The devastating impact of severe acute respiratory syndrome coronavirus 2 (SARS CoV-2) continues to be felt globally more than a year since it was first reported in Wuhan, China. As of the end of March 2021, more than 129 million individuals have been infected with the virus causing more than 2,778,619 deaths. Oman has documented 156,883 coronavirus disease 2019 (COVID-19) cases (3072/100,000 population) with 1,662 deaths with a fatality rate of (1.1%). The first two cases were reported by the governorate of Muscat, the capital of Oman, and were associated with a trip to Iran.

COVID-19 vaccines and non-pharmaceutical interventions (NPIs) have the potential to prevent serious infections, hospitalizations, and death. However, for the vaccines to be effective, countries must achieve herd immunity by vaccinating > 70% of the population. For many countries, the process may take two or three years. Therefore, without the wide availability of vaccines, the mainstay approach to control the transmission of the virus are NPIs, including social distancing, hand hygiene, use of face masks, restriction of social gatherings, lockdowns, and early detection of cases and quarantine. In hospitals, patients are generally managed by providing supplemental oxygen, antibiotics for secondary bacterial infection, and dexamethasone to control the hyperinflammatory response. Remdesivir and tocilizumab have also been advocated for managing hospitalized patients with moderate and severe COVID-19, respectively.

Over one year, epidemiological investigations into COVID-19 outbreaks have revealed that the factors...
influencing acquisition risk vary from one context to another. However, several local factors appear in well-established patterns that can be identified and avoided when well-studied, influenced by contact patterns, environmental factors, and socioeconomic inequalities.\(^5,9\) Transmission can take place in any setting, but some settings facilitate greater risk of acquisition due to a combination of environmental and behavioral factors. Therefore, understanding the behavioral and demographic characteristics of patients with COVID-19 infection and potential risk factors for acquisition of COVID-19 during the two weeks before illness onset and the epidemiological risk factors for severe illness leading to hospitalization could help significantly in the efforts to reduce community transmission.\(^5,10–12\)

There is a paucity of literature describing the community transmission risk factors for severe COVID-19, specifically in Oman. Therefore, our study aims to determine epidemiological risk factors associated with the potential acquisition of severe COVID-19 and hospitalization to manage and reduce transmission in the community and healthcare settings and enforce control measures.

**METHODS**

The Royal Hospital is the largest tertiary healthcare facility with nearly 1000 beds, designated for hospitalization of patients with moderate and severe COVID-19.

A prospective cohort study was conducted among patients hospitalized with laboratory-confirmed SARS-CoV-2 infection by real-time polymerase chain reaction at the Royal Hospital, Muscat, Oman. Patients were admitted into a designated isolation ward through the emergency room, general wards, transfers from other hospitals, or transfers (step down) from the intensive care unit (ICU) within the Royal Hospital.

A total of 143 individuals were enrolled from 9 August to 30 November 2020, who could self-report verbally. Pregnant women and patients < 18 were excluded.

The interview was conducted by trained health care workers (HCWs) within 48 hours following the patient’s admission to the hospital or ICU transfer. A questionnaire comprising six closed-ended questions was used to identify potential exposure risk factors for COVID-19. The questionnaire collected data on demographic characteristics (sex, age, place of residency, and nationality), clinical presentation, contact and exposures history in the 14 days before symptoms onset, features of severe COVID-19, and COVID-19 complications. For epidemiologic purposes, severe COVID-19 in adults is defined as dyspnea, a respiratory rate of 30 or more breaths per minute, a blood oxygen saturation of 93% or less, a ratio of the partial pressure of arterial oxygen to the fraction of inspired oxygen (PaO\(_2\):FiO\(_2\)) of < 300 mm Hg, or infiltrates in > 50% of the lung field.\(^1,3\)

COVID-19 complications included severe illness (severe pneumonia and acute respiratory distress syndrome (ARDS)), need for mechanical ventilation, acute renal failure, cardiac failure, and thromboembolic events. Using these complications, we developed an index score variable to measure the severity of COVID-19 in hospitalized patients. Patients having at least one severe illness or complications were classified as being severe, otherwise not severe.

