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One-year mortality and associated factors in older hospitalized COVID-19 survivors: a Nationwide Cohort Study in Korea

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This study aimed to evaluate the 1-year mortality rate among older patients with COVID-19 discharged from hospital and to identify risk factors associated with this outcome. Using a COVID-19 dataset from the Korean National Health Insurance System, this study's evaluation period spanned from October 8, 2020, through December 31, 2021. The primary outcome was the 1-year mortality rate following hospital discharge. A logistic regression model was employed for multivariable analysis to estimate the odds ratios for the outcomes, and the Kaplan-Meier method was used to analyze differences in 1-year survival rates. Among the 66,810 COVID-19 patients aged 60 years or older who were hospitalized during the study period, the in-hospital mortality rate was 4.8% ($n = 3219$). Among the survivors ($n = 63,369$), the 1-year mortality rate was 4.9% ($n = 3093$). Non-survivors, compared to survivors, were significantly older (79.2 ± 9.5 vs. 68.9 ± 7.8, $P < 0.001$) and exhibited a lower rate of COVID-19 vaccination (63.0% vs. 91.7%, $P < 0.001$). Additionally, non-survivors experienced a higher incidence of organ dysfunction, along with a greater proportion of required mechanical ventilation (14.6% vs. 1.0%, $P < 0.001$) and extracorporeal membrane oxygenation (4.0% vs. 0.1%, $P < 0.001$). Multivariable logistic regression analysis identified older age, male sex, cardiovascular disease, immunosuppression, organ dysfunction, illness severity, and corticosteroid use during hospitalization as factors associated with death within 1 year after hospital discharge. However, vaccination was found to have a long-term protective effect against death among COVID-19 survivors. The 1-year mortality rate after hospital discharge for older COVID-19 patients was comparable to the in-hospital mortality rate for these patients in Korea. The long-term mortality rate among hospitalized older COVID-19 patients was influenced by demographic factors and the severity of illness experienced during hospitalization.

Keywords COVID-19, Survivors, Mortality, Age factors, Critical illness

The manifestations of COVID-19 range from asymptomatic cases to life-threatening acute respiratory distress syndrome (ARDS)[1]. It is estimated that approximately 16% of patients with COVID-19 die from the disease while hospitalized[2]. Even after patients recover from the acute phase of the illness, long-term symptoms may persist in COVID-19 survivors[3]. Long-COVID syndrome can affect various organ systems and can manifest with a variety of symptoms, such as fatigue, chest pain, and cough. Factors such as immune dysregulation, autoimmunity, and endothelial abnormalities may play crucial roles in the development of long-COVID syndrome[4]. The enduring impact of COVID-19 extends beyond physical and mental health issues to include increased mortality. Iwashyna et al. found that individuals who had contracted COVID-19 faced a twofold increase in mortality risk within 2 years compared to those not infected with SARS-CoV-2[5]. The long-term mortality risk is affected by factors such as age and the severity of the SARS-CoV-2 infection[6,7]. A Swedish nationwide cohort study ($N = 8392$) reported a 360-day mortality rate of 29.8% following intensive care unit (ICU) admission, with male sex, advanced age, and various comorbidities being significant contributors to mortality[6].

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COVID-19 severity is often gauged by the type of oxygen therapy administered[8], but the correlation between the severity of the disease and long-term mortality remains unclear. Additionally, Hägglöf et al. observed that the 1-year mortality rate was 1.33 times higher in men than in women[6]. However, given the considerable variation in long-term mortality rates from COVID-19 across different countries and regions[9], such findings should be interpreted with caution. While several studies have been conducted[6,7,9], data on the long-term mortality of COVID-19 survivors, particularly among older adults, and the associated risk factors remain scarce. In Korea, the mortality rate from COVID-19 was relatively low during the pandemic, attributed to stringent quarantine measures[10], but the older demographic experienced an increase in excess mortality during the pandemic[11]. Furthermore, data on the long-term effects of COVID-19 vaccination, which is known to confer survival benefits[12], remain limited. Therefore, this study aimed to investigate the 1-year mortality rate and associated risk and protective factors among older survivors of COVID-19.

Results

Study population

During the study period, 576,613 patients were confirmed to have COVID-19 (Fig. 1). After the exclusion of patients under 60 years of age ($n=433,943$) and those not hospitalized ($n=75,860$), 66,810 older patients with COVID-19 were hospitalized. Additionally, we excluded patients who died in the hospital ($n=3219$, representing a 4.8% in-hospital mortality rate) and those with missing data ($n=222$). Ultimately, 63,369 individuals who survived hospitalization for COVID-19 were analyzed. Within 1 year, we compared survivors ($n=60,276$, 95.1%) to non-survivors ($n=3093$, 4.9%).

Patient characteristics

Compared with survivors, non-survivors were significantly older (79.2 ± 9.5 vs. 68.9 ± 7.8, $P<0.001$), had a higher proportion of men (50.4% vs. 47.3%, $P<0.001$), and were less vaccinated (63.1% vs. 91.8%, $P<0.001$) (Table 1). Cardiovascular events before SARS-CoV-2 infection were more prevalent in non-survivors (10.4% vs. 28.4%, $P<0.001$). During hospitalization, the incidence of supplemental oxygen or no oxygen was 94.8% among survivors and 68.8% among non-survivors, with the latter group receiving 12.6% HFNC, 14.6% MV, and 4.0% ECMO (Table 2). Non-survivors were more likely to receive medications such as IL-6 inhibitors (4.6% vs. 0.9%, $P<0.001$), antiplatelets (29.6% vs. 9.8%, $P<0.001$), corticosteroids (55.4% vs. 22.4%, $P<0.001$), and vasopressors (25.4% vs. 1.6%, $P<0.001$).

