Are patients on chronic hemodialysis treatment protected against mortality due to COVID-19? A single-center retrospective cohort of patients hospitalized with COVID-19 requiring hemodialysis treatment

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Abstract

Background: It is widely accepted that SARS-CoV-2 (Severe acute respiratory syndrome coronavirus 2), the pathogen causing COVID-19 (coronavirus disease 2019), not only affects the respiratory system but can damage other organs, including the kidneys. We aimed to assess the mortality of hospitalized COVID-19 patients who received hemodialysis treatment (patients with previously normal renal function - nCKD, patients with chronic kidney disease previously not requiring hemodialysis - CKDnonHD, and CKD patients on regular hemodialysis - pHD).

Material and methods: All COVID-19 patients admitted to our institution (01/OCT/2020-31/MAY/2021) who received hemodialysis treatment were followed up for all-cause mortality in the central database of the National Health Service until 01/DEC/2021. Data on demography, presenting signs and symptoms, and laboratory results at baseline were drawn from hospital charts. All-cause mortality was compared between nCKD, CKDnonHD, and pHD groups in crude and adjusted Cox-proportional hazard models.

Results: 83 of 108 (76.9%) were included in the analysis due to missing covariates. Over a median 26 (interquartile range 11-266) days of follow-up 20 of 22 (90.9%) of nCKD, 23 of 24 (95.8%) of CKDnonHD, and 17 of 37 (45.9%) of pHD patients died. All groups were similar in terms of age and sex distribution. In general, nCKD patients had fewer comorbidities (hypertension, diabetes mellitus, ischemic heart disease) but more severe presentations (dyspnea, O2 saturation, C-reactive protein, white blood cell count, and albumin). In contrast, pHD patients had the least severe presentation. In a model adjusted for independent predictors of all-cause mortality (C-reactive protein and serum albumin), CKDnonHD patients had increased (hazard ratio [HR] 1.91, 95% confidence interval [CI] 1.02-3.60), while pHD patients decreased mortality (HR 0.41, 95% CI 0.20-0.81) compared to nCKD patients. After further adjustment for the need for intensive care treatment, the difference in mortality between the nCKD and the pHD groups became non-significant.

Conclusion: Patients requiring acute hemodialysis during hospitalization due to COVID-19 had a remarkably high all-cause mortality. While CKD patients who were previously not requiring hemodialysis fared worse than those without known CKD before hospitalization, the better survival of chronic hemodialysis patients suggests the role of unmeasured confounding or selection bias related to the hospitalization of even asymptomatic patients to prevent the spread of disease during transport to treatment.

Introduction

Since December 2019, multiple cases of pneumonia caused by a novel coronavirus have been reported in Wuhan, Hubei Province. The disease has spread to many provinces within China and foreign countries, such as Japan, Thailand, the United States, and Europe, in a short time with strong infectivity [1]. The most frequent clinical courses of the infection include asymptomatic cases and mild and non-specific respiratory syndrome. The generalized and violent inflammatory response needing ICU assistance,

mechanical ventilation, and occasionally renal replacement therapy is much less frequent [2]. The Centers for Disease Control guidance on SARS-CoV-2 (severe acute respiratory syndrome coronavirus 2) related states that while everyone is at risk of COVID-19 (coronavirus disease 2019), certain populations have an increased risk for severe illness, including older adults, individuals with chronic kidney disease (CKD), individuals with chronic obstructive pulmonary disease, solid organ transplant recipients, those with obesity, cardiac conditions, and type 2 diabetes mellitus. Patients with end-stage kidney disease and those on dialysis treatment are at particular risk, owing to both dysfunctions of innate and adaptive immunity and a significant burden of comorbid conditions (cardiac disorders and type 2 diabetes) [3] [4].

All-cause mortality of COVID-19 patients requiring new-onset hemodialysis (HD) due to acute or acute-on-chronic kidney disease can be staggeringly high [5]. Patients on chronic HD treatment with a positive test for SARS-CoV-2 infection pose a further challenge: their regular transfer to the dialysis unit may facilitate the spread of the disease; hence, their threshold for hospital admission is lower, they are hospitalized even if they are asymptomatic [6]. This indication bias could lead to spuriously lower mortality among people on HD treatment hospitalized with a positive SARS-CoV-2 test.

