Comorbidities associated with risk of ICU admission in elderly patients with COVID-19
Data from academic hospital in Saudi Arabia

Saad Alsaad, MD* † Abdurahman Addweesh, MD †, Mohammed Beyari, MD ‡, Munib Alkhateb, MD ‡, Abdulrahman Alswat, MD ‡, Abdulrahman Alshabnan, MD ‡, Abdulaziz Alsaad, MD ‡, Haytham AlSaif, MD ‡

Abstract
The coronavirus disease 2019 (COVID-19) has affected millions of people worldwide, of which 5% required intensive care, especially mechanical ventilation. The prognosis depends on several factors including comorbidities. This study was conducted to identify the comorbidities associated with the intensive care unit (ICU) admission in elderly with COVID-19 admitted to a tertiary academic hospital. A retrospective cross-sectional study was conducted at KSUMC including all hospitalized patients (age ≥ 65 years) with laboratory-confirmed severe acute respiratory syndrome coronavirus 2 infection admitted between March 2020 and August 2021. Data collection included sociodemographic characteristics, underlying comorbidities, and the Charlson comorbidity index. Comorbidities were compared between the elderly patients with COVID-19 admitted to the ICU and those not admitted to the ICU. The odds ratios were calculated and a P value of < .05 and 95% confidence intervals were used to report the statistical significance. A total of 444 patients (ICU = 147, non-ICU = 297) were included in the study. The study revealed that elderly patients with COVID-19 admitted to ICU had a higher rate of mortality (n = 64, 67.4%; P < .0001) and a higher proportion of them had shortness of breath (n = 97, 38.3%; P = .007) compared to the elderly patients not admitted to ICU. The mean length of stay (P < .0001), and weight (P = .02) among ICU patients were higher than the values for the non-ICU group, while the mean oxygen saturation (SpO2; P = .006) was lower among the ICU group. The comorbidities that demonstrated a statistically significant association with ICU admission were heart failure (P = .004, odd ratio (OR) = 2.02, 95% confidence intervals (CI) [1.263, 3.540]), chronic obstructive pulmonary disease (COPD; P = .027, OR = 3.361, 95% CI [1.080, 10.464]), and chronic kidney disease (P = .021, OR = 1.807, 95% CI [1.087, 3.006]). The current study identified that the comorbidities such as COPD, heart failure, and factors like SpO2 and length of stay are associated with an increased risk of ICU admission in elderly patients with COVID-19. These findings highlight the clinical implications of comorbidity among geriatric population.

Keywords: comorbidities, Coronavirus disease 2019 (COVID-19), elderly, intensive care unit (ICU)

1. Introduction
The coronavirus disease 2019 (COVID-19) is a novel disease caused by the severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2). The transmission route of the virus is through air droplets. The first case was recorded in Wuhan, China, in December 2019, causing millions of deaths worldwide. On March 11, 2020, the World Health Organization announced it as a pandemic. The disease spread dramatically until it became an ongoing pandemic, causing considerable challenges and substantial harm to over 200 countries and regions worldwide. Clinical manifestations of COVID-19 may present with fever, headache, cough, expectoration, breathing difficulties, fatigue, pharyngalgia and loss of taste and smell.

The current management of COVID-19 is generally based on supportive therapy to prevent respiratory failure. However, increasing evidence indicates that many patients with COVID-19 are asymptomatic or have only mild symptoms but can...
Among the elderly patients with COVID-19.

It has been studied that comorbidities such as diabetes mellitus, hypertension, asthma, chronic kidney disease (CKD), heart failure, chronic obstructive pulmonary disease (COPD), and malignancies and human immunodeficiency virus are associated with the increased risk of intensive care unit (ICU) admission and mortality among the elderly patients suffering from COVID-19. Of these comorbidities, diabetes, hypertension and coronary heart disease are the most frequently encountered among COVID-19 patients. It has been suggested that impaired immune response with T-cell dysfunction and elevated interleukin-6 plays key role in the pathogenesis and severity of COVID-19 among diabetic patients. Moreover, risk of ICU admission among diabetic patients with COVID-19 is 14.2% than those without diabetes.