Complications and healthcare usage after hospital discharge

Compared with survivors, non-survivors had higher rates of complications: sepsis (21.0% vs. 1.3%, $P<0.001$), pulmonary embolism (4.6% vs. 0.9%, $P<0.001$), lower gastrointestinal bleeding (6.1% vs. 1.5%, $P<0.001$), and ischemic stroke (13.8% vs. 6.0%, $P<0.001$), respectively. Moreover, non-survivors had higher incidence rates of rehospitalization (83.0% vs. 27.6%, $P<0.001$), ICU admission (21.1% vs. 1.7%, $P<0.001$), and ER visit (75.7 vs. 33.9, $P<0.001$) (Table 3).

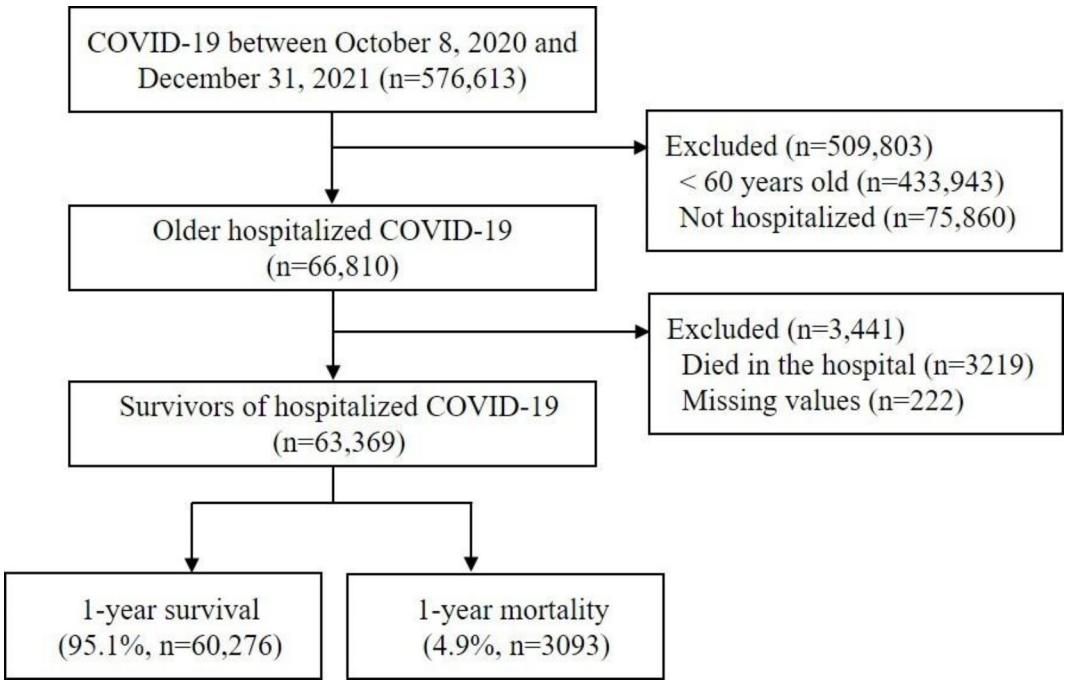

Fig. 1. Inclusion and exclusion flowchart.

Variable	Total ($n=63,369$)	1-Year survivors ($n=60,276$)	1-year non-survivors ($n=3093$)	*P* value
Age (years)	69.4 ± 8.2	68.9 ± 7.8	79.2 ± 9.5	< 0.001
Age group (%)				
60–69	38,628 (61.0)	38,030 (63.1)	598 (19.3)	< 0.001
70–79	16,056 (25.3)	15,191 (25.2)	865 (28.0)	
≥ 80	8685 (13.7)	7055 (11.7)	1630 (52.7)	
Male (%)	30,065 (47.4)	28,506 (47.3)	1559 (50.4)	< 0.001
CCI	0.7 ± 1.2	0.6 ± 1.1	2.0 ± 1.9	< 0.001
Comorbidity (%)				
Diabetes	12,371 (19.5)	11,114 (18.4)	1257 (40.6)	< 0.001
Hypertension	12,769 (20.2)	11,267 (18.7)	1502 (48.6)	< 0.001
Cardiovascular disease (%)[a]	7121 (11.2)	6244 (10.4)	877 (28.4)	< 0.001
Congestive heart failure	2453 (3.9)	2147 (3.6)	306 (9.9)	< 0.001
Cerebrovascular disease	2125 (3.4)	1710 (2.8)	415 (13.4)	< 0.001
Dementia	4144 (6.5)	3223 (5.3)	921 (29.8)	< 0.001
Chronic pulmonary disease	7841 (12.4)	7196 (11.9)	645 (20.9)	< 0.001
COPD or Asthma	1338 (2.1)	1087 (1.8)	251 (8.1)	< 0.001
Chronic liver disease	4858 (7.7)	4367 (7.2)	491 (15.9)	< 0.001
Chronic kidney disease	835 (1.3)	629 (1.0)	206 (6.7)	< 0.001
Malignancy	700 (1.1)	448 (0.7)	252 (8.1)	< 0.001
Immunosuppression[b]	1178 (1.9)	675 (1.1)	503 (16.3)	< 0.001
Income level (%)				
Q1 (lowest)	17,004 (26.8)	15,986 (26.5)	1018 (32.9)	< 0.001
Q2	12,057 (19.0)	11,599 (19.2)	458 (14.8)	
Q3	14,091 (22.2)	13,542 (22.5)	549 (17.7)	
Q4 (highest)	20,217 (31.9)	19,149 (31.8)	1068 (34.5)	
Vaccinated (%)	57,250 (90.3)	55,300 (91.7)	1,950 (63.0)	< 0.001
1	999 (1.6)	788 (1.3)	211 (6.8)	
2	9740 (15.4)	8838 (14.7)	902 (29.2)	
≥ 3	46,511 (73.4)	45,674 (75.8)	837 (27.1)	