Given these controversies, we aimed to assess the mortality of hospitalized COVID-19 patients who received hemodialysis treatment (patients with previously normal renal function - nCKD, patients with chronic kidney disease previously not requiring hemodialysis - CKDnonHD, and CKD patients on regular hemodialysis - pHD). We hypothesized that compared to nCKD, CKDnonHD patients would have higher while pHD patients lower all-cause mortality.

Material And Methods

Setting

As part of an ongoing cohort study of all hospitalized COVID-19 patients (≥ 18 years of age) cared for at Semmelweis University, we retrospectively collected data on all patients with confirmed SARS-CoV-2 infection who received the infection HD treatment between 01/OCT/2020 and 31/MAY/2021. According to the World Health Organization's interim guidelines, the diagnosis of SARS-CoV-2 infection was based on a positive antigen test confirmed by a polymerase chain reaction (PCR) test [7]. Baseline assessment and treatment of COVID-19 was performed in line with Semmelweis University treatment guideline [8]. In brief, standardized forms on demography, medical history, and presenting symptoms were filled in, and a standard set of laboratory parameters were collected. Patients received supportive care (nasal oxygen, non-invasive or invasive ventilatory support, low molecular weight heparin in preventive dose, and dexamethasone in line with international guidelines); however, no remdesivir treatment was administered because the FDA product label does not recommend using remdesivir in patients with an eGFR of < 30 mL/min. None of the study participants received vaccination against SARS-CoV-2 before hospitalization. Data on the need for mechanical ventilation and treatment in the intensive care unit (ICU) during hospitalization were also collected. Participants were followed up for all-cause mortality in the National Health Service database until 01/DEC/2021.

All study-related procedures have been performed in accordance with the ethical standards laid down in the 1964 Declaration of Helsinki and its later amendments. Local ethical approval was obtained Semmelweis University Regional and Institutional Committee of Science and Research Ethics (Registration number: SE-RKEB 245-1/2020). The need for informed consent was waived in accordance with Hungarian laws by the Ethics Committee as no specific study-related procedures were performed.

Participants

Altogether n = 108 patients treated for COVID-19 required HD treatment during the study period. These 25 patients were excluded due to missing baseline covariates, while no patients were lost for the mortality follow-up. Therefore, the final analytical sample comprised 83 patients: 22 with nCKD, 24 with CKDnonHD, 37 with pHD. (Fig. 1)

Patients in the study were not vaccinated against COV infection.

Predictors and covariates

Demographic and clinical data and vital signs and symptoms were drawn from each participant's electronic medical record (EMR). From *demographic* characteristics, we collected the age and sex of the patient.

The following *comorbidities* were recorded in the medical history: hypertension, ischemic heart disease (angina or prior myocardial infarction or history of revascularization), chronic obstructive pulmonary disease, treated diabetes mellitus (either type 1 or 2), and chronic kidney disease status. CKD was defined as an estimated glomerular filtration rate below 60 mL/min/1.73 m^2 based on at least two measurements at least three months apart up to 12 months before hospital admission [9, 10].

Among *vital signs*, we included systolic and diastolic blood pressure (measured with an automated device) and oxygen saturation (based on pulse oximetry). The only *symptom* we used in the current analysis was dyspnoea at presentation.

Laboratory data were collected directly from the hospital system and were measured in the same central laboratory (Central Laboratory of Department of Laboratory Medicine, Semmelweis University) on automated systems. We recorded blood cell counts, creatinine, high-sensitivity C-reactive protein (CRP), total protein, and albumin at hospital admission.

We also collected data on *intermediate outcomes*: the need for mechanical ventilation and ICU placement during the initial hospitalization as a marker of COVID-19 severity.