Prevalence of hypertension reaches up to 80% among the elderly and has been associated with worse COVID-19 outcome in terms of mortality. Similarly, cardiovascular complications such as congestive heart failure, atrial fibrillation, pulmonary embolism and acute coronary syndrome are high among the elderly patients with COVID-19 which result in longer hospital stay and increased mortality. In addition, there are several other risk factors which may contribute to ICU admission among the elderly patients with COVID-19.

Numerous studies have been conducted on different aspects of COVID-19; however, the literature on association of comorbidities with ICU admission among the elderly patients with COVID-19 is lacking from Saudi Arabia. Therefore, this study was conducted to identify the comorbidities and symptoms in the elderly patients with COVID-19 leading to a higher risk of ICU admission.

2. Methods

A retrospective cross-sectional study was conducted to evaluate the comorbidities associated with ICU admission in elderly patients with COVID-19 at King Saud University Medical City (KSUMC) in Riyadh, Saudi Arabia. The study was approved by the Institutional Review Board of the College of Medicine, King Saud University, which provided the research consent (E-21-6145). There were no ethical issues in conducting this study because it was a retrospective study targeting findings from existing clinical records. The authors declared that all methods were performed as per relevant guidelines and regulations (including the Declaration of Helsinki). All the elderly patients (age ≥ 65 years) with laboratory-confirmed SARS-CoV-2 infection admitted between March 2020 and August 2021 and hospitalized at KSUMC were included in the study.

All the patients younger than 65 and those with negative COVID-19 polymerase chain reaction tests were excluded from the study. To assess the comorbidities that contribute to ICU admission in elderly patients with COVID-19, the elderly patients with COVID-19 admitted to ICU were compared with those not admitted to the ICU. The reason for choosing patients with COVID-19 as the control group was that the study did not aim to test whether COVID-19 led to ICU admission but to determine the comorbidities that increased the risk of ICU admission in elderly patients with COVID-19. Cases were defined as elderly patients with COVID-19 at KSUMC admitted to the ICU. The control group was defined as the elderly patients with COVID-19 at KSUMC not admitted to the ICU.

Data were extracted from the electronic medical record using a data collection form with sociodemographic characteristics, including symptoms and vital signs at the time of admission and the underlying comorbidities such as endocrinopathy (diabetes, thyroid diseases and adrenal diseases), cardiac diseases (hypertension, ischemic heart disease, heart failure, dyslipidemia, arrhythmia, and valvular diseases), chronic respiratory diseases (COPD, bronchial asthma, interstitial lung disease, pulmonary vascular diseases, pulmonary tuberculosis, and obstructive sleep apnea), renal disease and end-stage renal diseases (CKD, glomerular disease, and urolithiasis), chronic liver disease (infectious hepatitis, liver cirrhosis and hepatic failure), diseases of the digestive system (noninfectious diseases of the upper or lower digestive system, pancreatic disease and biliary disease) chronic neurologic disease (cerebrovascular accidents, Parkinson, movement disorders, multiple sclerosis, epilepsy and Alzheimer disease), malignancies, rheumatologic diseases (rheumatoid arthritis and systemic lupus erythematosus) and hematologic disease (anemia, coagulopathy and bone marrow dysfunction). In addition, the Charlson comorbidity index (CCI) was calculated.

Data were analyzed using SPSS 26.0 (IBM Inc., Chicago, IL) statistical software. Descriptive statistics (i.e., the frequency, percentage, mean, and standard deviation) described the categorical and quantitative variables. A univariate analysis was conducted using the Student t test for independent samples. In addition, Pearson χ² test was used to assess the measure of association between the categorical study and outcome variables (ICU admission). The odds ratios were calculated to measure association. A multivariate binary logistic regression was used to find out the independent factors associated with ICU admission and a P value of <.05 and 95% confidence intervals were used to report the statistical significance and precision of the results.

