BMC Nephrology

RESEARCH

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Risk factors for the mortality of hemodialysis patients with COVID-19 in northern Hunan province, China

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Abstract

Purpose Exploring the risk factors for mortality of hemodialysis patients undergoing COVID-19 and the changes in mortality before and after the opening of the epidemic in northern Hunan province, China.

Methods We analyzed 230 hemodialysis patients with COVID-19 in the Yiyang Central Hospital from November 01, 2022 to February 28, 2023. Demographic data, laboratory data and public diseases were collected. Cox regression analysis was used to identify risk factors and independent predictors of mortality. The receiver operating characteristic (ROC) curve was used to determine the diagnostic value of risk factors in hemodialysis COVID-19 patients.

Results The average duration of the disease was 12.53 days. The mortality rate in our cohort was 28.70%. Independent predictors of mortality in our cohort were: age (hazard ratio [HR] 1.09; 95% confidence interval [CI], 1.05–1.14; $P<0.001$), elevated procalcitonin (PCT) levels (HR 1.02; 95%CI, 1.01–1.03; $P<0.001$), and higher white blood cell-neutrophil ratio (NWR) (HR 1.04; 95%CI, 1.04–1.07; $P=0.004$). Areas under the ROC curve (AUC) for age, NWR, PCT, age*NWR were 0.70 (95%CI: 0.62–0.77), 0.82 (95%CI: 0.75–0.90), 0.64 (95%CI: 0.55–0.73), and 0.89 (0.85,0.94).

Conclusion We discovered that old age, high levels of NWR and PCT might be predictors of mortality, reported the causes and prognostic predictors of mortality in hemodialysis populations with COVID-19 from northern Hunan, China.

Keywords Hemodialysis, COVID-19, Mortality, Prognosis

Introduction

The globally widespread coronavirus disease of 2019 (COVID-19) was first detected in Wuhan province, China, in December 2019 and is caused by the severe acute respiratory syndrome coronavirus [1]. Older hemodialysis patients and those with obvious comorbidities are reported to be more susceptible to severe viral and bacterial respiratory infections, as has been shown with COVID-19. Mortality in the hemodialysis population with COVID-19 is dramatically high and also come from chronic diseases such as diabetes and hypertension, and have higher mobility, aggregation and weaker immune system than the general population [2–4]. The latest

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data display that the global mortality rate of COVID-19 dropped from 3.85% in June 2020 to 0.35% in October 2022. During the same period, the mortality rate of United States decreased from 3.82% to 0.26%, and that of China from 2.81% to 0.12%, Germany from 9.43% to 0.27%, Japan from 3.44% to 0.13%, above countries except China have opened ([5, 6], https://coronavirus.jhu.edu/map.html). The death rate of dialysis patients complicated with the novel coronavirus accounts for 20% to 30% of the total death rate of the novel coronavirus [7]. On December 1, 2022, all parts of the country began to implement the policy of epidemic prevention and development. China's Hunan province opened to the public on December 10, but there is little information on trends in its mortality rate.

According to existing research, advanced age and complications with hypertension, diabetes, and cardiovascular and cerebrovascular diseases are risk factors for severe pneumonia with hypoxia, acute respiratory distress syndrome, multiple organ failure, and the need for intensive care units (ICU) and respiratory support [8, 9]. Risk factors for mortality in hemodialysis patients with COVID-19 include older age, elevated markers of inflammation, low albumin levels, respiratory support, and high ICU occupancy [10–13]. Up to now, the inflammatory indicators reported in the literature mainly include: white blood cell (WBC), neutrophil counts, lymphocyte counts, neutrophil–lymphocyte ratio (NLR), lymphocyte counts, C-reactive protein (CRP). It is not clear whether there are other inflammatory markers (procalcitonin, white blood cell-neutrophil ratio) associated with mortality.

This study mainly explored changes in mortality and risk factors of mortality in a cohort of hemodialysis patients co-infected with COVID-19 in northern Hunan province (Supplementary Fig. 1) [14], China before and after the opening of epidemic prevention, and determined whether old age and other inflammatory indicators could be used as predictors.

Materials and methods

Population

This investigation reviewed uremic patients undergoing hemodialysis at Yiyang Central Hospital. The study included 262 hemodialysis patients between November 1, 2022 and February 1, 2023. The inclusion criteria were: patients met diagnostic criteria for chronic kidney disease (CKD); the indication for hemodialysis was reached; at least once on hemodialysis; COVID-19 nucleic acid test positive. Exclusion criteria were: patients with incomplete clinical data; other organic heart disease and congenital heart disease. In the end, 230 patients were enrolled and met the demand in the study. These patients have not received COVID-19-related vaccines. The study protocol was designed and approved by the Institutional Ethics Committee of Yiyang Central Hospital. Informed consent was obtained from each patient.

Clinical and biochemical variables

As part of routine clinical care, pathology of electronic systems is a retrospective review, records for the first time in hemodialysis patients with biochemical variables, including complete blood count, calcium, phosphate, procalcitonin (PCT), parathormone (PTH), albumin, ferritin, total cholesterol, triglyceride, low density lipoprotein cholesterol (LDL), high-density lipoprotein cholesterol (HDL), CRP, brain natriuretic peptide (BNP), troponin T (TnT), erythrocyte sedimentation rate (ESR). Demographic data recorded included age, gender, the first hemodialysis catheter, ejection fraction (EF), presence of diabetes mellitus, ischemic heart disease (IHD), hypertension, cerebrovascular disease, and chronic obstructive pulmonary disease, respiratory support, intensive care, the use of corticosteroids. All patients assessed to be stable enough for chest imaging underwent chest computed tomography (CT), which reported as suggestive or non-suggestive of COVID-19, based on lung lesions. Severity was graded according to the rate of lung involvement (grades 1, 2, 3, and 4 correspond to < 25%, 26–50%, 51–75%, and > 75%, respectively). Data information was also obtained from the electronic medical record system to instructive the cause of death.

Statistical analyses

All data were recorded and analyzed using Spss software (version 26; IBM, Chicago, USA) and Graphpad Prism (version 8.0.1; Graphpad Software, California, USA). Descriptive statistics for the study cohorts were calculated, continuous variables were reported as mean ± standard deviation or median and interquartile ranges depending on their distribution, and their distribution was tested using Kolmogorov–Smirnov tests. Categorical variables are expressed as frequencies (%). Baseline characteristics of patients grouped according to survival or death were analyzed using the Student test, Mann–Whitney's U test or Analysis of variance for continuous variables and the Chi-Square test for categorical variables. Univariate Cox regression analyses were used to identify preidictors of cardiovascular and all-cause mortality, and significant predictors (factors with *P*-values less than 0.05 in univariate Cox regression analyses) were subsequently added to the multivariate model. The prognosis power of the meaningful predictors to predict mortality of patients with hemodialysis complicated with COVID-19 assessed based on the analysis of the Receiver Operating Characteristic (ROC).

Results

Basic information regarding the included patients

At last, 230 hemodialysis patients were included in the study. Their baseline characteristics were described in Table 1. After a total of 3 months of follow-up, 66 patients died (28.70%). All patients were divided into survival and death groups. The hemodialysis patients who died were significantly more likely to be advanced age, ischemic heart disease (IHD), cerebrovascular accident (CVA), need for respiratory support, ICU stay, use of corticosteroid, higher levels CT chest grades, lymphocyte count, NWR, NLR, troponin T, D-dimer, BNP, creatinine phosphate and PCT.

Comparison of respiratory support

Depending on clinical needs, different levels of respiratory support are provided, ranging from supplemental oxygen through a simple mask or non-rebreathing mask, to more advanced high nasal oxygen, continuous positive airway pressure ventilation, and occasional mechanical ventilation tracheal intubation [10]. The respiratory support mentioned in this study mainly includes the latter two types, collectively known as mechanical ventilation. For convenience, we divided the hemodialysis patients into three groups: no respiratory support, non-invasive respiratory support, and endotracheal intubation (Table 2). This table uncover that patients who are older, hypertensive, need for ICU stay, increased WBC, neutrophil counts, lymphocyte count, NWR, NLR, troponin T, D-dimer, BNP, creatinine, phosphate, PCT and CT chest grades, are more likely to need respiratory support. Moreover, mortality was strongly associated with the use of respiratory support.

Comparison of infected hemodialysis patients regarding intensive care unit need

Hemodialysis patients with COVID-19 who needed to stay at ICU were compared to patients who did not (Table 3). Patients who needed ICU stay had older age, hypertension, higher CT chest grades, WBC, neutrophil count, lymphocyte count, NLR, CRP, NWR, PCT, D-dimer, and creatinine. They also had statistically significantly use of corticosteroid, need for respiratory support and lower albumin at admission and suggested a higher mortality in patients requiring ICU.