Outcome

Hungary has a single-payer health insurance system that covers most social and health-related activities. For the current report, all participants were flagged with their NHS ID in the NHS Masterfile, and their last known status was recorded as dead or alive. Follow-up started at the time of hospital admission and was

censored at death or inactivation (due to expatriation) or end of follow-up (01/DEC/2021), whichever came first.

Statistical methods

Descriptive data are presented as number and percentages for categorical variables and mean ± standard deviation or median [interquartile range] for continuous variables. The normality of continuous variables was investigated by normality tests and by visual observation of histograms and Q-Q plots. Non-normally distributed variables were log-transformed as required.

Baseline data are presented stratified by CKD status and living status at follow-up. Comparisons between the CKD group are made using khi2-test or one-way ANOVA as appropriate. P values for both heterogeneity and trend are reported. For the comparison by living status, khi2-tests or 2-sample t-tests were performed.

Next, we fitted hierarchical Cox proportional hazards models to estimate hazard ratios (HRs) with 95% confidence intervals [CI] for the CKD status on all-cause mortality. The basal model (*Model 1*) was unadjusted. Then in subsequent models, we selected independent predictors of all-cause mortality by adding demographic (age and sex), anamnestic variables (congestive heart failure), presenting signs and symptoms (dyspnoea, oxygen saturation, diastolic blood pressure), and finally, laboratory measures at presentation (white blood cell count, C-reactive protein, creatinine, and albumin) using backward stepwise method. All variables that showed a univariate association with a p-value < 0.10 were made available for these models. *Model 2* shows how the relative risk of all-cause mortality when adjusted for these independent predictors selected through the previous process. Model 3 further added intermediate outcomes (need for mechanical ventilation and ICU treatment) using a backward stepwise method.

For graphical representation, Kaplan-Meyer survival curves (with a log-rank test) by CKD status and the survival function based on Model 2 are presented. We selected Model 2 over Model 3 as the intermediate outcomes were unknown at hospital admission, potentially leading to over adjustment.

All analyses were performed on IBM SPSS Statistics version 28.0.

Results

Baseline characteristics and intermediate outcomes by CKD status

The groups without CKD, those with CKD without prior HD treatment, and those on chronic HD treatment had similar age and sex distribution with male predominance. Patients without CKD had fewer comorbidities with a lower frequency of hypertension, diabetes, and ischemic heart disease compared to the CKD patients with or without HD treatment. Probably due to the lower absolute risks, no differences in

the prevalence of stroke, chronic obstructive pulmonary disease, or congestive heart failure were found. (Table 1)

We found significant trends representing more severe signs and symptoms from cases without CKD through those with CKD not on chronic HD to those on chronic HD treatment in terms of the frequency of dyspnoea, mean values of oxygen saturation, and diastolic blood pressure. (Table 1)

Laboratory values representing systemic inflammation also showed similar trends, with the highest white blood cell count and CRP values in the group without CKD and the lowest in the HD group. Those markers known to be markers of CKD (such as haemoglobin and creatinine) showed trends accordingly. Serum albumin was lowest in the group without CKD and increased across the CKD groups. (Table 1)

Both the need for mechanical ventilation and ICU treatment showed a strong trend with lower rates among patients on HD and those with CKD not on chronic HD treatment. (Table 1)

Baseline characteristics and intermediate outcomes by survival status

Deceased patients tended to be older, tended to have congestive heart failure less frequently in their medical history, tended to present more frequently with dyspnoea, and tended to have lower oxygen saturation (all $p < 0.1$). They had lower diastolic blood pressure, higher white blood cell count, higher CRP, lower creatinine, and lower albumin at admission (all $p < 0.05$). (Table 2)

In terms of intermediate outcomes, almost none of the surviving patients required mechanical ventilation or ICU treatment, while more than half of the deceased cases required these procedures. (Table 2)