Patient characteristics were described using frequencies and percentages for categorical variables and mean and standard deviation for continuous variables. The chi-square test was used to determine a significant relationship between independent variables and the severity of infection. Unadjusted and adjusted logistic model analyses were used to determine measures of association between independent variables (risk factors) and severity of COVID-19 infection. All statistical analysis were done using the R statistical analysis program (R Core Team (2020). R Foundation for Statistical Computing, Vienna, Austria). Tests < 0.050 were statistically significant.

The study was approved by the Royal Hospital Ethical Committees (SRC#26/2020). Consent was obtained from all patients willing to participate in the study by a member of the study team.

**RESULTS**

A total of 143 patients were included in the study; 95.8% (n = 137) were Omani citizens and 4.2% (n = 6) were non-citizens. Overall, the cohort consisted of 62.2% (n = 89) males and 37.8% (n = 54) females. The average age of the cohort was 50.6±16.5 years. More than half of the patients (73.4%, n = 105) were residents of Muscat and...
26.6% (n = 38) were from other governorates. Approximately 4.9% (n = 7) of patients were HCWs [Table 1].

Of the total number of patients diagnosed with COVID-19, 29.4% (n = 42) were admitted or stepped down from the ICU, while 24.5% (n = 35) required mechanical ventilation. The associated COVID-19 illnesses/complications were as follows: 14.0% severe pneumonia (n = 20), 13.3% ARDS (n = 19), 10.0% acute renal failure (n = 14), 3.5% cardiac failure (n = 5), and 1.4% thromboembolic events (n = 2).

Of the 143 patients who provided an exposure history, 11.9% (n = 17) reported domestic travel within 14 days. A total 29.4% (n = 42) had contact with a case of COVID-19 within 14 days at home, 7.7% (n = 11) at work, and 6.3% (n = 9) at the hospital. Close contact was defined as being in contact with an individual with COVID-19 for > 10 min within two meters or less: 35.0% (n = 50) were with a family member, 7.7% (n = 11) with a co-worker, and 10.5% (n = 15) with a friend. Twenty-one percent (n = 30) of the COVID-19 infected patients worked outside their home daily, 7.7% (n = 11) worked away from home 2–3 times a week, 4.9% (n = 7) worked out of home once a week, and 65.0% (n = 93) never worked out of their home in the preceding 14 days prior to the infection [Table 1].

Out of 60 patients with severe COVID-19, several risk factors were identified to be significant. Being female (n = 31; 51.7%; p = 0.010), attending a mass gathering within the last 10 days (n = 13; 21.7%; p = 0.017), attending a gathering with 10 people or less (n = 18; 30.0%; p = 0.034), being admitted at a hospital within the last 14 days (n = 38; 63.3%; p = 0.027) displayed potential risks for acquisition of severe infection and were significantly different from patients with less severe infections. However, being a HCW (n = 23; 38.9%; p = 0.041) displayed a marginal potential risk [Table 2].

Unadjusted logistic regression analysis showed that females (odds ratio (OR) = 2.67; 95% confidence interval (CI): 1.33–5.49; p = 0.006), working in the health care facility (OR = 9.58; 95% CI: 1.44–189.23; p = 0.044), being a HCW (OR = 2.36; 95% CI: 1.11–5.11; p = 0.027), attending a mass gathering in the past 14 days (OR = 4.04; CI: 1.42–13.32; p = 0.013), gathering with 10 people or less (OR = 2.74; 95% CI: 1.17–6.73; p = 0.022), admission to a hospital (OR = 2.30; 95% CI: 1.16–4.65; p = 0.018) were significantly associated with increased severe COVID-19 disease [Table 3].