Table 1. Baseline characteristics at admission. Numbers are presented as n (%) or mean ± standard deviation. *COPD* chronic obstructive pulmonary disease; *CCI* Charlson Comorbidity Index. [a]Cardiovascular diseases included angina pectoris, cardiac arrest, conduction disorders, cardiac dysrhythmia, cardiomyopathy, acute myocarditis, acute pericarditis, pericardial diseases, pulmonary heart diseases, deep vein thrombosis, heart valve disorder, and coronary artery disease. [b]Immunosuppression included malignancies, human immunodeficiency virus infection, organ transplantation, or prescribed corticosteroids for ≥ 30 days during hospitalization.

Risk factors for 1-year mortality

The multivariable logistic regression models for 1-year mortality, as depicted in Table 4, indicate that older age and COVID-19 severity are significant risk factors for 1-year mortality (Figs. 2 and 3). Additionally, male sex (OR 1.37 [95% CI 1.25–1.51], $P<0.001$) cardiovascular disease (OR 1.21 [95% CI 1.09–1.34], $P<0.001$), immunosuppression (OR 2.50 [95% CI 2.21–2.82], $P< 0.001$), vaccination (OR 0.21 [95% CI 0.19–0.23], $P<0.001$), macrolide use (OR 0.47 [95% CI 0.36–0.61], $P< 0.001$) antiplatelet therapy (OR 0.67 [95% CI 0.60–0.75], $P<0.001$), corticosteroid treatment (OR 1.29 [95% CI 1.17–1.43], $P<0.001$) renal replacement therapy (OR 2.21 [95% CI 1.64–2.99], $P<0.001$), and the extent of organ dysfunction (number of organs affected) were all significantly associated with 1-year mortality.

Change in quality of life

Following the diagnosis of COVID-19, there was an increase in job loss among patients compared to the period before they contracted the virus (24.1% vs. 21.8%, $P<0.001$) (Table S6). Furthermore, there was a significant rise in both mild to moderate and severe disabilities following a COVID-19 diagnosis (8.6% vs. 9.3%, $P<0.001$; and 4.1% vs. 4.6%, $P<0.001$). Among the survivors of COVID-19, the most frequently reported symptoms included myalgia (24.3%), anxiety (14.1%), and chest pain (13.6%) (Table S7). Depression was also prevalent (12.2%), with cough being the most common respiratory symptom (8.8%).

Discussion

Using nationwide data, we evaluated the 1-year mortality and associated symptoms and complications among COVID-19 survivors aged 60 years and older in Korea. The mortality rate among COVID-19 survivors within 1

Variable	Total ($n=63,369$)	1-year survivors ($n=60,276$)	1-year non-survivors ($n=3093$)	*P* value
Organ dysfunction (%)				
Cardiovascular	551 (0.9)	303 (0.5)	248 (8.0)	< 0.001
Respiratory	1203 (1.9)	779 (1.3)	424 (13.7)	< 0.001
Neurologic	1679 (2.6)	1364 (2.3)	315 (10.2)	< 0.001
Hematologic	1521 (2.4)	1263 (2.1)	258 (8.3)	< 0.001
Hepatic	125 (0.2)	84 (0.1)	41 (1.3)	< 0.001
Renal	679 (1.1)	418 (0.7)	261 (8.4)	< 0.001
Metabolic	107 (0.2)	84 (0.1)	23 (0.7)	< 0.001
No. of organ dysfunctions (%)				
0	58,527 (92.4)	56,480 (93.7)	2047 (66.2)	< 0.001
1	4078 (6.4)	3390 (5.6)	688 (22.2)	
2	567 (0.9)	330 (0.5)	237 (7.7)	
3	142 (0.2)	59 (0.1)	83 (2.7)	
≥ 4	55 (0.1)	17 (0.0)	38 (1.2)	
Severity of illness (%)				
No oxygen or supplemental oxygen	59,296 (93.6)	57,169 (94.8)	2127 (68.8)	< 0.001
HFNC	2818 (4.4)	2429 (4.0)	389 (12.6)	
MV	1071 (1.7)	619 (1.0)	452 (14.6)	
ECMO	184 (0.3)	59 (0.1)	125 (4.0)	
Medications (%)				
Hydroxychloroquine	135 (0.2)	117 (0.2)	18 (0.6)	< 0.001
Macrolides*	1837 (2.9)	1679 (2.8)	158 (5.1)	< 0.001
IL-6 inhibitor†	701 (1.1)	560 (0.9)	141 (4.6)	< 0.001
Antiplatelet	6817 (10.8)	5900 (9.8)	917 (29.6)	< 0.001
Corticosteroids	15,196 (24.0)	13,483 (22.4)	1713 (55.4)	< 0.001
Vasopressors	1735 (2.7)	950 (1.6)	785 (25.4)	< 0.001
Renal replacement therapy	460 (0.7)	338 (0.6)	122 (3.9)	< 0.001
Length of hospital stay (days)	16 ± 11	15 ± 10	31 ± 14	< 0.001
ICU admission (%)	809 (1.3)	392 (0.7)	417 (13.5)	< 0.001
Length of ICU stay (days)	12 ± 12	11 ± 12	13 ± 12	0.003
Duration of MV (days)	18 ± 15	15 ± 14	22 ± 16	< 0.001
Duration of ECMO (days)	21 ± 17	18 ± 13	22 ± 18	0.071