Transformations in the mortality rate before and after the opening of epidemic prevention

During the study period, 66 patients died. The curves for the mortality of the hemodialysis cohort are exhibited in Fig. 1. Figure 1 shows that the mortality rate has gradually increased from 1.74% to 6.09% before December 10, 2022. The mortality rate has sharply increased and reached 16.09% after 5 days of December 10, 2022. Over time, the mortality rate has gradually decreased.

Univariate and multivariate regression analysis related to mortality

In univariate analyses, age, use of corticosteroid and the labs including lymphocytes, monocytes, NWR, PCT, phosphate, D-dimer, BNP were associated with mortality.

In multivariate Cox regression analysis of mortality, increasing age (hazard ratio [HR] 1.09; 95% confidence interval [CI], 1.05–1.14; $p<0.001$), use of corticosteroid (HR 0.24; 95%CI, 010–0.55; $p=0.001$), higher NWR (HR 1.04; 95%CI, 1.01–1.07; $p=0.004$) and PCT (HR 1.02; 95%CI, 1.01–1.03; $p<0.001$) were independently associated with mortality. Increasing age (HR 1.03; 95%CI, 1.01–1.06; $p=0.003$) and neutrophils (HR 1.32; 95%CI, 1.04–1.69; $p=0.023$) were also significantly associated with all-cause mortality (Table 4).

Roc curves for age, NWR, and PCT

ROC analysis was performed for the diagnostic decision-marking features of age, NWR and PCT. The cut-off value of the prognosis power of the age, NWR and PCT were determined with ROC analysis (Fig. 2). Areas under the ROC curve (AUC) obtained for cut-off value analysis in detecting the mortality. The curves showed that the optimal thresholds for age, NWR and PCT were 66.50, 0.89 and 2.54, respectively. In these cases, the AUC were 0.70 (95%CI: 0.62–0.77), 0.82 (95%CI: 0.75–0.90) and 0.64 (95%CI: 0.55–0.73), the sensitivity were 0.76, 0.74 and 0.61, and the specificity were 0.60, 0.83 and0.68. In order to improve the predictive value, this study combined the two factors in pairs and found that the AUC increased. AUC were in sequence 0.84 (95%CI: 0.78–0.91) (NWR*PCT), 0.75 (95%CI: 0.67–0.82) (age*PCT) and 0.89 (95%CI: 0.85–0.94) (age*NWR). These results show that the established ROC curve has good stability and reliability (Table 5).

Discussion

In the current study, we found that the mortality rate of hemodialysis patients with COVID-19 has reached to the top 16.09% after 5 days of the opening day, and then gradually decreased. In this single-center study of a group of hospitalized hemodialysis with COVID-19 patients, we investigated the causes and predictors of mortality among hemodialysis with COVID-19 patients in northern Hunan, China. We found that advanced in age, higher NWR and PCT were predictors for mortality.

Our cohort showed that the mortality of hemodialysis populations infected with the COVID-19 is 28.70%. This is roughly the same mortality as reported in some published hemodialysis cohorts, including United States

Table 1 Baseline patient characteristics

Variables	All patients	Live($n=164$)	Death($n=66$)	*P*-values
Demographics				
Ages (years)	67 (58.0, 72.25)	64 (54.25, 71.00)	71 (66.75, 75.00)	**< 0.001**
Male gender, n (%)	151 (65.65)	102 (62.20)	49 (74.24)	0.08
Comorbidities				
Catheter at 1st HD, n (%)	103 (44.78)	67 (40.85)	36 (54.55)	0.06
Diabetes mellitus, n (%)	96 (41.74)	62 (37.80)	34 (51.52)	0.06
IHD, n (%)	41 (17.83)	22 (13.41)	19 (28.79)	**0.006**
Hypertension, n (%)	180 (78.26)	132 (80.49)	48 (72.73)	0.18
CVA, n (%)	53 (23.04)	28 (17.07)	25 (37.88)	**0.001**
COPD, n (%)	15 (6.52)	11 (6.70)	4 (6.06)	1.00
Laboratory Variables				
Hb [a] (g/L)	85.00 (70.00, 106.00)	87.36 ± 23.73	88.00 (71.00, 109.25)	0.75
WCC (× 10^9/L)	6.40 (4.74, 9.12)	6.29 (4.77, 8.98)	6.92 (4.60, 9.42)	0.71
Neutrophil (× 10^9/L)	5.22 (3.55, 8.10)	4.98 (3.64, 7.76)	5.77 (3.10, 8.44)	0.57
Lymphocytes [a] (× 10^9/L)	0.64 (0.41, 0.92)	0.69 (0.46, 0.97)	0.58 ± 0.34	**0.001**
Monocytes [a] (× 10^9/L)	0.50 (0.31, 0.70)	0.52 (0.33, 0.72)	0.50 ± 0.28	0.19
NWR	0.83 (0.74, 0.92)	0.79 (0.73, 0.87)	0.97 (0.87, 7.80)	**< 0.001**
LWR	0.10 (0.060, 0.16)	0.11 (0.07, 0.16)	0.08 (0.03, 0.14)	0.12
MWR	0.07 (0.05, 0.10)	0.08 (0.06, 0.10)	0.06 (0.04, 0.10)	0.65
NLR	7.81 (4.57, 15.34)	7.07 (4.40, 13.13)	10.57 (5.20, 26.24)	**0.02**
MNR	0.09 (0.06, 0.14)	0.10 (0.07, 0.14)	0.08 (0.05, 0.13)	0.07
MLR	0.74 (0.47, 1.25)	0.72 (0.48, 1.14)	0.85 (0.51, 1.43)	0.10
PMR	337.92 (209.52, 497.58)	341.54 (205.70, 504.41)	325.00 (215.33, 482.01)	0.89
PLR	242.91 (153.18, 420.13)	231.58 (152.77, 393.84)	289.89 (157.87, 488.15)	0.07
PNR	30.73 (19.05, 46.30)	32.38 (21.59, 47.09)	25.42 (16.98, 45.93)	0.15
Albumin [a] (g/L)	33.60 (30.00, 39.70)	33.84 ± 5.83	33.80 (29.25, 38.33)	0.99
Ferritin (ug/L)	433.10 (157.70, 997.50)	412.00 (173.20, 898.25)	536.30 (125.40,1112.30)	0.45
Total cholesterol [a] (mmol/L)	3.45 ± 1.03	3.51 ± 1.09	3.29 ± 0.84	0.14
HDL (mmol/L)	0.94 (0.76, 1.17)	0.95 (0.76, 1.16)	0.90 (0.79, 1.18)	0.91
LDL [a] (mmol/L)	1.80 (1.34, 2.36)	1.79 (1.39, 2.39)	1.75 ± 0.65	0.34
Triglycerides (mmol/L)	1.47 (1.05, 2.21)	1.55 (1.05, 2.26)	1.41 (1.03, 2.02)	0.36
CRP (mg/L)	61.92 (17.21, 138.03)	51.39 (16.45, 137.24)	77.50 (25.50, 161.10)	0.13
TnT (pg/ml)	79.25 (36.43, 170.25)	63.90 (31.74, 127.80)	170.00 (72.20, 294.20)	**< 0.001**
ESR [a]	74.00 (43.75, 96.50)	81.00 (44.00, 98.00)	68.57 ± 30.34	0.85
PCT (ng/L)	1.81 (0.71, 6.25)	1.60 (0.66, 3.83)	3.55 (0.93, 30.33)	**0.002**
PLT [a] (× 10^9/L)	155.50 (110.75, 218.75)	173.86 ± 81.78	140.00 (103.25, 188.50)	0.09
Phosphate [a] (mmol/L)	1.63 (1.30, 2.25)	1.69 (1.39, 2.44)	1.63 ± 0.58	0.049
Calcium (mmol/L)	1.93 (1.77, 2.10)	1.90 (1.74, 2.06)	1.98 (1.85, 2.13)	0.06
D-dimer (mg/L)	1.75 (1.00, 3.77)	1.39 (0.80, 2.69)	2.67 (1.77, 5.43)	**< 0.001**
EF (%)	57.56 (53.00, 65.00)	61.0 (53.25, 65.00)	60.00 (47.00, 65.00)	0.15
BNP, n (%)	97 (42.17)	57 (34.76)	40 (60.61)	**0.02**
PTH (pg/ml)	244.20 (145.40, 411.91)	264.78 (154.86, 410.38)	191.94 (110.83, 420.49)	0.21
Creatinine [a] (umol/L)	696.80 (494.25, 989.50)	740.90 (538.50, 1030.25)	638.94 ± 284.43	**0.004**
Clinical course				
Use of respiratory support				**< 0.001**
Noninvasive, n (%)	40 (17.39)	23 (14.02)	17 (25.76)	
Invasive, n (%)	34 (14.78)	17 (10.37)	17 (25.76)	
Use of corticosteroid, n (%)	100 (43.48)	75 (45.73)	25 (15.24)	**0.03**
Use of antiviral, n (%)	67 (29.13)	47 (28.66)	20 (30.30)	0.80