3. Results

A total of 444 elderly patients (ICU = 147, non-ICU = 297) with COVID-19 admitted to KSUMC were enrolled in the study to assess the risk factors that contribute to ICU admission due to COVID-19 infection. There were 229 (51.6%) females, and an overall mean age was 75.4 years. Furthermore, the patients were classified into two groups based on ICU admission: patients admitted to the ICU (147 cases or 33.1%) and patients not admitted to the ICU (the control group with 297 cases or 66.9%). The rates of categorical study variables among the ICU and non ICU elderly patients are illustrated in Figure 1.

In terms of sociodemographic and clinical characteristics of the study subjects, presenting with shortness of breath was significantly associated with the risk of admission to the ICU in COVID-19 elderly patients (n = 97, 66%, P = .007). The other variables of chest pain, cough, appetite loss, fatigue, decreased consciousness, vomiting, diarrhea, abdominal pain, and sore throat were not statistically significant (Table 1).

Comparison of the mean values of the quantitative variables showed a statistically significant difference in the mean values of weight, SpO2, and length of stay. Furthermore, the mean length of stay (P < .0001) and mean weight (P = .02) among ICU patients were higher than the values for the non-ICU group. Similarly, a significant difference was found between both groups in terms of shortness of breath and mean SpO2 (P = .007, P = .006 respectively). In contrast, no statistically significant differences were found between ICU and non-ICU patients in terms of age, CCI, height, body mass index, temperature, and systolic and diastolic blood pressure (Table 2).

The association between comorbidities and the ICU admission of elderly patients with COVID-19 indicated a
Alsaad et al. • Medicine (2022) 101:39 www.md-journal.com

statistically significant association for heart failure (P = .004, odd ratio (OR) = 2.02, 95% CI [1.263, 3.540]), COPD (P = .027, OR = 3.361, 95% CI [1.080, 10.464]), and CKD (P = .021, OR = 1.807, 95% CI [1.087, 3.006]). Polypharmacy, diabetes, hypertension, dyslipidemia, ischemic heart disease, other cardiac diseases, cerebrovascular accidents, asthma, interstitial lung diseases, pulmonary vascular diseases, pulmonary tuberculosis, obstructive sleep apnea, other respiratory diseases, endocrinopathy, genitourinary diseases, neurological diseases, rheumatological diseases, liver and gastrointestinal diseases, hematological diseases and malignancies were not significantly associated with ICU admission (Table 3).

The final model of multivariate analysis which included the following 5 variables (SpO2, length of stay, heart failure, COPD and chronic kidney disease) showed a significant association between SpO2 (P = .004, aOR = 0.989, 95% CI [0.982, 0.997]), length of stay (P < .0001, aOR = 1.083, 95% CI [1.060, 1.106]), heart failure (P = .044, aOR = 1.813, 95% CI [1.016, 3.237]), and COPD (P = .019, aOR = 4.263, 95% CI [1.270, 14.307]) with the ICU admission of elderly patients with COVID-19 (Table 4). In terms of outcome this study reported a significant association between the ICU admission of elderly patients with COVID-19 and the mortality rate (n = 64, 43.5%, P < .0001).

4. Discussion

The current study evaluated the clinical characteristics and highlighted the most likely comorbidities associated with a higher risk of ICU admission among the elderly patients with

Table 1
Association of Sociodemographic and clinical characteristics with ICU admission.