Analysis of all-cause mortality

Over a median of 26 (interquartile range 11–266) days of follow-up, 20 of 22 (90.9%) of patients without CKD, 23 of 24 (95.8%) of CKD patients not on HD treatment, and 17 of 37 (45.9%) of prior HD patients died. Compared to the group of non-CKD patients, the CKD patient not on HD treatment had an increased relative risk of mortality (RR 1.58, 95%CI 0.86–2.92), while the chronic HD group had a substantially decreased risk (RR: 0.25, 95%CI 0.13–0.49). (Fig. 2A, **Table 3** – Model 1)

After further adjustment for the independent predictors of mortality (CRP and albumin) assessed at hospital admission, the relative risk associated with CKD, not on chronic HD, increased to 91% (95%CI 1.02–3.60) and became statistically significant, while the relative risk associated with prior HD treatment increased but still remained significantly lower than that of the non-CKD patients. (**Table 3** – Model 2)

Further adjustment for ICU treatment increased the difference between the nCKD and the CKDnonHD groups, while the difference between the nCKD and the pHD groups attenuated and became non-significant. (Fig. 2B, **Table 3** – Model 3)

Discussion

According to the present analysis, patients requiring acute hemodialysis during hospitalization due to COVID-19 had an over 90% all-cause mortality over a median 26 days of follow-up. In general, non-CKD patients had fewer comorbidities but more severe presentations. In contrast, patients previously on hemodialysis had the least severe presentation. In a model adjusted for independent predictors of all-cause mortality, CKD patients had an almost 100 percent (95% CI 2-260%) increased, while patients previously on hemodialysis had a 60% lower mortality (95% CI 0.20–0.81) compared to non-CKD patients. After further adjustment for the need for intensive care treatment, the difference in mortality between the non-CKD and the prior hemodialysis groups became non-significant.

A third novel coronavirus leading to coronavirus disease 2019 was first identified in Wuhan, China, in December 2019. Until February 2022, over 386 million people were confirmed to contract COVID-19 worldwide, of whom almost 6 million died [11]. The typical clinical spectrum resulting from infection with the responsible virus, SARS-CoV-2 is broad, ranging from an asymptomatic response or development of a mild upper respiratory tract infection to critical illness [12].

Kidney involvement in patients with COVID-19 is multifactorial and can range from the presence of proteinuria and hematuria to acute kidney injury (AKI) requiring hemodialysis. According to the current literature, COVID-19 patients with acute kidney injury have an extremely high mortality. Furthermore, it remained an independent predictor of all-cause in-hospital death [6]. Based on the initial Wuhan report, the AKI associated mortality is at least 60%. Similarly high (70%) mortality was reported among chronic hemodialysis patients in the US [13, 14]. We also found that patients requiring acute hemodialysis treatment during a COVID-19 related hospitalization had an extremely high mortality. Our results extend further observations showing a mortality risk over 90% over an extended follow-up.

Among the groups in the present study, we found the highest mortality in CKD patients requiring acute hemodialysis during hospitalization, where almost all patients died. This is a staggering result in light of the fact that patients in the non-CKD group had a more severe presentation with significantly more frequently complaining of dyspnoea at admission and more frequently requiring mechanical ventilation and intensive care.

Mortality in our cohort was associated with the severity of COVID-19 infection, with significantly higher CRP and WBC values among patients who died. Several studies have documented the association between COVID-19 severity and circulating levels of CRP and interleukin-6 [15]. Hypoalbuminemia is common among COVID-19 patients and is closely related with inflammatory markers and clinical outcomes. Overall, there is a strong association of hypoalbuminemia with respiratory impairment, disease severity, and inflammatory state [16].