Table 1 (continued)

Variables	All patients	Live($n=164$)	Death($n=66$)	*P*-values
Use of ACEI or ARB, n (%)	54 (23.48)	38 (23.17)	16 (24.24)	0.86
Use of anticoagulant, n (%)	38 (16.52)	29 (17.68)	9 (13.64)	0.558
ICU stay, n (%)	73 (31.74)	41 (25.00)	32 (48.48)	**0.001**
CT chest				**< 0.001**
Grade 1, n (%)	18 (7.83)	15 (9.15)	3 (4.55)	
Grade 2, n (%)	72 (31.30)	59 (35.98)	13 (19.70)	
Grade 3, n (%)	82 (35.65)	58 (35.37)	24 (36.36)	
Grade 4, n (%)	49 (21.30)	27 (16.46)	22 (33.33)	

Continuous data are expressed as median (interquartile range) unless otherwise stated

Bold values represent significance at $p < 0.05$

HD hemodialysis, *IHD* ischemic heart disease, *CVA* cerebrovascular accident, *COPD* chronic obstructive pulmonary disease, *Hb* hemoglobin, *WCC* white cell count, *NWR* Neutrophil-to-white cell ratio, *LWR* Lymphocyte-to-white cell ratio, *MWR* Monocyte-to-white cell ratio, *NLR* Neutrophil-to-Lymphocyte ratio, *MNR* Monocyte-to-Neutrophil ratio, *MLR* Monocyte-to-Lymphocyte ratio, *PMR* blood platelet-to-Lymphocyte ratio, *PLR* blood platelet-to-Lymphocyte ratio, *PNR* blood platelet-to-Neutrophil ratio, *HDL* high-density lipoprotein, *LDL* low-density lipoprotein, *CRP* C-reactive protein, *TnT* troponin T, *ESR* erythrocyte sedimentation rate, *PCT* Procalcitonin, *PLT* blood platelet, *EF* ejection fraction, *BNP* brain natriuretic peptide (≥ 35,000 is expressed as"1″ and < 35,000 as "0″), *PTH* parathyroid hormone, *ACEI* angiotensin-converting enzyme inhibitor, *ARB* angiotensin receptor blocker, *ICU* intensive care units

[a] Mean ± SD

(28–31%) [15, 16], Italy (29%) [17], Spain (30.5%) [18], New York (31%) [15] and Japan 28.4% [19]. The mortality rose before and after the opening of the epidemic, reaching even after 5 days of the opening day, and then the mortality was taper off. This may be due to gradually advanced medical measures learned from other countries and Wuhan, mature clinical experience, and constant drug updates [7, 8, 20].

Age and chronic kidney disease have been identified as independent risk factors for death from COVID-19. Majority of the died hemodialysis patients are elderly [11]. Compared with younger hemodialysis patients, elderly hemodialysis patients may exhibit a more severe immunosuppressive state and weaker resistance, and they often have other chronic diseases, leading to a higher mortality rate of elderly hemodialysis patients with COVID-19 infection. Previous studies have reported that there is a statistically significant correlation between old age and mortality [10–12, 21]. Our results in this regard are consistent with findings from them, age was closely related to mortality, and the ROC curve suggested that the optimal cut-off value was 66.5, which meant that hemodialysis patients older than 66.5 years had higher mortality and worse prognosis. Vergara et al. reported that the age cut-off was 74.8 years and proved that patients aged 75 years or older have a higher mortality rate than patients aged 65 to 74 years [21]. The difference is mainly due to the different age distribution of the study objects.

Current literatures report that inflammatory parameters are associated with mortality in hemodialysis patients with COVID-19: higher values of WBC, neutrophil counts, lymphocyte counts, NLR and CRP [12, 22, 23]. In contrast, in this study, different inflammatory mediators exist as predictors: NWR and PCT. Inflammation starts when the immune system is activated to protect the body from invasion, such as bacteria or viruses [24]. Lymphocytes mainly produce antibodies against viral infection, and a high absolute and percentage of lymphocytes indicates viral infection. Erdinc et al. summarized the hematological manifestations of COVID-19 and reported that lymphocytopenia is the most common situation [25]. In the process of inflammation, white blood cells are a major component of immunity against pathogen invasion and activated and they move directly into the invading pathogen, subsequently isolating them [26]. In humans, neutrophils account for 50–70% of all circulating leukocytes [27]. Neutrophils not only have proinflammatory effects but may also exhibit anti-inflammatory or healing features, clearing dead cells and bacteria by their neutrophil phagocytic activity [26, 27]. NWR refers to the clinical neutrophil to leukocyte ratio. Consequently, the increase of NWR is commonly seen in various acute infections, acute injuries and acute poisoning of the body. CRP is a highly phylogenetically conserved plasma protein involved in the systemic response to inflammation. Its plasma concentration increases in inflammatory states, up to 1,000 times or more after acute inflammatory stimulation, a feature that has long been used for clinical purposes. However, CRP is a broad indicator of inflammation and cannot distinguish between inflammation caused by bacterial or viral infections [28]. PCT is a biomarker that is usually elevated in bacterial infections, but not viral infections [29]. Another retrospective study showed increased use of PCT compared to CRP, and that PCT were associated with more

