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Original Article

Transmission dynamics, responses, and clinical features for the first 1100 COVID-19 cases in South Batinah, Oman: Major lessons from a provincial perspective

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الملخص

أهداف البحث: هدفت هذه الدراسة إلى استكشاف وتحليل الملامح الوبائية ورصد واستجابة كوفيد-19، وديناميكيات انتقالها وتشكل المجموعات.

طرق البحث: تحليل استرجاعي لبيانات الرصد، بما في ذلك تتبع الاتصال، وعوامل الخطر، والمعلومات السريرية. أجريت تحليلات الانحدار اللوجستية الثنائية لتقييم احتمالات القبول، وتشكل المجموعات، وكونه حالة رئيسية. تم توضيح المجموعات باستخدام أنظمة البيانات الجغرافية وتحليل الشبكات وبرامج التصور.

النتائج: تم تشخيص ١١٠٠ حالة إصابة بفيروس كوفيد-١٩ في الفترة من ٢٠ مارس إلى ٧ يونيو ٢٠٢٠، وكانت ١٤٤ حالة منها (١٣,١٪) بدون أعراض. كانت المدة المتوسطة من بدء الأعراض حتى القبول في المستشفى ٧ أيام (٤,٥ - ١٠)، ومدة الأعراض نفسها كانت ٥ أيام (٣ - ٩). تم تحديد 89 مجموعة تحتوي على ٧٣٦ مريضا. وتم تمييز ثلاث مراحل توضح إجراءات الرصد والسيطرة. بدأت المجموعات في المرحلة الثانية وزادت وضوحا في المرحلة الثالثة. المرضى الذين تجاوزوا سن ٥٠ عاما وأولئك الذين يعانون من الحمى لديهم

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فرصة أكبر للقبول في المستشفى، بنسبة ١٢,٨٥ (٩٥٪ م.م. ٥,١٣ — ٣٢,١٩) و ٢,٥٣ (٩٥٪ م.م. ١,٢٤ — ٥,١٧) على التوالي. وقد لوحظ تشكل المجموعات بين الإناث والمرضى الذين لم يظهروا أعراضا وبين سكان ولاية عوابي، بنسب ٢,٣ (٩٥٪ م.م. ١,٧ — ٣,١) و ٦,٣٩ (٩٥٪ م.م. ٢,٣٣ — ١٧,٢) و ٣,٥٤ (٩٥٪ م.م. ٢,٠٦ — ٦,٠٧) على التوالي. وكان لدى المرضى العاملين في قطاعات الشرطة والدفاع فرصة أعلى لكونهم حالة رئيسية، بنسبة ٧,٨٨ (٩٥٪ م.م. ٣,٣٥ — ١٨,٥٢).

الاستنتاجات: يجب دعم التدخلات القائمة على الحالات من خلال التدابير الموسعة على مستوى السكان - خاصة قيود الحركة. يعد إنشاء فرق الوقاية أو وحدات المنطقة، أو من خلال الرعاية الأولية أمرا حاسما للسيطرة على الأوبئة المستقبلية. يجب أن تكون الوقاية دائما أولوية للفئات السكانية الضعيفة.

الكلمات المفتاحية: عمان، كوفيد-19؛ علم الوبائيات؛ استجابة سريعة؛ انتقال؛ مجموعات.

Abstract

Objectives: This study was aimed at exploring and analyzing the epidemiological profile, surveillance, and response to COVID-19, including transmission dynamics and cluster formation.

Methodology: This was a retrospective analysis of surveillance data, including contact tracing, risk factors, and clinical information. Binary logistic regressions were used to assess the likelihood of admission, cluster formation, and of each individual being an index patient. Clusters were demonstrated through geographic data systems, network analysis, and visualization software.