Moreover, the adjusted multivariate logistic regression analysis shows that working at a health care facility (OR = 33.42; 95% CI: 1.92–1386.88; p = 0.029) was significantly associated with severe COVID-19 infection. Incidentally, being female was only marginally significantly associated. Although being over 51 years showed increased odds of severe infection, it was not statistically significant [Table 3].

**DISCUSSION**

Patients with severe COVID-19 are at increased risk of morbidity and mortality. Our study has identified
several risk factors associated with the acquisition of severe COVID-19 and its complications. Females, HCWs, attending mass gatherings, and gathering with 10 people or less were significantly associated with severe COVID-19. On adjusted multivariate analysis working at a healthcare facility...
was the only significant risk factor associated with severe COVID-19.

Several reports from retrospective cohort studies in France\cite{13} and China\cite{14} demonstrated that being male was significantly associated with severe COVID-19. On the contrary, our study revealed females were associated with a 1.07-times increased risk of severe COVID-19 despite more males being hospitalized. This finding agrees with several other studies where a higher attack rate was observed in females rather than males.\cite{15-18} Furthermore, Gebhard et al,\cite{19} explored and assessed differentials that exist not only by gender but also by gender roles in the social and economic spheres of life. These differences may be due to the typical female role as caregivers within families that potentially require closer contact and longer contact period with the index cases,\cite{20} and in most cases, females comprise a large proportion of HCWs.\cite{21} Therefore, implementation of preventive measures to protect females from infection and prioritizing them for vaccination are essential. On multivariate logistic regression analysis, the effect of gender on severity of COVID-19 was not significant.

Although patients over the age of 51 are more likely to have serious illness, this result was not statistically significant in this cohort, probably due to the relatively small sample size. However, the OR of having severe disease among the 30–51 and > 51 age groups was 1.77 and 2.43, respectively, confirming that severe COVID-19 was seen in older patients rather than those aged 18–34 years. This is consistent with the findings of a multi-center observation study conducted in 18 hospitals designated for COVID-19 patients in Malaysia, which revealed that over half of serious cases were among those aged 51 years old and above.\cite{22}

In this cohort, attending mass gatherings (OR = 4.04; 95% CI: 1.42–13.32; \(p = 0.013\)) or a gathering of 10 people or less (OR = 2.74; 95% CI: 1.17–6.73; \(p = 0.022\)) was significantly associated with severe COVID-19. Mass gatherings bring people into proximity in environments that are conducive for the transmission of infections.\cite{23} The risk of infection is magnified if the disease is particularly contagious, as is the case with COVID-19 and its new variants.\cite{24} Moreover, in mass gatherings, people tend to lower their guard on NPIs measures, and this could potentially increase the likelihood of transmission. In a large retrospective cohort study involving 7700 close contacts of confirmed COVID-19 cases in Singapore, close physical proximity and increased duration of verbal interaction were independent risk factors for transmission among household and non-household contacts.\cite{25} These findings confirm the importance of NPIs that has been adopted by countries, such as social distancing, universal masking, and banning gatherings.

Our findings based on unadjusted logistic regression analysis showed that gatherings are associated with COVID-19 severity regardless of the number of people. Moreover, these findings bring out the differences, indicating that mass gatherings increased the odds of severe COVID-19 by four times. In contrast, gatherings with 10 people or less increased the chances of severe symptoms by almost three-times compared to those who did not get involved in any gatherings. This difference, though small, has epidemiological implications as to the possibility of COVID-19 re-infection in large gatherings and, if so, whether severity implies higher viral loads. A few studies have confirmed that indeed viral loads have a positive correlation with COVID-19 severity.\cite{26,27} Some of the other factors that influence transmission in settings of mass gatherings include prevalence and transmission pattern of COVID-19 in the community, the extent and duration of social interactions, and the demographic profile of participants.\cite{23,28}