Table 2. Severity of illness and management during hospitalization. Numbers are presented as n (%) or mean ± standard deviation. *HFNC* high-flow nasal cannula; MV, mechanical ventilation; *ECMO* extracorporeal membrane oxygenation; *IL-6* interleukin-6; *ICU* intensive care unit. *Macrolides included azithromycin and clarithromycin. †IL-6 inhibitors included tocilizumab, siltuximab, and baricitinib.

year was 4.9%, closely mirroring the in-hospital mortality rate of 4.8%. Factors linked to 1-year mortality included older age, male sex, COVID-19 severity, cardiovascular disease, immunosuppression, organ dysfunction, and corticosteroid use. Receiving two or more doses of the vaccine was more beneficial than receiving only one dose or being unvaccinated. When compared to the period before the diagnosis, quality of life declined significantly during the periods spanning the time of diagnosis, illness, and post-discharge, particularly in terms of employment and disability status. COVID-19 survivors experienced a range of physical and mental sequelae.

Long-term mortality is affected by various factors, including illness severity and age[6,9,13–15]. In a study focusing on COVID-19 patients discharged from the ICU, the 1-year mortality rate reached 29.9%[6]. Age also plays a critical role; Di Bari et al. found that the 1-year mortality rate for COVID-19 patients over 75 years old, hospitalized via the ED, was as high as 48.4%, in contrast to 33.9% for non–COVID-19 patients[16]. Our study, which included patients over 60 years of age, observed a relatively low 1-year mortality rate of 4.9%. These aforementioned studies included more severely ill patients, with more than 50% requiring intensive care[6,14], whereas only 1.7% of the patients in our study required MV, which may account for the observed difference in mortality rates.

A nationwide cohort study from Estonia indicated that underlying diseases, such as cardiovascular disease, cancer, and respiratory system diseases, were linked to increased long-term mortality in COVID-19 patients aged 60 years or older[17]. Our findings suggest that several factors, both prior to and following hospital discharge, are associated with long-term mortality. Organ dysfunction and the severity of illness during hospitalization affect long-term survival. Specifically, when compared to patients who either did not require oxygen therapy or received supplemental oxygen therapy alone, those who were treated with HFNC and MV experienced 12.7 and 33.3 times higher 1-year mortality, respectively. Notably, corticosteroids, which are administered to critically

Variables	Total ($n=63,369$)	1-year survivors ($n=60,276$)	1-year non-survivors ($n=3093$)	*P* value
Complications				
Post–COVID-19 condition (%)	2528 (4.0)	2374 (3.9)	154 (5.0)	<0.001
Sepsis (%)	1407 (2.2)	758 (1.3)	649 (21.0)	<0.001
Septic shock (%)	308 (0.5)	106 (0.2)	202 (6.5)	<0.001
Myocardial infarction (%)	917 (1.4)	835 (1.4)	82 (2.7)	<0.001
Thrombosis event (%)				
Deep vein thrombosis	600 (0.9)	496 (0.8)	104 (3.4)	<0.001
Pulmonary embolism	695 (1.1)	552 (0.9)	143 (4.6)	<0.001
Bleeding events (%)				
Upper gastrointestinal bleeding	839 (1.3)	797 (1.3)	42 (1.4)	0.524
Lower gastrointestinal bleeding	1074 (1.7)	884 (1.5)	190 (6.1)	<0.001
Stroke (%)				
Ischemic	4072 (6.4)	3646 (6.0)	426 (13.8)	<0.001
Hemorrhagic	740 (1.2)	622 (1.0)	118 (3.8)	<0.001
Ischemic or hemorrhagic	429 (0.7)	388 (0.6)	41 (1.3)	<0.001
Transient ischemic attack (%)	943 (1.5)	918 (1.5)	25 (0.8)	0.005
Healthcare usage				
Rehospitalization (%)	19,218 (30.3)	16,652 (27.6)	2566 (83.0)	<0.001
Hospital length of stay (days)	63 ± 75	62 ± 74	84 ± 87	<0.001
Use of MV (%)	919 (1.5)	274 (0.5)	645 (20.9)	<0.001
Use of vasopressors (%)	4732 (7.5)	3259 (5.4)	1473 (47.6)	<0.001
ICU admission (%)	1656 (2.6)	1002 (1.7)	654 (21.1)	<0.001
Length of ICU stay (days)	10 ± 16	6 ± 10	15 ± 21	<0.001
OPD visit (%)	58,572 (92.4)	57,146 (94.8)	1426 (46.1)	<0.001
ED visit (%)	22,779 (35.9)	20,439 (33.9)	2340 (75.7)	<0.001
Hospital discharge to ER visit (days)	113 ± 111	122 ± 112	39 ± 69	<0.001

Table 3. Complications and healthcare usage after hospital discharge. Numbers are presented as n (%) or mean ± standard deviation. *MV* mechanical ventilation; *ICU* intensive care unit; *OPD* outpatient department; *ED* emergency department.

ill COVID-19 patients to mitigate the inflammatory response[18], were associated with poor outcomes. This association may be due to the more frequent use of corticosteroids in severely ill patients. Nevertheless, given that corticosteroid use is tied to serious adverse reactions, such as septic shock and invasive fungal infections[19], the potential for detrimental long-term effects of corticosteroid administration cannot be disregarded.