Table 2 Comparison of patients regarding respiratory support need

Variables	All patients	Noninvasive respiratory support (*n* = 40)	Invasive respiratory support (*n* = 34)	NO Respiratory support (*n* = 156)	*P*-values
Demographics					
Ages [a] (years)	67.00 (58.0, 72.25)	72.00 (65.00, 75.00)	69.32 ± 11.56	64.50 (54.25, 71.00)	**< 0.001**
Male gender, n (%)	151 (65.65)	29 (72.50)	22 (64.71)	100 (64.10)	0.60
Comorbidities					
Catheter at 1st HD, n (%)	103 (44.78)	19 (47.50)	21 (61.76)	63 (40.38)	0.07
Diabetes mellitus, n (%)	96 (41.74)	17 (42.50)	17 (50.00)	62 (39.74)	0.54
IHD, n (%)	41 (17.83)	12 (30.00)	6 (17.65)	23 (14.74)	0.08
Hypertension, n (%)	180 (78.26)	28 (70.00)	20 (58.82)	132 (84.62)	**0.002**
CVA, n (%)	53 (23.04)	10 (25.00)	9 (26.47)	34 (21.79)	0.80
COPD, n (%)	15 (6.52)	2 (5.00)	0 (0.00)	13 (8.30)	0.48
Laboratory Variables					
Hb [a] (g/L)	85.00 (70.00, 106.00)	85.08 ± 29.36	95.06 ± 38.61	87.19 ± 21.85	0.44
WCC (× 10^9/L)	6.40 (4.74, 9.12)	8.36 (6.41, 12.34)	7.53 (5.78, 10.88)	5.71(4.52, 8.28)	**< 0.001**
Neutrophil (× 10^9/L)	5.22 (3.55, 8.10)	7.14 (5.12, 11.08)	5.86 (4.53, 9.73)	4.30 (3.01, 6.67)	**< 0.001**
Lymphocytes [a] (× 10^9/L)	0.64 (0.41, 0.92)	0.54 ± 0.31	0.61 (0.36, 0.94)	0.69 (0.46, 0.94)	**0.008**
Monocytes [a] (× 10^9/L)	0.50 (0.31, 0.70)	0.54 ± 0.29	0.46 (0.29, 0.61)	0.52 (0.32, 0.70)	0.65
NWR	0.83 (0.74, 0.92)	0.90 (0.83, 0.94)	0.85 (0.80, 0.94)	0.79 (0.71, 0.89)	**< 0.001**
LWR[a]	0.10 (0.06, 0.16)	0.05 (0.03, 0.11)	0.10 ± 0.07	0.12 (0.07, 0.18)	**< 0.001**
MWR[a]	0.07 (0.05, 0.10)	0.06 ± 0.04	0.06 (0.04, 0.08)	0.08 (0.06, 0.11)	**< 0.001**
NLR	7.81 (4.57, 15.34)	17.89 (7.51, 34.23)	10.42 (5.31, 23.79)	6.24 (3.90, 11.45)	**< 0.001**
MNR[a]	0.09 (0.06, 0.14)	0.07 ± 0.05	0.07 (0.04, 0.11)	0.11 (0.07, 0.16)	**< 0.001**
MLR	0.74 (0.47, 1.25)	0.95 (0.55, 1.89)	0.69 (0.42, 1.40)	0.73 (0.49, 1.06)	0.71
PMR	337.92 (209.52, 497.58)	331.72 (215.31, 491.74)	284.10(190.53,494.91)	346.92 (208.68, 505.00)	0.69
PLR	242.91 (153.18, 420.13)	354.37 (195.28, 664.37)	216.99(118.69,449.53)	231.58 (152.77, 361.39)	**0.02**
PNR[a]	30.73 (19.05, 46.30)	25.70 ± 15.44	23.60 ± 13.88	35.64 (24.91, 50.57)	**< 0.001**
Albumin[a] (g/L)	33.60 (30.00, 39.70)	32.39 ± 5.08	30.60 (27.65, 34.78)	34.63 ± 5.75	**0.003**
Ferritin[a] (ug/L)	433.10 (157.70, 997.50)	1000.26 ± 837.85	522.00(236.00,1112.80)	371.45 (146.70,801.08)	0.06
Total cholesterol [a] (mmol/L)	3.45 ± 1.03	3.57 ± 0.78	3.06 ± 1.01	3.49 ± 1.06	0.14
HDL [a] (mmol/L)	0.94 (0.76, 1.17)	1.01 ± 0.39	0.86 (0.77, 1.19)	0.95 (0.76, 1.15)	0.94
LDL [a] (mmol/L)	1.80 (1.34, 2.36)	1.86 ± 0.68	1.72 ± 0.60	1.82 (1.31, 2.42)	0.55
Triglycerides [a] (mmol/L)	1.47 (1.05, 2.21)	1.49 (1.19, 2.33)	1.55 ± 0.72	1.44 (1.04, 2.18)	0.77
CRP [a] (mg/L)	61.92 (17.21, 138.03)	75.51 (32.90, 216.54)	165.01 ± 114.40	41.90 (14.52, 112.35)	**< 0.001**
TnT (pg/ml)	79.25 (36.43, 170.25)	73.33 (22.00, 246.75)	143.00 (60.48, 305.75)	76.25 (36.75, 138.20)	**0.04**
ESR [a]	74.00 (43.75, 96.50)	88.00 (31.50, 102.50)	70.36 ± 32.40	69.71 ± 31.32	0.95
PCT (ng/L)	1.81 (0.71, 6.25)	2.59 (1.09, 11.12)	8.54 (1.45, 31.40)	1.42 (0.55, 3.45)	**< 0.001**
PLT [a] (× 10^9/L)	155.50 (110.75, 218.75)	183.78 ± 97.18	146.50 ± 77.77	162.00 (112.00, 215.00)	0.22
Phosphate [a] (mmol/L)	1.63 (1.30, 2.25)	1.98 ± 0.69	1.48 (1.30, 2.03)	1.62 (1.24, 2.27)	0.22
Calcium (mmol/L)	1.93 (1.77, 2.10)	1.92 (1.53, 2.03)	1.93 (1.77, 2.05)	1.48 (0.89, 2.44)	0.30
D-dimer (mg/L)	1.75 (1.00, 3.77)	2.48 (0.94, 5.26)	2.69 (1.74, 5.79)	1.48 (0.89, 2.44)	0.04
EF (%)	57.56 (53.00, 65.00)	60.00 (54.00, 66.50)	62.00 (57.25, 66.00)	60.00 (53.00, 65.00)	0.52
BNP, n (%)	97 (42.17)	19 (47.50)	11 (32.35)	67 (42.95)	0.40
PTH (pg/ml)	244.20 (145.40, 411.91)	264.16 ± 189.24	203.97(111.24,537.24)	253.34 (147.44, 411.14)	0.78
Creatinine [a] (umol/L)	696.80 (494.25, 989.50)	668.40 ± 395.30	620.97 ± 412.70	734.90(568.75,1045.33)	**< 0.001**
Clinical course					
Use of hormone, n (%)	100 (43.48)	23 (57.50)	24 (70.59)	53 (33.97)	**< 0.001**
Use of antiviral, n (%)	67 (29.13)	10 (25.00)	12 (35.29)	45 (28.85)	0.62
Use of ACEI or ARB, n (%)	54 (23.48)	11 (27.50)	3 (8.82)	40 (25.64)	0.09
Use of anticoagulant, n (%)	38 (16.52)	10 (25.00)	7 (20.59)	21 (13.46)	

Table 2 (continued)

Variables	All patients	Noninvasive respiratory support (*n* = 40)	Invasive respiratory support (*n* = 34)	NO Respiratory support (*n* = 156)	*P*-values
ICU Stay, n (%)	73 (31.74)	28 (70.00)	28 (82.35)	17 (10.90)	**< 0.001**
CT chest					**< 0.001**
Grade 1, n (%)	18 (7.83)	2 (5.00)	1 (2.94)	15 (9.62)	
Grade 2, n (%)	72 (31.30)	9 (22.50)	8 (23.53)	55 (35.26)	
Grade 3, n (%)	82 (35.65)	11 (27.50)	8 (23.53)	63 (40.38)	
Grade 4, n (%)	49 (21.30)	14 (35.00)	16 (47.06)	19 (12.18)	
Mortality, n (%)	66 (28.70)	17 (42.50)	17 (50.00)	32 (20.51)	**< 0.001**

Continuous data are expressed as median (interquartile range) unless otherwise stated

Bold values represent significance at $p < 0.05$

HD hemodialysis, *IHD* ischemic heart disease, *CVA* cerebrovascular accident, *COPD* chronic obstructive pulmonary disease, *Hb* hemoglobin, *WCC* white cell count, *NWR* Neutrophil-to-white cell ratio, *LWR* Lymphocyte-to-white cell ratio, *MWR* Monocyte-to-white cell ratio, *NLR* Neutrophil-to-Lymphocyte ratio, *MNR* Monocyte-to-Neutrophil ratio, *MLR* Monocyte-to-Lymphocyte ratio, *PMR* blood platelet-to-Lymphocyte ratio, *PLR* blood platelet-to-Lymphocyte ratio, *PNR* blood platelet-to-Neutrophil ratio, *HDL* high-density lipoprotein, *LDL* low-density lipoprotein, *CRP* C-reactive protein, *TnT* troponin T, *ESR* erythrocyte sedimentation rate, *PCT* Procalcitonin, *PLT* blood platelet, *EF* ejection fraction, *BNP* brain natriuretic peptide (≥ 35,000 is expressed as"1″ and < 35,000 as "0″), *PTH* parathyroid hormone, *ACEI* angiotensin-converting enzyme inhibitor, *ARB* angiotensin receptor blocker, *ICU* intensive care units

[a] Mean ± SD

interventions, such as ICU admission, use of vasopressors, and mechanical ventilation [30]. PCT levels are very high in hemodialysis patients with severe aggressive bacterial infections and decline rapidly during antibiotic treatment [31]. There is reported that PCT is increased in hemodialysis patients with COVID-19 [32]. Moreover, in our study, the most important one in the prediction model was PCT and mortality of hemodialysis patients with COVID-19 was statistically significantly different from high levels of NWR and PCT. The ROC curve in this research indicated that AUC was greatly improved when NWR and PCT combined, the accuracy of predicting death increased when combined PCT or NWR with advanced age. This suggests that in the early stage of the novel coronavirus infection, bacterial infection is often combined, and the mortality of hemodialysis patients will increase. Therefore, we should also pay attention to the treatment of bacterial infections in antiviral treatment. It is also crucial to improve the examination of inflammatory indicators, identify pathogenic bacteria in bacterial culture, and select appropriate antibiotics according to drug susceptibility tests.

Until 2023, the main antiviral drugs include: Azvudine, Nematovir/ritonavir and Remdesivir. In China, hemodialysis patients were not treated with Remdesivir because the clinical trials are insufficient and it may cause serious side effects and high resource consumption [33]. In our research, statistical data analysis showed that there was no significant correlation between the use of antiviral drugs and mortality, suggesting that the above two novel coronavirus specific drugs were not effective in patients with hemodialysis combined with novel coronavirus, and specific antiviral drugs should be developed for this group of people. Recently, the launch of a new antiviral drug called Monolavir for the treatment of novel coronavirus in hemodialysis patients significantly reduces the risk of hospitalization or death in adults at high risk of COVID-19 who have not been vaccinated [34, 35]. Monolavir improves poor prognoses, but whether combination with other drugs can improve efficacy needs further study. Gagan et al. reported that corticosteroid use can reduce mortality [36], and our study had the same conclusion. Literatures have reported that the increase of D-dimer in hemodialysis patients is associated with mortality [22, 37, 38]. Therefore, Perna et al. proposed that anticoagulant drugs can protect patients from COVID-19 virus infection during each hemodialysis procedure [39]. However, in our study, the use of D-dimer and anticoagulant drugs was not statistically significant with mortality. One reason might contribute to this: in our hemodialysis patient population, the regular use of anticoagulant drugs on hemodialysis, including during the period of COVID-19 infection, the level of D-dimer in the patients has been maintained at a low level with no significant difference.