Results: A total of 1100 COVID-19 cases were diagnosed from 20 March to 7 June 2020, of which 144 (13.1%) were asymptomatic. The median time from symptom onset to admission was 7 days (IQR, 4.5−10), and the median symptom duration was 5 days (IQR, 3−9). Eighty-nine clusters containing 736 patients were identified. The surveillance and control actions were divided into three phases. Clusters began to form in phase 2 and became more pronounced in phase 3. Patients ≥50 years of age and patients presenting with fever had relatively higher odds of admission: OR = 12.85 (95% CI 5.13−32.19) and 2.53 (95% CI 1.24−5.17), respectively. Cluster formation was observed among females, asymptomatic patients, and people living in Awabi: OR = 2.3 (95% CI 1.7−3.1), 6.39 (95% CI 2.33 −17.2), and 3.54 (95% CI 2.06−6.07), respectively. Patients working in the police and defense sectors had higher odds of being an index patient: OR = 7.88 (95% CI 3.35−18.52).

Conclusion: Case-based interventions should be supported by population-wide measures, particularly movement restrictions. Establishing prevention teams or district units, or primary care will be crucial for the control of future pandemics. Prevention should always be prioritized for vulnerable populations.

Keywords: Clusters; COVID-19; Index; Oman; Response; Transmission

Introduction

The COVID-19 pandemic had major effects in Oman, as in most other countries. The emergence of SARS-CoV-2 at the end of 2019 was sudden, and no rigorous scientific information was available to guide the public health response. Consequently, countries used various response strategies to mitigate the pandemic's effects, and minimize infections and mortality.[1,2] Learning from the experiences of Oman and other countries is important to support preparation for future unpredictable events. Previous articles from other governorates have addressed some aspects of Oman's experience, but this article is the first to highlight the experience of a provincial region, the South Batinah Governorate (SBG), which experienced one of the early case surges in the country.[3−11] The experience of SBG was quite different from, and in some ways better than, that of the other regions, thus providing unique insights into the crisis. This provincial perspective has not been sufficiently explored in many countries, particularly in the Middle East region. We believe that this experience provides essential lessons on the improvements needed to develop effective response strategies for future disease outbreaks.

Objective

This study was aimed at understanding the epidemiological profile, surveillance, and response actions, by exploring the transmission dynamics and cluster formation chronologically from the first case reported through 7 June 2020.

Materials and Methods

Setting

SBG is located on the northern side of Oman, near the shores of the Oman Sea and west of the Muscat Governorate. The 2019 census indicated that the region has 437 818 inhabitants.[12] The governorate is divided into six subdistricts: Rustaq, Barka, Musanaa, Nakhal, Wadi Al Maawel, and Awabi, by descending population size. All districts have governmental primary health facilities, but the only secondary hospital and the Directorate General for Health Services are in Rustaq. The Disease Surveillance and Control department (DSC) within the Directorate General for Health Services is responsible for managing and controlling all communicable disease issues, including surveillance, rapid response, and infection control. The department has eight qualified staff in epidemiology, infection control, vaccination, environmental and occupational health, and a small but growing entomological division. The staff includes additional health inspectors with varying levels of expertise, mainly in malaria control, and some unspecialized support staff.

Study design

A retrospective analysis of the surveillance data for the first 1100 COVID-19 cases was performed, examining information from contact tracing, risk factors, and clinical data. The study aim was to understand the epidemiology and transmission dynamics at the beginning of the COVID-19 pandemic.

Data collection

A comprehensive Excel spreadsheet was developed by the DSC after the detection of the first cases in SBG. The spreadsheet included all aspects of demography, clinical progress, testing, contact tracing, and risk factors for infection. Demographic information included names, areas of residence and work, sex, nationalities, ages, and occupations. Housewives and housemaids, retired people, those 70 years of age or older, and students were categorized as not working. Health care workers included those in both governmental and private sectors. The clinical progression data included symptom onset, manifestations, and admissions. The laboratory testing data comprised sample collection dates, release dates, and testing sites. For 22 entries, the collection date was missing and was assumed to be the notification day. When neither the reporting date nor the collection date was available, the collection date was considered to be 1 day after symptom onset. The number of days from sample collection to symptom onset was considered zero if patients were tested before developing symptoms or remained asymptomatic. Each case was given a unique serial number, and its related infection transmissions were identified and documented chronologically. Potential sources of infection were explored for every index case. A cluster was defined as a minimum of three COVID-19 cases confirmed by polymerase chain reaction. DSC staff added and verified cases on a daily basis throughout the study period, with the support of other departmental staff and the ground response team. For clusters in which the index case was uncertain, the person first developing symptoms was assumed to be the index patient.