Similarly, to our findings, another study found that the development of AKI during hospitalization for COVID-19 was associated with a substantially increased mortality. This risk was further amplified when AKI resulted in dialysis. After adjusting for demographics, comorbid conditions, and illness severity, the risk for death remained higher among those with AKI stages 1–3 (adjusted HR, 3.4 [95% CI, 3.0-3.9]) and AKI stage 3D (adjusted HR, 6.4 [95% CI, 5.5–7.6]) compared with those without AKI [17]. Furthermore,

even CKD not requiring renal replacement therapy remained an independent risk factor for in-hospital death [adjusted OR (aOR) 7.35 (95%CI 2.41–22.44)] and poor prognosis [aOR 3.01 (95%CI 1.23–7.33)] [18]. Dialysis treatment (aHR 3.69), post organ transplantation status (aHR 3.53), and CKD itself (aHR 2.52 for patients with eGFR < 30 mL/min/1.73 m^2) represent three of the four comorbidities associated with the highest mortality risk from COVID-19. The relative risk associated with CKD Stages 4 and 5 is higher than that of diabetes (aHR range 1.31–1.95) or chronic heart disease (aHR 1.17) [5]. Nephrologists and intensivists face immense daily challenges while caring for these patients in the inpatient setting and end-stage renal disease patients on chronic dialysis in inpatient and outpatient settings [19].

In contrast to our findings, a few papers reported of an extremely severe course and prognosis in hemodialysis patients with COVID-19 had. Compared with the expected 1.2% mortality in matched controls on dialysis treatment without COVID-19, COVID-19 patients on hemodialysis had an absolute mortality over 20%, and a relative risk of 21 (95% confidence interval [CI] 18.6–23.9) [20–22]. A large cohort with over 80 thousand participants demonstrated positive associations between social deprivation and the risk of COVID-19, as well as almost all chronic health conditions, including hemodialysis [23].

Many patients with end-stage renal disease (ESRD) are on peritoneal dialysis (PD). Cohorts from China found that a similar incidence of symptomatic COVID-19 among patients on PD to that of the general population, indicating that the PD population was not at high risk for COVID-19. The multiple and severe comorbidities, but not the infection itself, may contribute to the prolonged hospitalization and increased mortality of patient on PD [24]. The overall mortality (8.5%) of PD patients between 1 January, 2020 and 12 April, 2020 was increased compared to the mortality (5.7%) of the corresponding period of 2019. Two systematic reviews report comparable mortality with PD and extracorporeal dialysis in critically ill patients with AKI [25]. Based on this, acute PD might be a suitable treatment option for COVID-19 related AKI [26, 27].

The surprisingly low mortality of our patients with previous HD treatment and SARS-CoV-2 infection could be partially explained by the fact that an important indication for the hospitalization of patients on chronic HD was the isolation of these patients and to prevent transmission during transport to the dialysis unit. This is supported by the finding that patients in the pHD group had the least severe presentation at admission. Complete isolation of hemodialysis patients with COVID-19 is general clinical practice worldwide [28].

Although isolation most likely played a vital role in the lower risk of death in patients on chronic hemodialysis, nearly half of these patients still died during the extended follow-up. Mortality reported in other patient groups suggests that in addition to the effect of acute COVID-19 and its immediate complications and severe complications and consequent deaths can be expected months after hospitalization. These factors are likely played a role in the high overall mortality of the non-CKD and CKD non-dialysis patients. Although fewer patients in CKD group not previously on HD required intensive care, in-hospital and overall mortality was highest in this group.

Strengths and limitations

Our study has some strengths that has to be mentioned. As most participants were also included in a prospective data collection, more details were collected with a better precision that one would expect in usual clinical care. Furthermore, the follow-up period did not end with the emission of patients, so mortality follow-up was at least 6 months for each participant (although given the high mortality, the mean and median was much shorter).. To the best of our knowledge, our study has the longest overall follow-up period among HD patients with COVID-19. It should also be noted that we were able to track mortality data of all included participants.

However certain limitations of our study should be acknowledged. First, the number of participants was small leading to limited statistical power. Due to this, we had to limit the number of covariates in the multivariate models and given the wide confidence intervals, the magnitudes of effect sizes cannot be judged well. Our analysis of chronic HD patients is limited by selection bias related to the fact that the indication for hospitalization was not always the severity of disease but the need for isolation. Given the sudden onset of the COVID-19 epidemic and the significant strain on the health care system, we had to exclude a substantial number of potential participants due to missing covariates. Furthermore, as intensive care admission was not decided at the time of admission for all cases, its use in the final model could lead to overadjustment. However, the requirement for intensive care is strongly related to disease severity.