Critically ill hemodialysis patients with COVID-19 often develop hypoxemia and respiratory failure, as well as other potential extrapulmonary complications, including an increased risk of shock, acute kidney injury, and thromboembolism. Between 6 and 10% of COVID-19 hemodialysis patients progress to acute respiratory distress syndrome, and mortality in hemodialysis patients with COVID-19-associated ARDS may exceed 20% to 40%. Therefore, as the disease progresses, critically ill hemodialysis patients require respiratory support and

Table 3 Comparison of patients regarding intensive care unit need

Variables	All patients	ICU stay ($n=73$)	NO ICU stay ($n=157$)	*P*-values
Demographics				
Ages (years)	67.00(58.00,72.30)	70.00 (61.50, 76.50)	65.00 (56.00, 71.50)	**0.002**
Male gender, n (%)	151 (65.65)	52 (71.23)	99 (63.06)	0.22
Comorbidities				
Catheter at 1st HD, n (%)	103 (44.78)	41 (56.16)	62 (39.49)	**0.02**
Diabetes mellitus, n (%)	96 (41.74)	33 (45.21)	63 (40.13)	0.49
IHD, n (%)	41 (17.83)	14 (19.18)	27 (17.20)	0.72
Hypertension, n (%)	180 (78.26)	46 (63.01)	134 (85.35)	**< 0.001**
CVA, n (%)	53 (23.04)	21 (28.77)	32 (20.38)	0.16
COPD, n (%)	15 (6.52)	2 (2.74)	13 (8.28)	0.20
Laboratory Variables				
Hb [a] (g/L)	85.00(70.00,106.00)	87.10 ± 25.91	85.00 (71.00, 106.00)	0.25
WCC (× 10^9/L)	6.40 (4.74, 9.12)	7.89 (5.06, 11.60)	6.21 (4.68, 8.31)	**0.006**
Neutrophil (× 10^9/L)	5.22 (3.55, 8.10)	6.63 (4.10, 9.89)	4.66 (3.23, 6.85)	**0.001**
Lymphocytes [a] (× 10^9/L)	0.64 (0.41, 0.92)	0.64 ± 0.42	0.66 (0.46, 0.94)	**0.03**
Monocytes (× 10^9/L)	0.50 (0.31, 0.70)	0.46 (0.28, 0.70)	0.52 (0.33, 0.70)	0.24
NWR	0.83 (0.74, 0.92)	0.88 (0.81, 0.94)	0.79 (0.73, 0.90)	**< 0.001**
LWR[a]	0.10 (0.06, 0.16)	0.08 (0.04, 0.12)	0.12 ± 0.07	**< 0.001**
MWR	0.07 (0.05, 0.10)	0.06 (0.04, 0.09)	0.08 (0.06, 0.11)	**< 0.001**
NLR	7.81 (4.57, 15.34)	10.92 (6.60, 26.00)	6.24 (4.07, 12.06)	**< 0.001**
MNR	0.09 (0.06, 0.14)	0.07 (0.04, 0.11)	0.11 (0.07, 0.16)	**< 0.001**
MLR	0.74 (0.47, 1.25)	0.74 (0.47, 1.48)	0.74 (0.49, 1.16)	0.52
PMR	337.92 (209.52, 497.58)	363.66 (212.48, 538.73)	337.00 (208.38, 493.70)	0.79
PLR	242.91 (153.18, 420.13)	250.88 (148.14, 500.00)	237.50 (154.28, 400.28)	0.33
PNR	30.73 (19.05, 46.30)	25.76 (14.39, 35.12)	34.75 (23.58, 49.71)	**< 0.001**
Albumin [a] (g/L)	33.60 (30.00, 39.70)	31.62 ± 5.75	34.00 (30.75, 38.78)	**< 0.001**
Ferritin (ug/L)	433.10 (157.70, 997.50)	912.20 (330.75,1470.65)	364.40 (136.38, 753.08)	**0.001**
Total cholesterol [a] (mmol/L)	3.45 ± 1.03	3.35 ± 0.96	3.48 ± 1.05	0.39
HDL [a] (mmol/L)	0.94 (0.76, 1.17)	0.94 ± 0.32	0.95 (0.76, 1.18)	0.35
LDL [a] (mmol/L)	1.80 (1.34, 2.36)	1.72 ± 0.62	1.86 (1.35, 2.44)	0.10
Triglycerides (mmol/L)	1.47 (1.05, 2.21)	1.43 (1.02, 2.27)	1.49 (1.07, 2.17)	0.86
CRP (mg/L)	61.92 (17.21, 138.03)	99.04 (34.13, 228.92)	44.11 (15.10, 122.90)	**< 0.001**
TnT (pg/ml)	79.25 (36.43, 170.25)	101.20 (27.00, 288.40)	76.39 (37.14, 142.13)	0.20
ESR	74.00 (43.75, 96.50)	82.50 (45.00, 101.25)	72.50 (42.75, 96.00)	0.46
PCT (ng/L)	1.81 (0.71, 6.25)	3.97 (1.25, 28.68)	1.46 (0.60, 3.61)	**< 0.001**
PLT [a] (× 10^9/L)	155.50 (110.75, 218.75)	161.53 ± 87.22	164.00 (114.50, 215.50)	0.25
Phosphate [a] (mmol/L)	1.63 (1.30, 2.25)	1.85 ± 0.69	1.45 (0.57, 3.49)	0.73
Calcium [a] (mmol/L)	1.93 (1.77, 2.10)	1.91 (1.48, 2.04)	1.93 ± 0.26	0.06
D-dimer (mg/L)	1.75 (1.0, 3.77)	1.42 (0.88, 2.45)	2.53 (1.38, 5.42)	**< 0.001**
EF (%)	57.56 (53.00, 65.00)	60.00 (54.00, 65.00)	61.00 (53.00, 65.00)	0.90
BNP, n (%)	97 (42.17)	31 (42.47)	66 (42.04)	0.90
PTH (pg/ml)	244.20 (145.40, 411.91)	103.97 (130.59, 425.18)	253.34 (147.77, 408.36)	0.86
Creatinine [a] (umol/L)	696.80 (494.25, 989.50)	615.48 ± 367.79	748.00 (576.60, 1041.55)	**< 0.001**
Clinical course				
Use of respiratory support				**< 0.001**
Noninvasive, n (%)	40 (17.39)	28 (38.35)	12 (7.64)	
Invasive, n (%)	34 (14.78)	28 (38.35)	6 (3.82)	
Use of corticosteroid, n (%)	100 (43.48)	43 (58.90)	57 (36.31)	**0.001**
Use of antiviral, n (%)	67 (29.13)	19 (26.03)	48 (30.57)	0.48

Table 3 (continued)

Variables	All patients	ICU stay ($n=73$)	NO ICU stay ($n=157$)	*P*-values
Use of ACEI or ARB, n (%)	54 (23.48)	13 (17.81)	41 (26.11)	0.17
Use of anticoagulant, n (%)	38 (16.52)	24 (32.88)	22 (14.01)	0.34
CT chest				**< 0.001**
Grade 1, n (%)	18 (7.83)	4 (5.48)	14 (8.92)	
Grade 2, n (%)	72 (31.30)	12 (16.44)	60 (38.22)	
Grade 3, n (%)	82 (35.65)	26 (35.62)	56 (35.67)	
Grade 4, n (%)	49 (21.30)	25 (34.25)	24 (15.29)	
Mortality, n (%)	66 (28.70)	32 (43.84)	34 (21.66)	**0.001**

Continuous data are expressed as median (interquartile range) unless otherwise stated