Surveillance, case definitions, contact tracing, and rapid response activity

Notifications were shared manually from Central Public Health Laboratories through WhatsApp and direct phone calls until April 2020, when COVID-19 was integrated into the main electronic surveillance notification system (Tarassud) of the Ministry of Health.[13] The DSC was responsible for receiving all notifications in SBG, from governmental or private hospitals, and for providing technical advice, consultation, testing coordination, and rapid response and control throughout the pandemic period. The Rapid Response Team (RRT) was composed of the director of disease surveillance and control (a medical epidemiologist), an infection control specialist, and two other specialized nursing staff members. The RRT team initially responded to all reported cases throughout the governorate. However, by mid-April, an urgent need existed to build and train district teams to accommodate the rapid increase in cases. Consequently, stage 2 of the pandemic response was initiated, and the RRT started to enroll more staff from primary health institutions, mainly general practitioners, nurses, health inspectors, and other paramedical and administrative staff. Ground response teams were established first in Barka and Awabi, where the outbreaks in SBG were originally detected, and subsequently in the remaining districts. For geographical reasons, one team covered Nakhal and Wadi Maawel. Training and team formation were completed between 12 April and 24 April 2020. More details are shown in Figure 1.

By 9 May, the number of cases was increasing dramatically, and the ground teams were exhausted. This time marked the start of the third stage of the pandemic response. Daily case investigations, contact tracing, and follow-up activities were assumed by the 21 primary health facilities across the governorate. This process was completed on 10 June 2020. Figure 1 shows how the case investigations and follow-ups progressed from the DSC to the ground teams, and finally to primary health care.

Every person with a suspected case was placed in self-isolation or institutional isolation until the test results were released. From May 2022, compliance with isolation measures was ensured by requiring patients to wear a medical bracelet connected to a mobile application. The system, Tarassud Plus, was a technological solution to one aspect of infection control.[14] For cases testing positive, isolation continued for 14 days, with daily monitoring and evaluation. This quarantine period was decreased to 10 days in July. Contacts for each case quarantined for 14 days and were offered testing if they developed symptoms. Suspected cases were initially defined as those with a travel history, but this definition underwent several modifications as case detections increased.

Further details on laboratory testing and the evolving case definitions have been described in an article published in May 2022.[13]

Laboratory testing

From the outset of the pandemic, samples from SBG were sent to the Central Public Health Laboratory in Muscat on a daily basis, where reverse transcriptase polymerase chain reaction was performed. From late April onward, the governmental secondary hospital in SBG started Xpress SARS-CoV-2/GeneXpert (Cepheid) point-of-care testing.[13]

Statistical analysis

Data were collected and organized in Excel version 2016 (Microsoft, Redmond, WA). Analysis was performed in SPSS 23.0 (IBM Corp.; Armonk, New York, USA). Descriptive statistics (median and Interquartile range (IQR)) were generated for numerical data, whereas frequencies and percentages were calculated for categorical data. Binary logistic regression was used to assess the influence of demographic and clinical variables on three different outcomes: admission vs. non-admission; cluster formation vs. no cluster formation; and likelihood of each individual being the index patient for the clusters vs. contacts. We calculated the odds ratios (ORs) and 95% confidence intervals (CIs) with bivariate and multivariate analyses. P values ≤ 0.2 were used for the multivariate analyses; however, only P-values ≤ 0.05 were considered statistically significant.

The clustering figures were developed with Gephi version 0.9.7, by using Force Atlas and Fruchterman

Reingold layout algorithms. Each case was given a unique ID number and was displayed as a small circle, and the source and target of every edge (transmission route) were identified.