| Characteristics                    | ICU (n = 147) n (%) | Non-ICU (n = 297) n (%) | P value |
|------------------------------------|--------------------|------------------------|---------|
| Gender                             |                    |                        | .054    |
| Male                               | 87 (59.2)          | 147 (49.5)             |         |
| Female                             | 60 (40.8)          | 150 (50.5)             |         |
| Mortality symptoms                 | 64 (43.9)          | 31 (10.4)              | <.0001  |
| Chest pain                         | 15 (10.2)          | 43 (14.5)              | .209    |
| Shortness of breath                | 97 (66)            | 156 (52.5)             | .007    |
| Cough                              | 55 (37.4)          | 95 (32)                | .255    |
| Loss of appetite                   | 9 (6.1)            | 10 (3.4)               | .177    |
| Fatigue                            | 20 (13.6)          | 45 (15.2)              | .665    |
| Decrease level of consciousness    | 13 (8.8)           | 18 (6.1)               | .279    |
| Vomiting                           | 9 (6.1)            | 26 (8.8)               | .333    |
| Diarrhea                           | 6 (4.1)            | 13 (4.4)               | .885    |
| Fever                              | 41 (27.9)          | 59 (19.9)              | .057    |
| Abdominal pain                     | 6 (4.1)            | 10 (3.4)               | .704    |
| Sore throat                        | 4 (2.7)            | 5 (1.7)                | .465    |
| Other symptoms                     | 4 (2.7)            | 7 (2.4)                | .816    |

ICU = intensive care unit.

Figure 1. Rates of comorbidities variables among the intensive care unit (ICU) and non-ICU elderly patients.
COVID-19. The study revealed significant association of both COPD and heart failure with ICU admission. Although the literature supports the findings of the study in the general population; however, there is paucity in literature that has specifically addressed the geriatric population.[16] Diabetes mellitus and hypertension have been reported to increase the risk of ICU admission in previous studies but were not reported in the present study.[12,17] In the present study, the mortality rate, mean length of stay and weight were significantly higher in ICU patients. Moreover, the present study reported significantly increased number of patients with shortness breath, and lower values of SpO2 in the ICU group.

Although not specific to the geriatric population, COPD had been reported to be associated with a higher risk of ICU admission.[6,18] Moreover, multiple studies have revealed that COPD is one of the most significant risk factors for developing severe COVID-19.[19,20] A meta-analysis conducted by Jain and Yuan[16] have reported COPD as the significant predictive comorbidity for severe COVID-19 and ICU admission. Current evidence suggests that patients with COPD have a higher risk of ICU admission and severe COVID-19 because they are prone to viral infections, including SARS-CoV-2. This outcome is primarily due to the increased expression of ACE2 receptors in the small airways and could also be related to a poor lung reserve.[18]

Finally, combination of multiple comorbidities increases the risk of complications and ICU admission, especially

### Table 2

Comparison of mean values of quantitative study variables between ICU and non-ICU patients.

| Variable       | ICU (N = 147) (mean) | Non-ICU (N = 297) (mean) | Mean difference | t value | P value | 95% CI of difference of mean |
|----------------|----------------------|--------------------------|-----------------|---------|---------|-----------------------------|
| Age            | 75.41                | 75.38                    | 0.03            | 0.036   | .971    | −1.617, 1.678               |
| Length of stay | 21.437               | 10.198                   | 11.238          | 9.314   | <.0001  | 8.866, 13.609               |
| CCI            | 5.05                 | 4.70                     | 0.347           | 1.863   | .063    | −0.019, 0.714               |
| Height         | 161.97               | 161.19                   | 0.8105          | 0.634   | .526    | −1.725, 3.346               |
| Weight         | 80.90                | 77.57                    | 5.106           | 0.501   | .02     | 8.8102, 9.402               |
| BMI            | 32.5                 | 29.75                    | 2.629           | 1.164   | .245    | −1.812, 7.070               |
| Temperature    | 37.47                | 37.21                    | 0.2707          | 1.365   | .173    | −0.119, 2.121               |
| SpO2           | 73.71                | 81.71                    | −7.854          | −2.736  | .006    | −13.497, 2.121             |
| Systolic BP    | 130.9               | 130.3                    | 0.523           | 0.222   | .824    | −4.098, −2.922              |
| Diastolic BP   | 88.85 (17)           | 70.06 (20.95)            | −1.200          | −0.795  | .427    | −4.166, −1.466             |

BMI = body mass index, BP = blood pressure, CCI = Charlson comorbidity index, CI = confidence interval, ICU = intensive care unit, OR = odd ratio.