Bold values represent significance at $p < 0.05$

HD hemodialysis, *IHD* ischemic heart disease, *CVA* cerebrovascular accident, *COPD* chronic obstructive pulmonary disease, *Hb* hemoglobin, *WCC* white cell count, *NWR* Neutrophil-to-white cell ratio, *LWR* Lymphocyte-to-white cell ratio, *MWR* Monocyte-to-white cell ratio, *NLR* Neutrophil-to-Lymphocyte ratio, *MNR* Monocyte-to-Neutrophil ratio, *MLR* Monocyte-to-Lymphocyte ratio, *PMR* blood platelet-to-Lymphocyte ratio, *PLR* blood platelet-to-Lymphocyte ratio, *PNR* blood platelet-to-Neutrophil ratio, *HDL* high-density lipoprotein, *LDL* low-density lipoprotein, *CRP* C-reactive protein, *TnT* troponin T, *ESR* erythrocyte sedimentation rate, *PCT* Procalcitonin, *PLT* blood platelet, *EF* ejection fraction, *BNP* brain natriuretic peptide (≥ 35,000 is expressed as"1″ and < 35,000 as "0″), *PTH* parathyroid hormone, *ACEI* angiotensin-converting enzyme inhibitor, *ARB* angiotensin receptor blocker, *ICU* intensive care units

[a] Mean ± SD

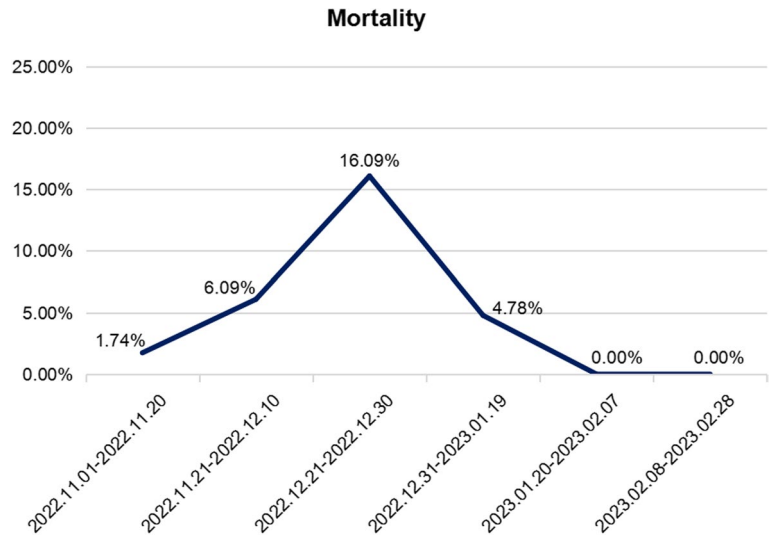

Fig. 1 Variety in the mortality rate before and after the opening of epidemic

intensive monitoring in the ICU [40, 41]. In a study from Turkey, a total of 134 (23.6%) hemodialysis patients needed ICU care and 91 of them (67.9%) required mechanical ventilation [42], the total number of people in the study was 567 compared to 73 (31.74%) and 69 (30.0%) hemodialysis patients in our cohort. Unlike some studies that show that hemodialysis patients requiring respiratory support and ICU admission usually have high mortality [10, 11], our findings showed ICU admission and use of respiratory support were not risk factors for mortality and were not predictive of poor outcomes. Most patients with critical hemodialysis come for respiratory support and intubation. Intubation has been reported to increase infection and mortality, so whether to intubation is still a question to consider.

This study has some limitations. Firstly, this study is a single-center, small-sample study, and only can show the situation in northern Hunan province, China. Secondly, the study was conducted on a Chinese population, so the findings may not be applicable to other ethnic groups. Thirdly, when we performed multivariate Cox regression analysis and adjusted for factors, we only included variables in univariate analysis with $P < 0.05$, which may have lost relevant risk factors affecting death to some extent. Finally, this study is a retrospective study and it has its inherent limitations such as information bias.

Table 4 Univariate and multivariate cox regression model for mortality

	Unadjusted Cox analysis		Adjusted Cox analysis	
Variables	***P*-values**	**Hazards ratio (95% CI)**	***P*-values**	**Hazards ratio (95% CI)**
Demographics				
Ages (years)	**< 0.001**	1.05 (1.02, 1.07)	**< 0.001**	1.09 (1.05, 1.14)
Male gender	0.79	1.08 (0.62, 1.88)		
Comorbidities				
Catheter at 1st HD	0.18	1.40 (0.86, 2.28)		
Diabetes mellitus	0.30	1.30 (0.80, 2.10)		
IHD	0.33	1.31 (0.76, 2.24)		
Hypertension	0.22	0.71 (0.41, 1.23)		
CVA	**0.01**	1.91 (1.16, 3.16)		
COPD	0.90	1.07 (0.39, 2.95)		
Laboratory Variables				
Hb (g/L)	0.87	1.00 (0.99, 1.01)		
WCC (×10^9/L)	0.69	1.01 (0.95, 1.08)		
Neutrophil (×10^9/L)	0.79	1.01 (0.95, 1.08)		
Lymphocytes (×10^9/L)	**0.01**	0.41 (0.20, 0.83)		
Monocytes (×10^9/L)	**0.03**	0.39 (0.16, 0.92)		
NWR	**0.003**	1.02 (1.01, 1.04)	**0.004**	1.04 (1.01, 1.07)
LWR	0.62	0.45 (0.02, 10.62)		
MWR	0.08	0.00 (0.00, 2.09)		
NLR	0.12	10.92(6.60,26.00)		
MNR	0.58	1.45 (0.39, 5.32)		
MLR	0.35	1.12 (0.89, 1.42)		
PMR	0.52	1.00 (1.00, 1.00)		
PLR	0.22	1.00 (1.00, 1.00)		
PNR	0.35	1.00 (1.00, 1.00)		
Albumin (g/L)	0.19	1.00 (1.00, 1.01)		
Ferritin (ug/L)	0.29	1.00 (1.00, 1.00)		
Total cholesterol (mmol/L)	0.16	0.84 (0.65, 1.07)		
HDL (mmol/L)	0.82	1.08 (0.57, 2.04)		
LDL (mmol/L)	0.35	0.85 (0.61, 1.19)		
Triglycerides (mmol/L)	0.23	0.85 (0.66, 1.10)		
CRP (mg/L)	0.81	1.00 (1.00, 1.00)		
TnT (pg/ml)	0.05	1.00 (1.00, 1.00)		
ESR	0.67	1.00 (0.99, 1.01)		
PCT (ng/L)	**0.001**	1.01 (1.01, 1.02)	**< 0.001**	1.02 (1.01, 1.03)
PLT (×10^9/L)	0.07	1.00 (0.99, 1.00)		
Phosphate (mmol/L)	**0.02**	0.57 (0.36, 0.90)		
Calcium (mmol/L)	0.87	1.08 (0.45, 2.56)		
D-dimer (mg/L)	**0.001**	1.11 (1.05, 1.17)		
EF (%)	0.56	0.99 (0.97, 1.02)		
BNP	**0.008**	2.06 (1.21, 3.51)		
PTH (pg/ml)	0.30	1.00 (1.00, 1.00)		
Creatinine (umol/L)	**0.004**	1.00 (1.00, 1.00)		
Clinical course				
Use of respiratory support	0.11			
Use of corticosteroid	**0.001**	0.42 (0.25, 0.71)	**0.001**	0.24 (0.10, 0.55)
Use of antiviral	0.21	0.71 (0.42, 1.21)		
Use of ACEI or ARB	0.15	0.66 (0.37, 1.16)		

Table 4 (continued)

Variables	Unadjusted Cox analysis		Adjusted Cox analysis	
	P-values	Hazards ratio (95% CI)	*P*-values	Hazards ratio (95% CI)
Use of anticoagulant	0.17	0.61 (0.30, 1.23)		
CT chest	0.17			

Continuous data are expressed as median (interquartile range) unless otherwise stated

Bold values represent significance at $p < 0.05$

HD hemodialysis, *IHD* ischemic heart disease, *CVA* cerebrovascular accident, *COPD* chronic obstructive pulmonary disease, *Hb* hemoglobin, *WCC* white cell count, *NWR* Neutrophil-to-white cell ratio, *LWR* Lymphocyte-to-white cell ratio, *MWR* Monocyte-to-white cell ratio, *NLR* Neutrophil-to-Lymphocyte ratio, *MNR* Monocyte-to-Neutrophil ratio, *MLR* Monocyte-to-Lymphocyte ratio, *PMR* blood platelet-to-Lymphocyte ratio, *PLR* blood platelet-to-Lymphocyte ratio, *PNR* blood platelet-to-Neutrophil ratio, *HDL* high-density lipoprotein, *LDL* low-density lipoprotein, *CRP* C-reactive protein, *TnT* troponin T, *ESR* erythrocyte sedimentation rate, *PCT* Procalcitonin, *PLT* blood platelet, *EF* ejection fraction, *BNP* brain natriuretic peptide (≥ 35,000 is expressed as"1″ and < 35,000 as "0″), *PTH* parathyroid hormone, *ACEI* angiotensin-converting enzyme inhibitor, *ARB* angiotensin receptor blocker, *ICU* intensive care units

