0.63 (0.22–1.64)	0.358	0.72 (0.02–4.03)	0.749	0.84 (0.31–2.30)	0.735	128.8 (4.16–3982.73)	**0.0055***
Wave 3	1.60 (0.76–3.31)	0.21	0.68 (0.08–3.08)	0.629	0.98 (0.43–2.24)	0.957	0.1034 (0.0007759–13.79)	0.3600

[26,27]. Indeed, analysis of our cohort revealed an almost two third prevalence of hypertension, and high prevalence of diabetes mellitus, obesity cardiovascular disease and lung disease. Deprivation level was significantly associated with mortality risk, with each 1-unit increase in the deprivation index (indicating less deprivation) associated with a halving of the mortality risk. This finding is consistent with studies in the general population, where higher deprivation has been linked to increased COVID-19 mortality [28]. Interestingly, in our cohort, deprivation was not significantly associated with SARS-CoV-2 infection or hospital admission. This could be explained by the uniform conditions in dialysis units, where all patients, regardless of socio-economic status, received the same level of care, minimising the impact of socio-economic disparities on infection and admission rates. However, long-term outcomes like mortality, which can be influenced by broader socio-economic factors, continue to be affected by deprivation levels.

A significantly higher proportions of deaths occurred during the second wave. This may reflect emergence of the Alpha variant during this time. Indeed, our data showed a high prevalence of the Alpha variant in the second wave, followed by a high prevalence of the Delta variant in the third wave. Several studies have observed the Alpha variant to be more virulent than the wild-type virus in the general population [29-31]. One small retrospective study noted a higher mortality rate in those undergoing HD treatments is in wave 2 compared to wave 1 [32]. There are several strengths to this study. Firstly, it describes a comprehensive characterisation of the cohort of HD patients infected with SARS-CoV-2 during an extensive period covering three waves of COVID in a major London university hospital serving a multi-ethnic inner-city population. Secondly, we describe these patients over an extended period of time, thereby capturing the change in outcomes between each wave of the UK pandemic.

A limitation was changing testing protocols, with only symptomatic testing in wave 1 and routine testing in wave 2. Despite this, wave 2 had worse outcomes, supporting our hypothesis that the Alpha variant caused worse outcomes in this cohort. Our data excludes SARS-CoV-2 tests from outside the hospital, potentially underestimating total infections. However, few patients reported additional community testing, and confirmatory swabs were taken upon hospital admission, ensuring most cases were captured after routine testing began. Future studies on viral genotype and HD outcomes could clarify SARS-CoV-2 strain effects on severity. This could help predict future strain severity and guide vaccine development. Furthermore, future studies may analyse of the efficacy of vaccinations and other treatments against different strains and corresponding clinical outcomes. In conclusion, our study reported the characteristics of a large cohort of HD patients infected with SARS-CoV-2 and found age, number of co-morbidities, ethnicity and the second wave of SARS-CoV-2 to be associated with adverse outcomes.

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AUTHORS' CONTRIBUTIONS

TH and TM conceived and conceptualized the research idea and supervised the project. CNG and SRS performed the data analyses. CG and AD made substantial conceptual contributions in data analyses and discussions. CNG, SRS and TH wrote the first draft of the manuscript. CNG, SRS, CG, AD and TH reviewed and contributed to the final draft of the manuscript.

ETHICS STATEMENT

This study was a retrospective analysis of anonymized, routinely collected clinical data, and therefore did not require formal ethical approval. Data were collected and analyzed in a manner that ensured patient confidentiality and compliance with all relevant data protection regulations. Any clinical decisions and routine practices in patient care remained unaffected by the study design.

REFERENCES

1. UK Renal Registry Report 2021.
2. Chung EY, Palmer SC, Natale P, Krishnan A, Cooper TE, Saglimbene VM, et al. Incidence and Outcomes of COVID-19 in People With CKD: A Systematic Review and Meta-analysis. Am J Kidney Dis. 2021; 76: 804-815.
3. Swain RB, Lin X, Wallentin FY. COVID-19 pandemic waves: Identification and interpretation of global data. Heliyon. 2024; 10: e25090.
4. Kraemer MUG, Hill V, Ruis C, Dellicour S, Bajaj S, McCrone JT, et al. Spatiotemporal invasion dynamics of SARS-CoV-2 lineage B.1.1.7. emergence. Science. 2021; 373: 889-895.
5. Over half of UK adults vaccinated with second dose.
6. Coronavirus (COVID-19) weekly insights.
7. Chaudhuri K, Chakrabarti A, Lima JM, Chandan JS, Bandyopadhyay S. The interaction of ethnicity and deprivation on COVID-19 mortality risk: a retrospective ecological study. Sci Rep. 2021; 11: 11555.
8. MRC Biostatistics Unit and PHE: Estimates of COVID-19 hospitalised mortality and length of stay: data from March 2020 to September 2021, 7 December 2021.
9. Ward T, Fyles M, Glaser A, Paton RS, Ferguson W, Overton CE. The real-time infection hospitalisation and fatality risk across the COVID-19 pandemic in England. Nat Commun. 2024; 15: 4633.
10. Coronavirus (COVID-19) latest insights: Hospitals.
11. Siddiq S, Ahmed S, Akram I. Clinical outcomes following COVID-19 infection in ethnic minority groups in the UK: a systematic review and meta-analysis. Public Health. 2022.
12. COVID-19 confirmed deaths in England (to 31 December 2021): report.
13. Williamson EJ, Walker AJ, Bhaskaran K, Bacon S, Bates C, Morton CE, et al. Factors associated with COVID-19-related death using OpenSAFELY. Nature. 2020; 584: 430-436.
14. Goffin E, Candellier A, Vart P, Noordzij M, Arnol M, Covic A, et al. COVID-19-related mortality in kidney transplant and haemodialysis patients: a comparative, prospective registry-based study. Nephrol Dial Transplant Off Publ Eur Dial Transpl Assoc - Eur Ren Assoc. 2021; 36: 2094–105.
15. Semenzato L, Botton J, Drouin J, Cuenot F, Dray-Spira R, Weill A, et al. Chronic diseases, health conditions and risk of COVID-19-related hospitalization and in-hospital mortality during the first wave of the epidemic in France: a cohort study of 66 million people. Lancet Reg Health - Eur. 2021; 8: 100158.
16. Williamson EJ, Walker AJ, Bhaskaran K, Bacon S, Bates C, Morton CE, et al. OpenSAFELY: factors associated with COVID-19 death in 17 million patients. Nature. 2020; 584: 430-436.
17. Lano G, Braconnier A, Bataille S, Cavaille G, Moussi-Frances J, Gondouin B, et al. Risk factors for severity of COVID-19 in chronic dialysis patients from a multicentre French cohort. Clin Kidney J. 2020; 13: 878-888.