Hägglöf et al. found that men had a 1.33 times higher 360-day mortality risk than women in a Swedish nationwide study of COVID-19 ICU patients[6]. Similarly, a German nationwide cohort study indicated that being female was protective against 6-month mortality in COVID-19 patients (OR, 0.63 in females)[20]. While these studies typically included more male than female patients, our study comprised fewer male patients at 47.4%. Nevertheless, our research demonstrated that male sex was associated with poorer long-term mortality (OR, 1.45). Although no definitive theoretical hypothesis has been established to explain the gender disparities in long-term mortality among COVID-19 patients, biological and sociocultural differences between men and women are evident. Such differences may contribute to higher rates of ICU admission and the prevalence of sepsis in men[21]. Zettersten et al. proposed that the increased risk of adverse long-term outcomes in male COVID-19 patients might be attributable to the influence of sex hormones on inflammation[22].

Vaccines designed to prevent COVID-19 infection offer protection against severe disease and death[23]. Moreover, vaccines have a sustained effect on reducing post–COVID-19 conditions (OR of vaccination, 0.57)[24], and long-term health consequences[25]. Lam et al. demonstrated the potential of vaccination in lowering the risk of long-term mortality following a COVID-19 infection[25]. Compared to patients who received a complete vaccination series and a booster dose, those who were unvaccinated faced a higher risk of all-cause mortality within 1 year. Consistently, our study results demonstrated that receiving two or more vaccine doses provided greater benefits compared to receiving only one dose or remaining unvaccinated. One possible explanation for this finding is that vaccines, by reducing the severity of COVID-19, lead to a decreased risk of long COVID[26]. Additionally, vaccines may diminish long-term mortality by curtailing the exaggerated inflammatory immune response linked to viral persistence[27].

We found that numerous patients experienced a variety of physical and mental issues after being discharged from the hospital following COVID-19. These persistent symptoms are known to be associated with female sex and older age[24]. We also found that 1-year non-survivors experienced various critical events, such as sepsis, myocardial infarction, pulmonary thromboembolism, stroke, and gastrointestinal bleeding, more frequently than survivors. While some studies have suggested that disease severity is not linked to post–COVID-19

Variables	Univariate analysis		Multivariable analysis	
	OR (95% CI)	P-value	OR (95% CI)	P-value
Age group		< 0.001		< 0.001
60–69	Reference		Reference	
70–79	3.62 (3.26–4.03)		3.46 (3.02–3.96)	
≥ 80	14.69 (13.33–16.19)		19.90 (17.51–22.63)	
Male	1.13 (1.05–1.22)	< 0.001	1.37 (1.25–1.51)	< 0.001
CCI		< 0.001		< 0.001
≤ 1	Reference		Reference	
≥ 2	2.04 (1.88–2.21)		1.39 (1.23–1.57)	
Cardiovascular disease*	2.81 (2.60–3.03)	< 0.001	1.21 (1.09–1.34)	< 0.001
Immunosuppression	2.80 (2.55–3.07)	< 0.001	2.50 (2.21–2.82)	< 0.001
Vaccination	0.15 (0.14–0.17)	< 0.001	0.21 (0.19–0.23)	< 0.001
No. of organ dysfunction		< 0.001		< 0.001
0	Reference		Reference	
1	2.84 (2.60–3.10)		1.44 (1.29–1.60)	
2	11.38 (9.94–13.02)		2.63 (2.17–3.19)	
3	33.20 (25.83–42.67)		4.13 (2.85–5.98)	
≥ 4	84.82 (49.59–145.07)		7.79 (3.61–16.80)	
Severity of COVID-19		< 0.001		< 0.001
No oxygen or supplemental oxygen therapy	Reference		Reference	
HFNC	27.50 (23.09–32.77)		12.95 (10.34–16.20)	
MV	60.39 (51.84–70.35)		35.43 (27.91–44.97)	
ECMO	142.88 (80.52–253.51)		102.61 (52.51–200.50)	
Hydroxychloroquine	0.79 (0.46–1.34)	0.377	0.85 (0.44–1.64)	0.6198
Macrolides	0.50 (0.41–0.60)	< 0.001	0.47 (0.36–0.61)	< 0.001
IL-6 inhibitor	3.50 (1.57–7.84)	0.002	0.70 (0.19–2.52)	0.5852
Antiplatelet	1.13 (1.04–1.22)	< 0.001	0.67 (0.60–0.75)	< 0.001
Corticosteroids	2.13 (1.98–2.29)	< 0.001	1.29 (1.17–1.43)	< 0.001
Renal replacement therapy	6.70 (5.48–8.20)	< 0.001	2.21 (1.64–2.99)	< 0.001
ICU admission after discharge	15.86 (14.26–17.64)	< 0.001	1.06 (0.87–1.30)	0.5503

Table 4. Univariate and multivariable logistic regression model for 1year mortality among COVID-19 survivors. *OR* odds ratio; *CI* confidence interval; *CCI* Charlson Comorbidity Index; *HFNC* high-flow nasal cannula; *MV* mechanical ventilation; *ECMO* extracorporeal membrane oxygenation; *IL-6* interleukin 6; *ICU* intensive care unit. [a]Cardiovascular diseases not included in the CCI: angina pectoris, cardiac arrest, conduction disorders, cardiac dysrhythmia, cardiomyopathy, acute myocarditis, acute pericarditis, pericardial diseases, pulmonary heart diseases, deep vein thrombosis, heart valve disorder, and coronary artery disease.

conditions[24,28,29], our study findings indicate that patients who were critically ill during hospitalization were more likely to suffer from long-term complications and mortality. This discrepancy may arise because previous studies on long-COVID syndrome relied on data collected using ICD-10 codes (e.g., U09.9) or based on mild symptom reports[30]. Severe COVID-19 that necessitates hospitalization can provoke a more intense immune response and cytokine storm, potentially leading to more prolonged organ damage.