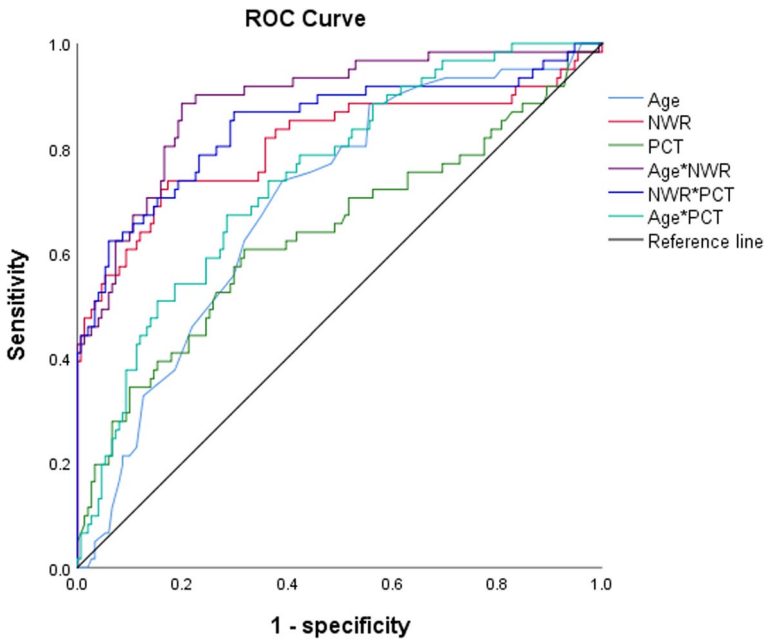

Fig. 2 Operating characteristic (ROC) curve analysis of single factor and combined ROC curve analysis of two factors were performed

Table 5 ROC analysis results for the value of age, NWR and PCT in predicting mortality

Factors	AUC	95% CI	Cut-off	Sensitivity–specificity	*P*-values
Age	0.69	(0.62,0.77)	66.5	0.76–0.60	< 0.001
NWR	0.82	(0.75,0.90)	0.89	0.74–0.83	< 0.001
PCT	0.64	(0.55,0.73)	2.54	0.61–0.68	0.002
Age*NWR	0.89	(0.85,0.94)	0.22	0.89–0.78	< 0.001
Age*PCT	0.75	(0.68,0.82)	0.29	0.67–0.72	< 0.001
PCT*NWR	0.84	(0.78,0.91)	0.17	0.87–0.70	< 0.001

ROC receiver operating characteristic, *NWR* Neutrophil-to-white cell ratio, *PCT* Procalcitonin

Conclusion

In conclusion, we found that the mortality rate of hemodialysis patients with COVID-19 has reached to the highest after 5 days of the opening. We revealed that advanced age, high levels of NWR and PCT, and corticosteroid use were all associated with mortality, and age*NWR might have the ability to predict the mortality in hemodialysis patients with COVID-19. The first three are positively correlated with mortality and are also risk predictors of death. Therefore, for hemodialysis patients infected with COVID-19, advanced aged patients should be paid attention and anti-bacterial

infection treatment and corticosteroid should be used immediately if necessary. This study might provide some experience to face the similar situation in hemodialysis patients with virus and aids in preparedness for future infectious disease outbreaks.

Abbreviations

COVID-19	Coronavirus disease of 2019
the US	The United State
ICU	Intensive care units
WBC	White blood cell
NLR	Neutrophil–lymphocyte ratio
CRP	C-reactive protein
CKD	Chronic kidney disease
PCT	Procalcitonin
ESR	Erythrocyte sedimentation rate
PTH	Parathormone
LDL	Low density lipoprotein cholesterol
HDL	High-density lipoprotein cholesterol
BNP	Brain natriuretic peptide
TnT	Troponin T
EF	Ejection fraction
IHD	Ischemic heart disease
CT	Computed tomography
ROC	Receiver operating characteristic
CVA	Cerebrovascular accident
NWR	Neutrophil-to-white cell ratio
HR	Hazard ratio
AUC	Areas under the ROC curve

Supplementary Information

The online version contains supplementary material available at https://doi.org/10.1186/s12882-025-03946-2.

Supplementary Material 1: Supplementary Figure 1. A map of China and the location of Yiyang in Hunan province.

Clinical trial number
Not applicable.

Authors' contributions
Zhangxiu He, Zhong Peng: Study design, Data acquisition, Statistical analysis, Manuscript drafting. Zhong Peng, Ning Gao and Shuzhu Zhong: Study design, Data acquisition, Statistical analysis. Fengyi Yu, Zixu Tang, Song Zhao and Zihao Liao: Data acquisition. Umwiza Gloria: Data interpretation, Critical revision of the manuscript. Ming Chen and Wei Long: Study concept, Study design, Data acquisition, Statistical analysis, Data interpretation. All authors reviewed the manuscript.

Funding
This work was supported by the National Natural Science Foundation of China [grant numbers 81900678], Hunan Clinical Medical Technology Innovation and Guidance Project (2021SK51811), Hunan University of Traditional Chinese Medicine Joint Fund (2023XYLH085), Scientific Research Project of Hunan Health Committee [grant numbers 202103051523, B202303109098, and D202303039177], Innovation Project of Yiyang Science and Technology Bureau (2024YR21).

Data availability
Data is provided within the manuscript or supplementary information files.

Declarations

Ethics approval and consent to participate
The study was approved by the Ethics Committee of Yiyang Central Hospital. As this study was not a clinical trial with intervention, informed consent was exempted by the Ethics Committee.

Consent for publication
Not applicable.

Competing interests
The authors declare no competing interests.

Received: 31 March 2024 Accepted: 6 January 2025
Published online: 16 January 2025

References

1. Huang C, Wang Y, Li X, et al. Clinical features of patients infected with 2019 novel coronavirus in Wuhan, China [published correction appears in Lancet. 2020 Jan 30;:]. Lancet. 2020;395(10223):497–506. https://doi.org/10.1016/S0140-6736(20)30183-5.
2. Guan WJ, Ni ZY, Hu Y, et al. Clinical characteristics of coronavirus disease 2019 in China. N Engl J Med. 2020;382(18):1708–20. https://doi.org/10.1056/NEJMoa2002032.
3. Deng SQ, Peng HJ. Characteristics of and Public Health responses to the coronavirus disease 2019 outbreak in China. J Clin Med. 2020;9(2):575. https://doi.org/10.3390/jcm9020575. Published 2020 Feb 20.
4. Vaziri ND, Pahl MV, Crum A, Norris K. Effect of uremia on structure and function of immune system. J Ren Nutr. 2012;22(1):149–56. https://doi.org/10.1053/j.jrn.2011.10.020.
5. Dong E, Du H, Gardner L. An interactive web-based dashboard to track COVID-19 in real time [published correction appears in Lancet Infect Dis. 2020 Sep;20(9):e215]. Lancet Infect Dis. 2020;20(5):533–4. https://doi.org/10.1016/S1473-3099(20)30120-1.
6. Dong E, Ratcliff J, Goyea TD, et al. The Johns Hopkins University Center for Systems Science and Engineering COVID-19 Dashboard: data collection process, challenges faced, and lessons learned [published correction appears in Lancet Infect Dis. 2022 Nov;22(11):e310]. Lancet Infect Dis. 2022;22(12):e370–6. https://doi.org/10.1016/S1473-3099(22)00434-0.
7. El Karoui K, De Vriese AS. COVID-19 in dialysis: clinical impact, immune response, prevention, and treatment. Kidney Int. 2022;101(5):883–94. https://doi.org/10.1016/j.kint.2022.01.022.
8. Wang D, Hu B, Hu C, et al. Clinical characteristics of 138 hospitalized patients With 2019 novel coronavirus-Infected pneumonia in Wuhan, China [published correction appears in JAMA. 2021 Mar 16;325(11):1113]. JAMA. 2020;323(11):1061–9. https://doi.org/10.1001/jama.2020.1585.
9. Kang YJ. Mortality rate of infection with COVID-19 in Korea from the perspective of underlying disease. Disaster Med Public Health Prep. 2020;14(3):384–6. https://doi.org/10.1017/dmp.2020.60.
10. Nithya G, Lamech TM, Arumugam V, et al. A clinical study on the changing dynamics of disease severity, management strategies and outcomes of COVID-19 in patients requiring haemodialysis. J Nephrol. 2021;34(4):999–1006. https://doi.org/10.1007/s40620-021-01072-4.
11. Gokhale CN, Chavhan SS, Mahajan HN, Adsul BB, Kumbhar MA, Ingale AR. A comparative cross-sectional analysis on outcomes of Covid-19 patients requiring dialysis. J Family Med Prim Care. 2021;10(9):3228–32. https://doi.org/10.4103/jfmpc.jfmpc_12_21.
12. Hendra H, Vajgel G, Antonelou M, et al. Identifying prognostic risk factors for poor outcome following COVID-19 disease among in-centre haemodialysis patients: role of inflammation and frailty. J Nephrol. 2021;34(2):315–23. https://doi.org/10.1007/s40620-020-00960-5.
13. Cheruiyot S, Shabani J, Shah J, GATHU C, Sokwala A. Associated factors and outcomes of acute kidney injury in COVID-19 patients in Kenya. Can J Kidney Health Dis. 2024;11:20543581241227016. https://doi.org/10.1177/20543581241227015. eCollection 2024.
14. Chen SY, Gong TF, He JL, Li F, Li WC, Xie LX, Xie XR, Liu YS, Zhou YF, Liu W. Molecular characterization and phylogenetic analysis of spirometra