Whereas COVID-19 severity is influenced by host factors (such as age, comorbidities, and immune function), the association between the clinical seriousness of index and secondary cases is not fully studied.\cite{25} However, a retrospective cohort study showed that close contact between adults and those exposed to index cases with dry cough symptoms was associated with an increased possibility of infection.\cite{29} Our findings show that 40.0% of the patients reported being in close contact with an index patient in quarantine/isolation. Of those, over 51.0% had a severe infection. Further, this risk of infection was significantly higher in adults aged at least 60 years.\cite{22,30,31}

In this study, patients working at a healthcare facility had increased odds of developing severe disease by at least nine-times compared to patients who did not work at a health care facility. Additionally, being a medical HCW increased the odds of acquiring severe illness by over two times compared to non-medical HCWs. These findings are consistent with an observational and prospective

\[ p = \]
cohort study using the UK and US COVID-19 Symptom Study, which indicated that frontline HCWs were 12-times more likely to be tested positive after a multivariable adjustment.33 Although both of these factors yielded statistically significant results with severity of COVID-19, it is worth explaining the differences in increased ORs. HCWs are more exposed due to their frequent bedside visits to patients, caring for patients with severe conditions, and the number of hours they spend with patients. Several potential factors have been postulated as the underlying reason for the increase in risk among HCWs. These include poor compliance with personal protective equipment, high-risk exposure to infected patients, overwork, performing aerosol-generating procedures, poor infection control practices, and pre-existing comorbidities.32–35

The uniqueness of our study can be attributed to the index of severity developed as an outcome variable. Most recent studies have only used some clinical factors to measure COVID-19 severity.36–38 Those results are more confirmatory but less predictive because of failure to focus on important transmission risk factors and comorbidities that in most cases exacerbate the worsening disease among COVID-19 patients.

There were some limitations in the study. Firstly, the nature of the retrospective study inevitably resulted in recall bias. Secondly, the transmission risk factors identified in this cohort might be more specific to the hospitalized population studied and cannot be generalized. Thirdly, the relatively small number of the cohort and exclusion of children and pregnant women could have underestimated the effects of certain modes of transmission. However, clinicians are strongly encouraged to study these variables for their relevant populations, as lifestyle and exposure vary across populations and countries.

CONCLUSION
The study sought to determine risk factors associated with COVID-19 patients’ hospitalization and the potential transmissibility and severity to inform control measures. Being a female, working at a healthcare institution, attending mass gatherings within the last 10 days prior to the onset of the disease, gathering with 10 people or less during the last 14 days, and being admitted at a hospital within the last 14 days may identify individuals at high risk of severe COVID-19. At a hospital level, the highlighted HCWs should be included in the triage scale to identify potential severe COVID-19 illness early.

Disclosure
The authors declared no conflicts of interest. No funding was received for this study.

Acknowledgements
The authors would like to acknowledge all the study participants who were instrumental in the development of the manuscript.