Conclusions

Patients requiring acute hemodialysis during hospitalization due to COVID-19 had a remarkably high all-cause mortality. While CKD patients not previously requiring hemodialysis fared worse than those without known CKD before hospitalization, the much better survival of chronic hemodialysis patients suggests the role of unmeasured confounding or selection bias related to the hospitalization of even asymptomatic patients to prevent the spread of disease during transport to treatment. Our results might suggest that efforts to prevent acute renal impairment in COVID-19 patients could reduce COVID-19 associated mortality.

Declarations

Ethics approval and consent to participate: All study-related procedures have been performed in accordance with the ethical standards laid down in the 1964 Declaration of Helsinki and its later amendments. Local ethical approval was obtained Semmelweis University Regional and Institutional Committee of Science and Research Ethics (Registration number: SE-RKEB 245-1/2020). The need for informed consent was waived in accordance with Hungarian laws by the Ethics Committee as no specific study-related procedures were performed.

Consent for publication: Enrolled patients signed the informed consent and agreed to participate in the study and agreed to publish the results in an online open-access publication. Our manuscript contains no identifying information or images of patients. However, the consent form is not applicable. Only aggregate data are used, no identifiable patient data is revealed.

Availability of data and material: The datasets generated and/or analysed during the current study are not publicly available due to intellectual property but are available from the corresponding author on reasonable request.

Conflict of interests: None

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Authors' contributions: ÁGP designed the study and coordinated its execution. ÁGP and ÁT wrote the first version of the manuscript. PK, MJ, ÁK collected study data. ÁT and NL performed statistical analysis. All authors critically revised the manuscript. IT oversaw and coordinated the study and manuscript preparation.

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Tables

Tables 1 to 3 are available in the Supplementary Files section.