### Table 3

Association of comorbidities variables with the ICU admission.

| Variable                     | ICU (N = 147) | Non-ICU (N = 297) | χ² value | P value | OR | 95% CI of OR |
|------------------------------|---------------|-------------------|----------|---------|----|-------------|
| Polypharmacy                 | 106 (72.1)    | 221 (74.4)        | 0.521    | .470    | 0.843 | 0.529, 1.342 |
| Diabetes                     | 86 (68.5)     | 145 (48.9)        | 3.703    | .055    | 1.479 | 0.991, 2.203 |
| Hypertension                 | 106 (72.1)    | 218 (73.4)        | 0.083    | .773    | 0.937 | 0.602, 1.549 |
| Dyslipidemia                 | 30 (20.4)     | 69 (23.2)         | 0.453    | .501    | 0.847 | 0.532, 1.374 |
| Cardiac diseases             |               |                   |          |         |     |             |
| Ischemic heart disease       | 27 (18.4)     | 39 (13.2)         | 2.088    | .148    | 1.1483 | 0.867, 2.535 |
| Heart failure                | 34 (23.1)     | 37 (12.5)         | 8.335    | .004    | 2.114 | 1.263, 5.540 |
| Other cardiac diseases       | 22 (15)       | 30 (10.1)         | 2.2251   | .134    | 1.566 | 0.869, 2.925 |
| Respiratory diseases         |               |                   |          |         |     |             |
| COPD                         | 8 (5.4)       | 5 (1.7)           | 4.888    | .027    | 3.361 | 1.089, 10.462 |
| Bronchial asthma             | 14 (9.5)      | 36 (12.1)         | 0.664    | .415    | 0.763 | 0.398, 1.464 |
| Intestinal lung disease      | 7 (4.8)       | 5 (1.7)           | 3.544    | .060    | 2.920 | 0.911, 9.363 |
| Pulmonary vascular diseases  | 4 (2.7)       | 7 (2.4)           | 0.054    | .816    | 1.159 | 0.334, 4.023 |
| Pulmonary tuberculosis       | 3 (2)         | 5 (1.7)           | 0.071    | .790    | 1.217 | 0.287, 5.162 |
| Obstructive sleep apnea      | 1 (0.7)       | 6 (2)             | 1.138    | .286    | 0.332 | 0.040, 2.785 |
| Other respiratory diseases   | 6 (4.1)       | 7 (2.4)           | 1.029    | .310    | 1.763 | 0.582, 5.343 |
| Neurological diseases        |               |                   |          |         |     |             |
| Cerebrovascular accidents    | 21 (14.3)     | 33 (11.1)         | 0.928    | .335    | 1.333 | 0.741, 2.398 |
| Other neurological diseases  | 12 (8.2)      | 38 (12.8)         | 2.111    | .146    | 0.606 | 0.306, 1.198 |
| Genitourinary diseases       |               |                   |          |         |     |             |
| Chronic kidney disease       | 33 (22.4)     | 41 (13.8)         | 5.290    | .021    | 1.807 | 1.087, 3.006 |
| Other Genitourinary diseases | 21 (14.3)     | 35 (11.8)         | 0.558    | .455    | 1.248 | 0.698, 2.231 |
| Endocrinopathy (except diabetes) | 20 (13.6) | 41 (13.8)         | 0.003    | .954    | 0.983 | 0.553, 1.748 |
| Liver and gastrointestinal diseases | 9 (6.1) | 26 (8.8)          | 0.938    | .333    | 0.680 | 0.310, 1.491 |
| Rheumatological diseases     | 6 (4.1)       | 5 (1.7)           | 2.341    | .126    | 2.485 | 0.746, 8.282 |
| Hematological diseases       | 6 (4.1)       | 12 (4)            | <0.001   | .983    | 1.011 | 0.372, 2.749 |
| Malignancies                 | 10 (6.8)      | 14 (4.7)          | 0.839    | .360    | 1.475 | 0.639, 3.407 |