REFERENCES
1. Huang C, Wang Y, Li X, Ren L, Zhao J, Hu Y, et al. Clinical features of patients infected with 2019 novel coronavirus in Wuhan, China. Lancet 2020 Feb;395(10223):497-506.
2. World Health Organization. COVID-19 dashboard. 2021 [cited 2021 March 31]. Available from: https://covid19.who.int/.
3. World Health Organization. EMRO. COVID-19 dashboard. 2021 [cited 2021 March 31]. Available from: https://covid19.who.int/region/emro/country/om.
4. Khamis F, Al-Zakwani I, Al Naamani H, Al Lawati S, Pandak N, Omar MB, et al. Clinical characteristics and outcomes of the first 63 adult patients hospitalized with COVID-19: an experience from Oman. J Infect Public Health 2020 Jul;13(7):906-913.
5. Khamis F, Al Rashidi B, Al-Zakwani I, Al Wahaibi AH, Al Awaidy ST. Epidemiology of COVID-19 infection in Oman: analysis of the first 1304 cases. Oman Med J 2020 Jun;35(3):e145.
6. Anderson RM, Vegvari C, Truscott J, Collyer BS. Challenges in creating herd immunity to SARS-CoV-2 infection by mass vaccination. Lancet 2020;396(10263):1614-1616.
7. Salama C, Han J, Yau L, Reiss WG, Kramer B, Neidhart JD, et al. Tocilizumab in patients hospitalized with COVID-19 pneumonia. New england Journal of Medicine 2020;396(10263):1614-1616.
8. Ran J, Zhao S, Han L, Chong MK, Qiu Y, Yang Y, et al. The changing patterns of COVID-19 transmissibility during the social unrest in the United States: A nationwide ecological study with a before-and-after comparison. One Health 2021 Jun;12:100201.
9. Ran J, Zhao S, Han L, Qu y Cao P, Yang Z, et al. Effects of particulate matter exposure on the transmissibility and case fatality rate of COVID-19: a nationwide ecological study in China. Journal of Travel Medicine 2020;27(6):taaa133.
10. Khamis F, Memish Z, Bahrani MA, Dowaike SA, Pandak N, Bolushi ZA, et al. Prevalence and predictors of in-hospital mortality of patients hospitalized with COVID-19 infection. J Infect Public Health 2021 Jun;14(6):759-765.
11. Kacouffer C, Le Hyaric C, Fabacher T, Mootien J, Dervieux
B, Ruch Y, et al; Covid Alsace Study Group; COVID Alsace Study Group. Clinical characteristics and risk factors associated with severe COVID-19: prospective analysis of 1,045 hospitalised cases in North-Eastern France, March 2020. Euro Surveill 2020 Dec;25(48):2000895.

14. Liu S, Luo H, Wang Y, Cuevas LE, Wang D, Ju S, et al. Clinical characteristics and risk factors of patients with severe COVID-19 in Jiangsu province, China: a retrospective multicentre cohort study. BMC Infect Dis 2020 Aug;20(1):584.

15. Wu Z, McGoogan JM. Characteristics of and important lessons from the coronavirus disease 2019 (COVID-19) outbreak in China: summary of a report of 72,314 cases from the Chinese center for disease control and prevention. JAMA 2020 Apr;323(13):1239-1242.

16. Wenham C, Smith J, Morgan R. COVID-19: the gendered impacts of the outbreak. Lancet 2020;395(10227):846-848.

17. World Health Organization. Delivered by women, led by men: a gender and equity analysis of the global health and social workforce. 2019 [cited 2021 March 21]. Available from: https://apps.who.int/iris/handle/10665/311322.

18. Liu T, Liang W, Zhong H, He J, Chen Z, He G, et al. Risk factors associated with COVID-19 infection: a retrospective cohort study based on contacts tracing. Emerg Microbes Infect 2020 Dec;9(1):1546-1553.

19. Gebhard C, Regitz-Zagrosek V, Neuhauser HK, Morgan R, Klein SL. Impact of sex and gender on COVID-19 outcomes in Europe. Biol Sex Differ 2020 May;11(1):29.

20. Bi Q, Wu Y, Mei S, Ye C, Zou X, Zhang Z, et al. Epidemiology and transmission of COVID-19 in 391 cases and 1286 of their close contacts in Shenzhen, China: a retrospective cohort study. Lancet Infect Dis 2020;20(8):911-919.

21. Bonioli M, McIsaac M, Xu L, Wuliji T, Diallo K, Campbell J. Gender equity in the health workforce: analysis of 104 countries. Geneva: World Health Organization. 2019 [cited date]. Available from: https://www.who.int/hrh/resources/gender_equity-health_workforce_analysis/en/.

22. Sim BL, Chidambaram SK, Wong XC, Pathmanathan MD, Peariasamy KM, Hor CP, et al. Clinical characteristics and risk factors for severe COVID-19 infections in Malaysia: A nationwide observational study. Lancet Reg Health West Pac 2020 Nov;4:100055.