Notably, compared to the period before the diagnosis of COVID-19, there was an increase in job loss after the COVID-19 diagnosis. COVID-19–associated economic recession might have contributed to the increase in unemployment. However, we also found that various degrees of disability increased after COVID-19 hospitalization. Previous studies investigating ECMO or ARDS have shown that disability and job loss increased among patients after the acute phase of illness[31,32]. Therefore, we suggest that in older adults hospitalized due to COVID-19, disability may persist, making it difficult to maintain employment.

Several studies have reported long-term mortality in COVID-19 survivors, primarily in Western countries[6,7,9,14–16]. Our study, conducted in Korea, may limit the generalizability of the results due to the study population being confined to Asians. However, it is significant in representing the long-term outcomes of COVID-19 in this demographic. Early in the COVID-19 pandemic, reports indicated that the case fatality rate among Asian Americans was about three times higher than that of non-Hispanic Whites[33], leading researchers to suggest that Asian Americans might be more vulnerable to severe outcomes from COVID-19. In contrast, Asian countries reported relatively low case fatality rates during the same period, likely due to strong quarantine measures[34]. Additionally, the Centers for Disease Control and Prevention reported that Asians in the United

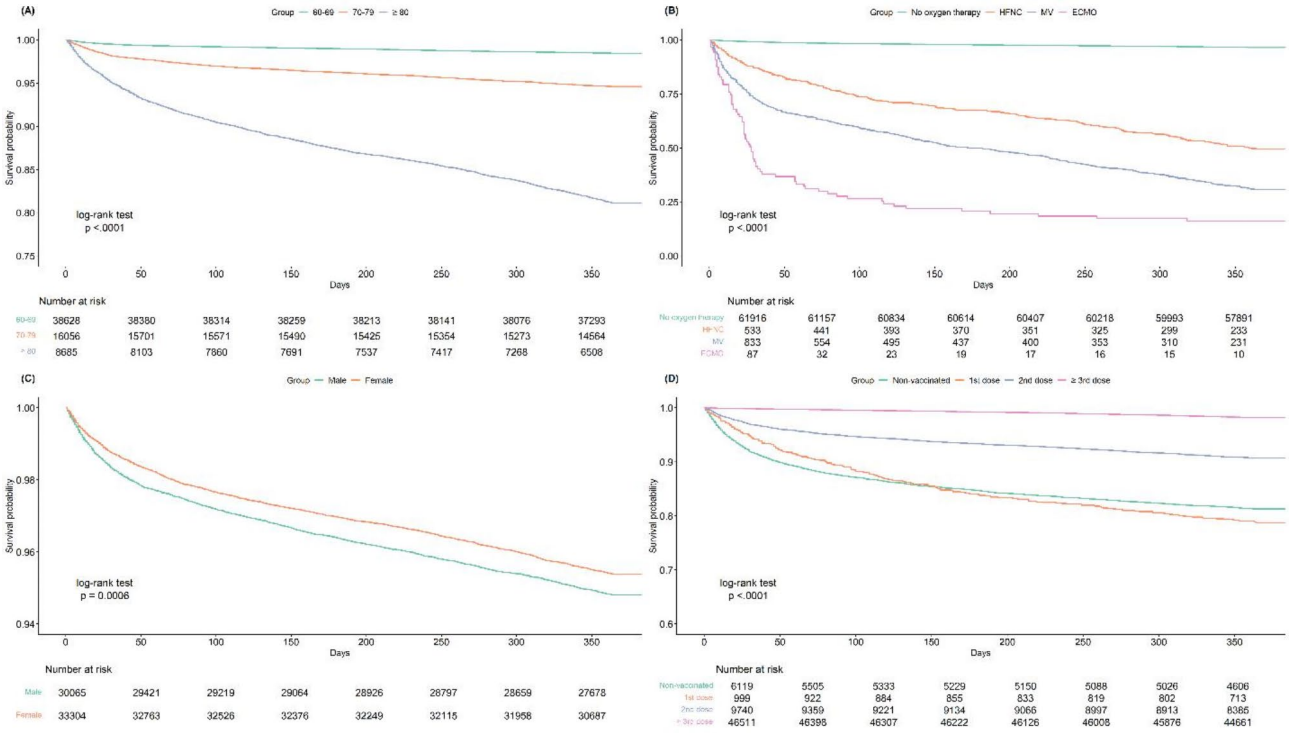

Fig. 2. Kaplan-Meier analysis of 1-year survival data according to (**A**) age group, (**B**) severity of illness, (**C**) sex, and (**D**) number of vaccinations. *HFNC* high-flow nasal cannula; *MV* mechanical ventilation; *ECMO* extracorporeal membrane oxygenation.