CI = confidence intervals, COPD = chronic obstructive pulmonary disease, ICU = intensive care unit, OR = odd ratio.
among the elderly patients. Previous studies support this study and reveal that CKD is associated with a higher risk of ICU admission, severe COVID-19 and a high mortality rate.[11,12] In addition, patients with CKD are prone to viral infections, which could be explained by an impaired immune cell function.[13] In the current study, heart failure with COVID-19 in elderly patients is a major risk factor for ICU admission. Other studies have also linked heart failure with a higher mortality rate in patients with COVID-19, a higher risk of severe COVID-19 and developing acute decompensated heart failure.[24,25]

Our study has several limitations. Most importantly, the current study was conducted in one hospital, limiting the ability to generalize the findings for the elderly population in Saudi Arabia. A multicenter study with a larger sample size is recommended to generalize the results. Another limitation was the relatively small sample size to understand the causality of comorbidity with risk of ICU admission among the elderly patients.

5. Conclusion
The current study reveals that COPD and heart failure as well as factors like SpO2 and length of stay were associated with a higher risk of ICU admission among the elderly patients with COVID-19 in Saudi Arabia. These findings highlight clinical implications of comorbidity among geriatric population. Diagnosing and treating patients with these comorbidities should be a priority to decrease the rate of ICU admission.

Acknowledgments
The authors are grateful to the Deanship of Scientific Research, King Saud University, for funding through the Vice Deanship of Scientific Research Chairs. The Research team would like to thank gratefully the team from Scribbr for proofreading the manuscript.

Author contributions
Conceptualization: Saad Alsaad, Abdurahman Addweesh, Mohammed Beyari, Munib Alkhateb, Abdulrahman Alswat, Abdulrahman Alshabnan.
Data curation: Saad Alsaad, Abdurahman Addweesh, Mohammed Beyari, Munib Alkhateb, Abdulrahman Alswat, Abdulrahman Alshabnan.
Formal analysis: Saad Alsaad, Abdurahman Addweesh, Mohammed Beyari, Munib Alkhateb, Abdulrahman Alswat, Abdulrahman Alshabnan.
Investigation: Saad Alsaad, Abdurahman Addweesh, Mohammed Beyari, Munib Alkhateb, Abdulrahman Alswat, Abdulrahman Alshabnan.
Software: Abdulaziz Alsaad.
Supervision: Saad Alsaad, Haytham AlSaif.
Validation: Abdulaziz Alsaad, Haytham AlSaif.
Writing – original draft: Saad Alsaad, Abdurahman Addweesh, Mohammed Beyari, Munib Alkhateb, Abdulrahman Alswat, Abdulrahman Alshabnan.
Writing – review & editing: Saad Alsaad, Abdulaziz Alsaad, Haytham AlSaif.