tapeworms from Snakes in Hunan Province. Vet Sci. 2022;9(2):62. https://doi.org/10.3390/vetsci9020062.
15. Valeri AM, Robbins-Juarez SY, Stevens JS, et al. Presentation and outcomes of patients with ESKD and COVID-19. J Am Soc Nephrol. 2020;31(7):1409–15. https://doi.org/10.1681/ASN.2020040470.
16. Fisher M, Yunes M, Mokrzycki MH, Golestaneh L, Alahiri E, Coco M. Chronic hemodialysis patients hospitalized with COVID-19: short-term outcomes in the Bronx, New York. Kidney360. 2020;1(8):755–62 Published 2020 Jun 18.
17. Alberici F, Delbarba E, Manenti C, et al. A report from the Brescia Renal COVID Task Force on the clinical characteristics and short-term outcome of hemodialysis patients with SARS-CoV-2 infection. Kidney Int. 2020;98(1):20–6. https://doi.org/10.1016/j.kint.2020.04.030.
18. Goicoechea M, Sánchez Cámara LA, Macías N, et al. COVID-19: clinical course and outcomes of 36 hemodialysis patients in Spain. Kidney Int. 2020;98(1):27–34. https://doi.org/10.1016/j.kint.2020.04.031.
19. COVID-19 Task Force Committee of the Japanese Association of Dialysis Physicians; Japanese Society for Dialysis Therapy; Japanese Society of Nephrology. Cumulative number of registered cases of novel coronavirus infection among dialysis patients. https://www.jsdt.or.jp/info/3559.html. Accessed 31 Jul 2022.
20. Chavda VP, Kapadia C, Soni S, et al. A global picture: therapeutic perspectives for COVID-19. Immunotherapy. 2022;14(5):351–71. https://doi.org/10.2217/imt-2021-0168.
21. Vergara A, Molina-Van den Bosch M, Toapanta N, et al. The impact of age on mortality in chronic haemodialysis population with COVID-19. J Clin Med. 2021;10(14):3022. https://doi.org/10.3390/jcm10143022. Published 2021 Jul 7.
22. Bacharaki D, Karagiannis M, Sardeli A, et al. Clinical presentation and outcomes of chronic dialysis patients with COVID-19: a single center experience from Greece. World J Nephrol. 2022;11(2):58–72. https://doi.org/10.5527/wjn.v11.i2.58.
23. Kular D, Chis Ster I, Sarnowski A, et al. The characteristics, dynamics, and the risk of death in COVID-19 positive dialysis patients in London, UK. Kidney 360. 2020;1(11):1226–43. https://doi.org/10.34067/KID.0004502020. Published 2020 Sep 10.
24. Fullerton JN, Gilroy DW. Resolution of inflammation: a new therapeutic frontier. Nat Rev Drug Discov. 2016;15(8):551–67. https://doi.org/10.1038/nrd.2016.39.
25. Erdinc B, Sahni S, Gotlieb V. Hematological manifestations and complications of COVID-19. Adv Clin Exp Med. 2021;30(1):101–7. https://doi.org/10.17219/acem/130604.
26. Summers C, Rankin SM, Condliffe AM, Singh N, Peters AM, Chilvers ER. Neutrophil kinetics in health and disease. Trends Immunol. 2010;31(8):318–24. https://doi.org/10.1016/j.it.2010.05.006.
27. Doeing DC, Borowicz JL, Crockett ET. Gender dimorphism in differential peripheral blood leukocyte counts in mice using cardiac, tail, foot, and saphenous vein puncture methods. BMC Clin Pathol. 2003;3(1):3. https://doi.org/10.1186/1472-6890-3-3. Published 2003 Sep 12.
28. Black S, Kushner I, Samols D. C-reactive protein. J Biol Chem. 2004;279(47):48487–90. https://doi.org/10.1074/jbc.R400025200.
29. Hamade B, Huang DT. Procalcitonin: where are we now? Crit Care Clin. 2020;36(1):23–40. https://doi.org/10.1016/j.ccc.2019.08.003.
30. Gluck E, Nguyen HB, Yalamanchili K, et al. Real-world use of procalcitonin and other biomarkers among sepsis hospitalizations in the United States: a retrospective, observational study. PLoS One. 2018;13(10):e0205924. https://doi.org/10.1371/journal.pone.0205924. Published 2018 Oct 17.
31. Assicot M, Gendrel D, Carsin H, Raymond J, Guilbaud J, Bohuon C. High serum procalcitonin concentrations in patients with sepsis and infection. Lancet. 1993;341(8844):515–8. https://doi.org/10.1016/0140-6736(93)90277-n.
32. Chan L, Jaladanki SK, Somani S, et al. Outcomes of patients on maintenance dialysis hospitalized with COVID-19. Clin J Am Soc Nephrol. 2021;16(3):452–5. https://doi.org/10.2215/CJN.12360720.
33. Wang Y, Zhang D, Du G, et al. Remdesivir in adults with severe COVID-19: a randomised, double-blind, placebo-controlled, multicentre trial [published correction appears in Lancet. 2020May30;395(10238):1694]. Lancet. 2020;395(10236):1569–78. https://doi.org/10.1016/S0140-6736(20)31022-9.
34. Singh AK, Singh A, Singh R, Misra A. Molnupiravir in COVID-19: a systematic review of literature. Diabetes Metab Syndr. 2021;15(6):102329. https://doi.org/10.1016/j.dsx.2021.102329.
35. Whitley R. Molnupiravir - a step toward orally bioavailable therapies for Covid-19. N Engl J Med. 2022;386(6):592–3. https://doi.org/10.1056/NEJMe2117814.
36. Kumar G, Patel D, Hererra M, et al. Do high-dose corticosteroids improve outcomes in hospitalized COVID-19 patients? J Med Virol. 2022;94(1):372–9. https://doi.org/10.1002/jmv.27357.
37. Tylicki L, Puchalska-Reglińska E, Tylicki P, et al. Predictors of mortality in hemodialyzed patients after SARS-CoV-2 infection. J Clin Med. 2022;11(2):285. https://doi.org/10.3390/jcm11020285. Published 2022 Jan 6.
38. Bao WJ, Fu SK, Zhang H, Zhao JL, Jin HM, Yang XH. Clinical characteristics and short-term mortality of 102 hospitalized hemodialysis patients infected with SARS-CoV-2 omicron BA.2.2.1 variant in Shanghai, China. New Microbes New Infect. 2022;49:101058. https://doi.org/10.1016/j.nmni.2022.101058.
39. Perna AF, Capolongo G, Trepiccione F, Simeoni M, Zacchia M, Ingrosso D. COVID-19, low-molecular-weight heparin, and hemodialysis. Kidney Blood Press Res. 2020;45(3):357–62. https://doi.org/10.1159/000508460.
40. Recovery Collaborative Group, Horby P, Lim WS, et al. Dexamethasone in hospitalized patients with Covid-19. N Engl J Med. 2021;384(8):693–704. https://doi.org/10.1056/NEJMoa2021436.
41. Beigel JH, Tomashek KM, Dodd LE. Remdesivir for the treatment of Covid-19 - preliminary report. Reply N Engl J Med. 2020;383(10):994. https://doi.org/10.1056/NEJMc2022236.
42. Turgutalp K, Ozturk S, Arici M, et al. Determinants of mortality in a large group of hemodialysis patients hospitalized for COVID-19. BMC Nephrol. 2021;22(1):29.

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