Figures

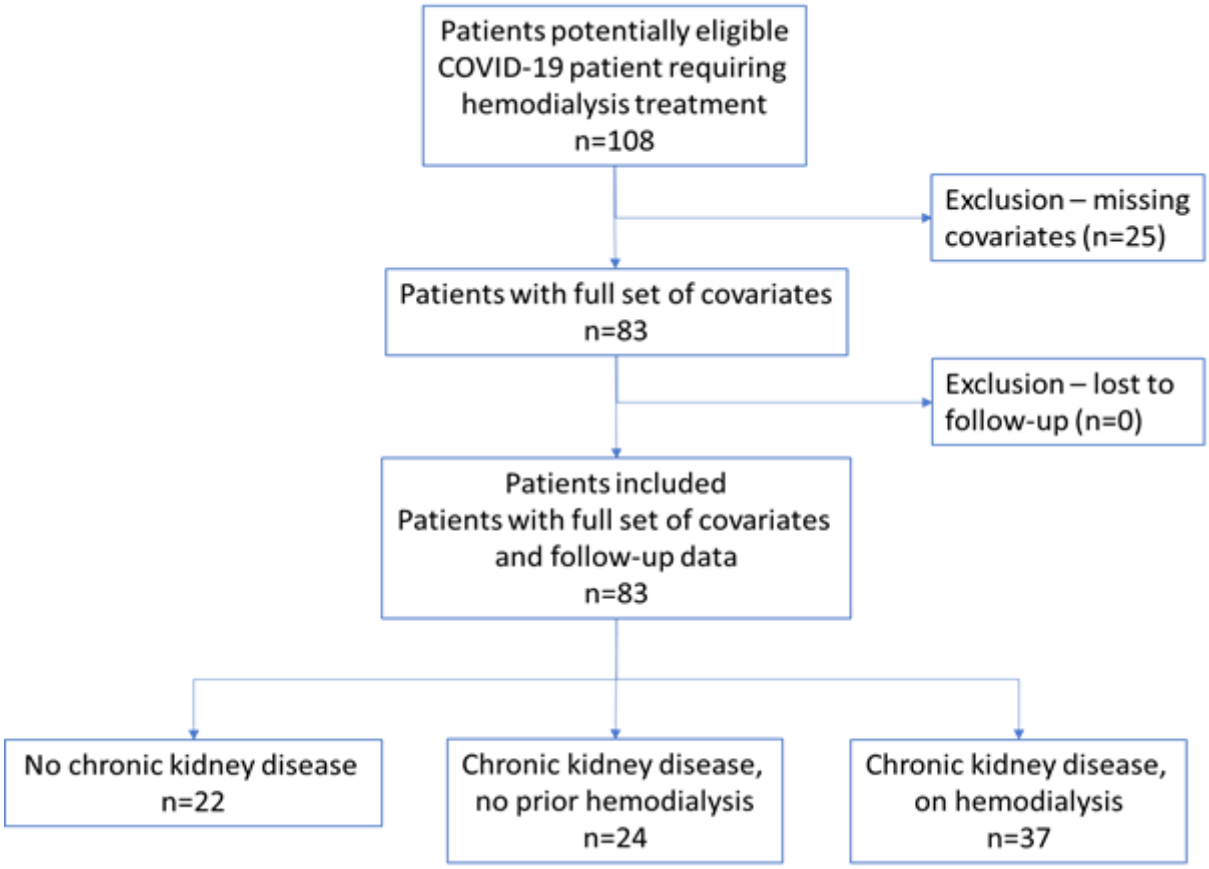

Figure 1

Flow chart of the selection of participants

COVID-19 – coronavirus disease 2019

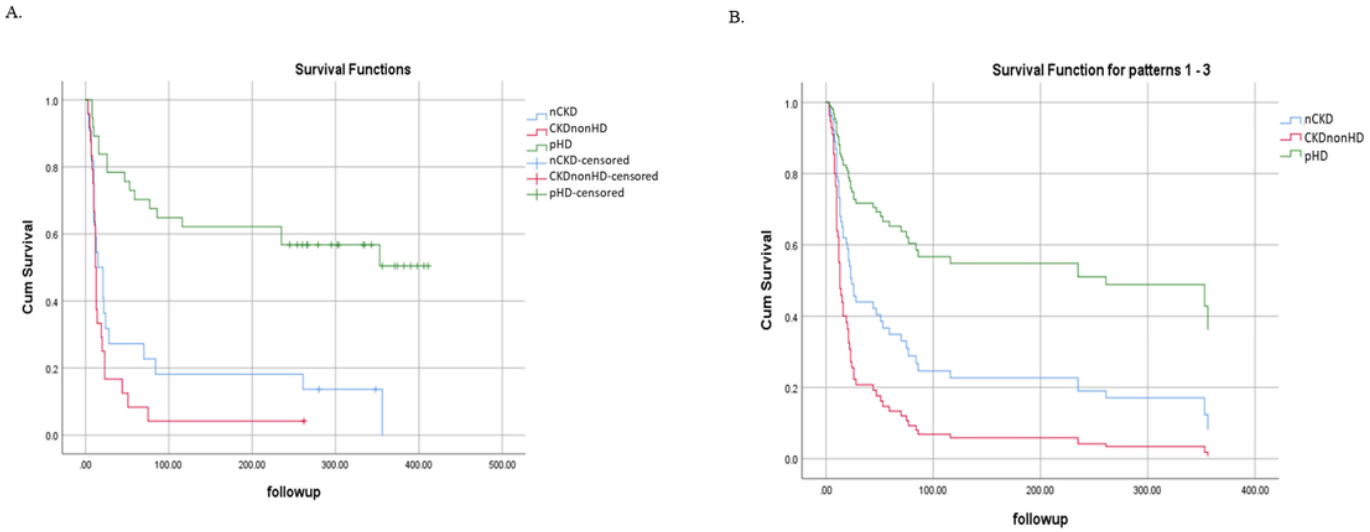

Figure 2

Survival function by CKD status: (A) based on Kaplan-Mayer survival curves, (B) based on Cox-models adjusted for serum albumin and C-reactive protein

Supplementary Files

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- Table13.docx