References
[1] Akhtar Z, Islam MA, Aleem MA, et al. SARS-CoV-2 and influenza virus coinfection among patients with severe acute respiratory infection during the first wave of COVID-19 pandemic in Bangladesh: a hospital-based descriptive study. BMJ Open. 2021;11:e033768.
[2] Cucinotta D, Vaneli M. WHO declares COVID-19 a pandemic. Acta Biomed. 2020;91:157.
[3] Zhang H, Du F, Cao XJ, et al. Clinical characteristics of coronavirus disease 2019 (COVID-19) in patients out of Wuhan from China: a case control study. BMC Infect Dis. 2021;21:207.
[4] Moraes EN, Viana LG, Resende LMF, et al. COVID-19 in long-term care facilities for the elderly: laboratory screening and disease dissemination prevention strategies. Cien Saude Colet. 2020;25:3445–58.
[5] Gao Z, Xu Y, Sun C, et al. A systematic review of asymptomatic infections with COVID-19. J Microbiol Immunol Infect. 2021;54:12–6.
[6] Pardhan S, Wood S, Vaughan M, Trott M. The risk of COVID-19 related hospitalization, intensive care unit admission and mortality in people with underlying asthma or COPD: a systematic review and meta-analysis. Front Med. 2021;8:6684808.
[7] Reeves RR, Willoughby SG. Significant cognitive impairment likely associated with COVID-19 infection with relatively nonsevere symptoms. J Osteopath Med. 2022;122:119–23.
[8] Alonso-Lana S, Marque M, Ruiz A, Boada M. Cognitive and neuropsychiatric manifestations of covid-19 and effects on elderly individuals with dementia. Front Aging Neurosci. 2020;12:588772.
[9] Ejaz H, Ahsan HI, Zafar A, et al. COVID-19 and comorbidities: deleterious impact on infected patients. J Infect Public Health. 2020;13:1833–9.
[10] Schifferl EL, Flack JM, Ito S, Muntner P, Webb RC. Hypertension and COVID-19. Am J Hypertens. 2020;33:373–4.
[11] Kulcsar KA, Coleman CM, Beck SE, Frieman MB. Comorbid diabetes results in immune dysregulation and enhanced disease severity following MERS-CoV infection. JCI Insight. 2019;4:e131774.
[12] Wang D, Hu B, Hu C, Zhu F, Liu X, Zhang J. Clinical characteristics of 138 hospitalized patients with 2019 novel coronavirus-infected pneumonia in Wuhan, China. JAMA. 2020;323:1061–9.
[13] Koudelka M, Sovová E. COVID-19 causing hypotension in frail geriatric hypertensive patients? Medicina. 2021;57:633.
[14] Mónica RS, Maribel QF, Javier J, et al. Cardiac complications in a geriatric population hospitalized with COVID-19: The OCTA-COVID cohort. Rev Esp Geriatr Gerontol. 2022;57:63–70.
[15] Sadeghi A, Eslami P, Moghadam AD, et al. COVID-19 and ICU admission associated predictive factors in Iranian patients. Caspian J Intern Med. 2020;11(Suppl 1):512–9.
[16] Jain V, Yuan JM. Predictive symptoms and comorbidities for severe COVID-19 and intensive care unit admission: a systematic review and meta-analysis. Int J Public Health. 2020;65:533–46.
[17] Roncon L, Zunn M, Zuliani G, Rigatelli G. Patients with arterial hypertension and COVID-19 are at higher risk of ICU admission. Br J Anaesth. 2020;125:e254–5.
[18] Leung JM, Ntikura M, Yang CWT, Sin DD. COVID-19 and COPD. Eur Respir J. 2020;56:2002180.
[19] Gerayeli FV, Milne S, Cheung C, et al. COPD and the risk of poor outcomes in COVID-19: a systematic review and meta-analysis. EClinicalMedicine. 2021;33:100789.
[20] Higham A, Mathioudakis A, Vestbo J, Singh D. COVID-19 and COPD: a narrative review of the basic science and clinical outcomes. Eur Respir Rev. 2022;29:200199.
[21] Ji W, Huh K, Kang M, et al. Effect of underlying comorbidities on the infection and severity of COVID-19 in Korea: a nationwide case-control study. J Korean Med Sci. 2020;35:e237.
[22] Cai R, Zhang J, Zhu Y, Liu L, Liu Y, He Q. Mortality in chronic kidney disease patients with COVID-19: a systematic review and meta-analysis. Int Urol Nephrol. 2021;53:1623–9.
[23] Betjes MGH. Immune cell dysfunction and inflammation in end-stage renal disease. Nat Rev Nephrol. 2013;9:255–65.
[24] Bhatt AS, Jering KS, Vaduganathan M, et al. Clinical outcomes in patients with heart failure hospitalized with COVID-19. JACC: Heart Fail. 2021;9:65–73.
[25] Reji JR, Caro-Codon J, Rosillo SO, et al. Heart failure in COVID-19 patients: prevalence, incidence and prognostic implications. Eur J Heart Fail. 2020;22:2203–15.