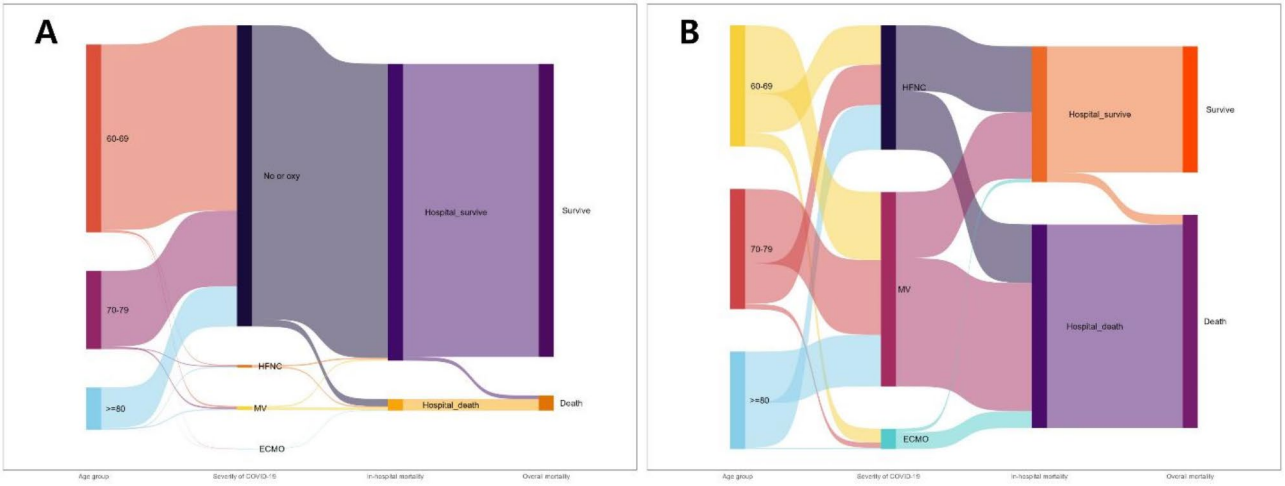

Fig. 3. Sankey diagram of 1-year mortality among COVID-19 survivors. (**A**) Entire study cohort; (**B**) patients treated with HFNC, MV, or ECMO. *HFNC* high-flow nasal cannula; *MV* mechanical ventilation; *ECMO* extracorporeal membrane oxygenation.

States have lower rates of long-COVID syndrome compared to Hispanics or Whites[35]. Hispanic/Latinx patients have been shown to be more likely to develop long-COVID syndrome after experiencing COVID-19 ARDS, but this disparity was attributed to socioeconomic factors rather than racial differences[36]. Even within Western countries, 1-year mortality rates vary significantly, with rates as high as approximately 12% in Italy and the United Kingdom and as low as 2% in Sweden[9]. Therefore, structural and healthcare-related barriers appear to be more critical than racial differences in determining long-term COVID-19 mortality.

Our study had several limitations. First, because it was a retrospective registry-based study, we could not collect information on complications during hospitalization and detailed demographics, such as smoking history or body mass index. Additionally, data on functional dependencies or cognitive impairment, which are

recognized risk factors for rehospitalization or death, were not available[37]. Second, it is challenging to ascertain whether the causes of rehospitalization, ED or OPD visits, and post-discharge complications were directly related to COVID-19. Third, this study included only patients in the early phase of the COVID-19 pandemic and did not account for patients affected by various COVID-19 variants, potentially limiting the generalizability of the findings. The Korean government's stringent quarantine policies led to a relatively low number of initial patients with COVID-19. Furthermore, the enrollment period for this dataset was restricted to allow for the assessment of 1-year post-discharge mortality. Despite these limitations, this was a comprehensive nationwide study with a large cohort, providing insights into the natural history of hospitalized older patients with COVID-19.

Conclusion

The 1-year mortality after hospital discharge for patients with COVID-19 was found to be comparable to the in-hospital mortality rate in Korea. The long-term mortality of hospitalized COVID-19 patients is influenced by factors such as age and the severity of illness experienced during hospitalization. It is imperative that we maintain vigilance and provide thorough care for older patients who have undergone critical care, even after their discharge from the hospital.

Methods

Data source and ethical statement

This study used the K-COV-N database, which is linked to the Korean National Health Insurance Service (NHIS) database, the nationwide COVID-19 vaccination registry, and COVID-19–positive patient information from the Korea Disease Control and Prevention Agency (KDCA). The NHIS database encompasses healthcare claims for approximately 97% of the population in the Republic of Korea. Diagnoses are recorded using the International Statistical Classification of Diseases and Related Health Problems, Tenth Revision (ICD-10) codes, and prescription information for drugs and procedures is compiled in the NHIS database to facilitate financial support for treatment expenses. Data extraction was conducted by an independent medical record technician at the NHIS center, who was unaffiliated with this study.

The study protocol was approved by the institutional review board of Chung-Ang University (1041078-20221111-BR-010). Informed consent was waived because data analyses were performed retrospectively using anonymized data from the South Korean NHIS database. All procedures in this study were performed according to the relevant guidelines and regulations.

Study design and population

The study encompassed patients with confirmed COVID-19 who were hospitalized between October 8, 2020, and December 31, 2021. Older adults, defined as individuals aged 60 years or above, who were hospitalized within 2 weeks following a confirmed COVID-19 diagnosis, were categorized as older hospitalized patients with COVID-19[38]. The analysis focused on patients who were discharged alive. Exclusion criteria included (1) age under 60 years, (2) absence of hospitalization within 14 days post–COVID-19 diagnosis, (3) death during hospitalization, and (4) lack of sufficient clinical data.