23. McCloskey B, Zumla A, Ippolito G, Blumberg L, Arbon P, Cicero A, et al; WHO Novel Coronavirus-19 Mass Gatherings Expert Group. Mass gathering events and reducing further global spread of COVID-19: a political and public health dilemma. Lancet 2020 Apr;395(10230):1096-1099.

24. Davies NG, Abbott S, Barnard RC, Jarvis CI, Kucharski AJ, Munday JD, et al. Estimated transmissibility and impact of SARS-CoV-2 lineage B.1.1.7 in England. Science 2021;373(6538).

25. Ng OT, Marimuthu K, Koh V, Pang J, Linn KZ, Sun J, et al. SARS-CoV-2 seroprevalence and transmission risk factors among high-risk close contacts: a retrospective cohort study. Lancet Infect Dis 2021 Mar;21(3):333-343.

26. Shi F, Wu T, Zhu X, Ge Y, Zeng X, Chi Y, et al. Association of viral load with serum biomarkers among COVID-19 cases. Virology 2020 Jul;546:122-126.

27. Zhang X, Tan Y, Ling Y, Lu G, Liu F, Yi Z, et al. Viral and host factors related to the clinical outcome of COVID-19. Nature 2020 Jul;583(7816):437-440.

28. Hopkins N, Reicher S. Mass gatherings, health, and well-being: from risk mitigation to health promotion. Soc Issues Policy Rev 2021;15(1):114-145.

29. Hu P, Ma M, Jing Q, Ma Y, Gan L, Chen Y, et al. Retrospective study identifies infection related risk factors in close contacts during COVID-19 epidemic. Int J Infect Dis 2021 Feb;103:395-401.

30. Luo L, Liu D, Liao X, Wu X, Jing Q, Zheng J, et al. Contact settings and risk for transmission in 3410 close contacts of patients with COVID-19 in Guangzhou, China: a prospective cohort study. Ann Intern Med 2020 Dec;173(11):879-887.

31. Xin H, Jiang F, Xue A, Liang J, Zhang J, Yang F, et al. Risk factors associated with occurrence of COVID-19 among household persons exposed to patients with confirmed COVID-19 in Qingdao Municipal, China. Transbound Emerg Dis 2021 Mar;68(2):782-788.

32. Nguyen LH, Drew DA, Graham MS, Joshi AD, Guo CG, Ma W, et al. Risk of COVID-19 among frontline health-care workers and the general community: a prospective cohort study. Lancet Public Health 2020 Sep;5(9):e475-e483.

33. Mhango M, Dzobo M, Chitungo I, Dzinamarira T. COVID-19 risk factors among health workers: a rapid review. Saf Health Work 2020 Sep;11(3):262-265.

34. Wander PL, Orlov M, Merel SE, Enquobahrie DA. Risk factors for severe COVID-19 illness in healthcare workers: too many unknowns. Infect Control Hosp Epidemiol 2020 Nov;41(11):1369-1370.

35. Chou R, Dana T, Buckley DI, Selph S, Fu R, Totten AM. Epidemiology of and risk factors for coronavirus infection in health care workers: a living rapid review. Ann Intern Med 2020 Jul;173(2):120-136.

36. Lake MA. What we know so far: COVID-19 current clinical knowledge and research. Clin Med (Lond) 2020 Mar;20(2):124-127.

37. Li T, Wang Q, Zhang D, Ding J, Huang Q, Tang YQ, et al. Lymphopenia predicts disease severity of COVID-19: a descriptive and predictive study. Signal Transduct Target Ther 2020;5(1):1-3.

38. Shang W, Dong J, Ren Y, Tian M, Li W, Hu J, et al. The value of clinical parameters in predicting the severity of COVID-19. J Med Virol 2020 Oct;92(10):2188-2192.