18. Keller N, Chantrel F, Krummel T, Bazin-Kara D, Faller AL, Muller C, et al. Impact of first-wave COronaVIrus disease 2019 infection in patients on haemoDIALysis in Alsace: the observational COVIDIAL study. Nephrol Dial Transplant. 2020; 35: 1338-1411.

19. Sullivan MK, Rankin AJ, Jani BD, Mair FS, Mark PB. Associations between multimorbidity and adverse clinical outcomes in patients with chronic kidney disease: a systematic review and meta-analysis. BMJ Open. 2020; 10: e038401.

20. Wu T, Zuo Z, Kang S, Jiang L, Luo X, Xia Z, et al. Multi-organ Dysfunction in Patients with COVID-19: A Systematic Review and Meta-analysis. Aging Dis. 2020; 11: 874-894.

21. Vriese ASD, Reynders M. IgG Antibody Response to SARS-CoV-2 Infection and Viral RNA Persistence in Patients on Maintenance Hemodialysis. Am J Kidney Dis. 2020; 76: 440-441.

22. Shaikh A, Zeldis E, Campbell KN, Chan L. Prolonged SARS-CoV-2 Viral RNA Shedding and IgG Antibody Response to SARS-CoV-2 in Patients on Hemodialysis. CJASN. 2021; 16 p: 290-292.

23. Van Praet J, Reynders M, De Bacquer D, Viaene L, Schoutteten MK, Caluwé R, et al. Predictors and Dynamics of the Humoral and Cellular Immune Response to SARS-CoV-2 mRNA Vaccines in Hemodialysis Patients: A Multicenter Observational Study. J Am Soc Nephrol JASN. 2021; 32: 3208–3220.

24. Grupper A, Sharon N, Finn T, Cohen R, Israel M, Agbaria A, et al. Humoral Response to the Pfizer BNT162b2 Vaccine in Patients Undergoing Maintenance Hemodialysis. Clin J Am Soc Nephrol CJASN. 2021; 16: 1037–1042.

25. Aoun M, Khalil R, Mahfoud W, Fatfat H, Bou Khalil L, Alameddine R, et al. Age and multimorbidities as poor prognostic factors for COVID-19 in hemodialysis: a Lebanese national study. BMC Nephrol. 2021; 22: 73.

26. Carrero JJ, Stenvinkel P. Inflammation in end-stage renal disease--what have we learned in 10 years?. Semin Dial. 2010; 23: 498–509.

27. Himmelfarb J, Stenvinkel P, Ikizler TA, Hakim RM. The elephant in uremia: oxidant stress as a unifying concept of cardiovascular disease in uremia. Kidney Int. 2002; 62: 1524–1538.

28. Albani V, Welsh CE, Brown H, Matthews FE, Bambra C. Explaining the deprivation gap in COVID-19 mortality rates: A decomposition analysis of geographical inequalities in England. Soc Sci Med. 2022; 311: 115319.

29. Grint DJ, Wing K, Houlihan C, Gibbs HP, Evans SJW, Williamson E, et al. Severity of Severe Acute Respiratory System Coronavirus 2 (SARS-CoV-2) Alpha Variant (B.1.1.7) in England. Clin Infect Dis Off Publ Infect Dis Soc Am. 2022; 75: e1120-e1127.

30. Florensa D, Mateo J, Spaimoc R, Miret C, Godoy S, Solsona F, et al. Severity of COVID-19 cases in the months of predominance of the Alpha and Delta variants. Sci Rep. 2022; 12: 15456.

31. Cetin M, Balci PO, Sivgin H, Cetin S, Ulgen A, Dörtok Demir H, et al. Alpha variant (B.1.1.7) of SARS-CoV-2 increases fatality-rate for patients under age of 70 years and hospitalization risk overall. Acta Microbiol Immunol Hung. 2021.

32. Wand O, Mor O, Zuckerman N, Fadeela A, Benchetrit S, Nacasch N, et al. Outcomes From Infections With Variant Strains of SARS-CoV-2 Among Patients Receiving Maintenance Hemodialysis. Am J Kidney Dis. 2021; 78: 617-619.