Data collection and definitions

Patient characteristics encompassed age, sex, comorbidities, Charlson Comorbidity Index (CCI) using ICD-10 codes, number of vaccinations, and income level at hospital admission (Table S1). Income levels were categorized into four quartiles, ranging from Q1, the lowest, to Q4, the highest.

Cardiovascular disease was defined as the presence of any of the following conditions[39]: angina pectoris, cardiac arrest, conduction disorders, cardiac dysrhythmia, cardiomyopathy, acute myocarditis, acute pericarditis, pericardial diseases, pulmonary heart diseases, deep vein thrombosis, heart valve disorder, or coronary artery disease. Immunosuppression was defined as the presence of any malignancies, HIV or AIDS, organ transplantation, or the prescription of corticosteroids for 30 days or more during hospitalization[40]. The assessment of organ dysfunction, severity of illness, and various treatments was conducted during hospitalization. Organ dysfunction included conditions affecting the cardiovascular, respiratory, neurologic, hematologic, hepatic, renal, and metabolic systems (Table S2). The severity of COVID-19 was evaluated using an ordinal scale: no oxygen or supplemental oxygen group, high-flow nasal cannula (HFNC), mechanical ventilation (MV), and extracorporeal membrane oxygenation (ECMO) (Table S3)[8]. Medications prescribed included hydroxychloroquine, macrolides, IL-6 inhibitors, antiplatelet agents, corticosteroids, and vasopressors. Additionally, data on renal replacement therapy, hospital stay duration, ICU admission, ICU stay length, MV duration, and ECMO duration were compiled.

The primary outcome of this study was the 1-year mortality rate following hospital discharge. Healthcare usage within the first year after discharge was documented, including rehospitalization, hospital stay length, MV usage, vasopressor usage, ICU admission, ICU stay duration, outpatient department (OPD) visits, emergency department (ED) visits, and transitions from hospital discharge to ED visits. After discharge, survivors' ICD-10 codes related to various complications were investigated, including post–COVID-19 condition, sepsis, septic shock, myocardial infarction, thrombotic events (deep vein thrombosis and pulmonary embolism), bleeding events (upper and lower gastrointestinal bleeding), strokes (ischemic, hemorrhagic, and mixed), and transient ischemic attacks (Table S4). Long-term symptoms experienced during healthcare usage were also investigated (Table S5)[13].

Changes in patients' status before and after COVID-19 diagnoses were assessed based on employment, disability, and annual income levels. The types of disability included physical, neurobiological, visual, auditory, speech-related, intellectual, mental, renal, heart, respiratory, hepatopathy, intestinal and urinary fistula–

related, and epileptic disabilities. Each disability was rigorously classified according to legal standards by specialist physicians in the respective fields, with a grading system ranging from 1 to 6[41]. Grades 1 through 3 were considered severe disabilities, while grades 4 through 6 were categorized as mild to moderate disabilities, respectively.

Statistical analysis

Categorical variables are presented as numbers (percentages), and continuous variables are presented as median (interquartile range). To compare differences between 1-year survivors and non-survivors, the chi-square test and Student's t-test were used for categorical and continuous variables, respectively. McNemar's test was performed to compare changes in quality of life before and after the diagnosis of COVID-19. Multivariable logistic regression analyses were conducted to estimate the odds ratios (ORs) and 95% confidence intervals (CIs) for factors associated with 1-year mortality. Variables with $P < 0.1$ in univariate analysis and those deemed clinically relevant were included in the multivariable logistic regression model. After addressing multicollinearity among variables, the final multivariable regression model comprised age, sex, CCI, cardiovascular disease not included in the CCI, immunosuppression, vaccination status, extent of organ dysfunction (number of organs affected), severity of COVID-19 (no oxygen or supplemental oxygen therapy, HFNC, MV, and ECMO), hydroxychloroquine use, macrolide use, IL-6 inhibitor use, antiplatelet use, corticosteroid use, renal replacement therapy status, and ICU admission post-discharge. The OR for each variable was reported with a 95% CI. Additionally, Kaplan-Meier curves were plotted up to 1 year from the respective index dates, and differences between age groups, illness severity, sex, and number of vaccinations were compared using log-rank tests. Sankey diagrams visualized the overall distribution of variables according to age group, COVID-19 severity, in-hospital mortality, and 1-year post–COVID-19 mortality. Statistical analyses were executed using SAS Enterprise software version 7.1 (SAS Inc., Cary, NC, USA) and R Studio software version 4.3.1 (R Studio Inc., Boston, MA, USA), with statistical significance established at $P < 0.05$.

Data availability

The datasets used and analyzed in the current study are available from the corresponding author upon reasonable request.

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Author contributions

MSB and SYJ conceived and designed the study. EK, JYK, SYJ, and MSB collected the primary data and conducted data analyses. EK, KMM, TWK, WYK, SYJ, and MSB interpreted the results and prepared the first draft. All the authors revised the draft for important intellectual content and approved the final manuscript submitted for publication.

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Declarations

Competing interests

The authors declare no competing interests.

Ethics approval and consent to participate

The study protocol was approved by the Institutional Review Board of Chung-Ang University (1041078-20221111-BR-010). Informed consent was waived because data analyses were performed retrospectively using anonymized data from the South Korean NHIS database. All procedures in this study were performed according to the relevant guidelines and regulations.

Consent for publication

Not applicable.

Additional information

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