Results

A total of 1100 COVID-19 cases were diagnosed from 20 March to 7 June 2020, of which 956 (86.9%) were

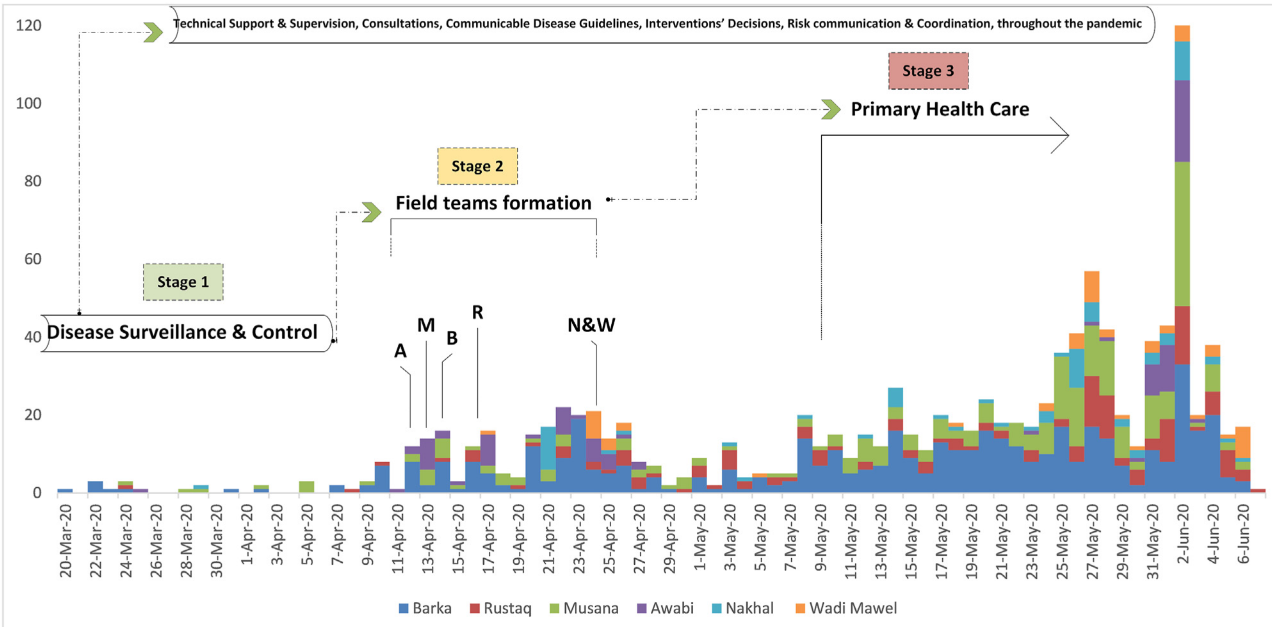


Figure 1: Epicurve of COVID19 cases in SBG distributed by districts and the three stages of response (A: Awabi, M: Musana, B: Barka, R: Rustaq, N&W: Nakhal & Wadi Mawel).

Table 1: Distribution of symptoms, durations, occupations, and risk factors for cases with unknown sources.

Symptoms	N	%	Median	IQR
Symptomatic patients	956	86.9	–	–
Asymptomatic patients	144	13.1	–	–
Duration of symptoms[a]	291/956	30.4	5	3–9
Duration from sample collection to result release[a]	1061/1100	96.5	2	1–3
Duration from symptom onset to sample collection[a]	939/1100	85.4	1	1–3
Duration from symptom onset to admission[a]	45/47	95.8	7	4.5–10
Duration from symptom onset to death[a]	11/11	100	16	11–37
Occupations	**N = 1024**	**%**		
HCW	41	3.7		
Government	70	6.4		
Police and Defense	118	10.7		
Company	330	30		
Not working	465	42.3		
Possible risk factors for unknown sources	**N = 388**	**%**		
Patient going to work	269	24.5		
Sick person at work	104	9.5		
Household member going to work	52	4.7		
Shopping	42	3.8		
Social gathering	37	3.4		
Sick person at home	32	2.9		
Souq Mawaleh/vegetable shops	26	2.4		
Visiting a clinic	16	1.5		
Health care work	14	1.3		
Airport exposure	10	0.9		
Souq Matrah	7	0.6		
Travel	3	0.3		
Psychiatric patient	1	0.1		

[a] Analysis was limited to patients with complete data; durations are shown in days.

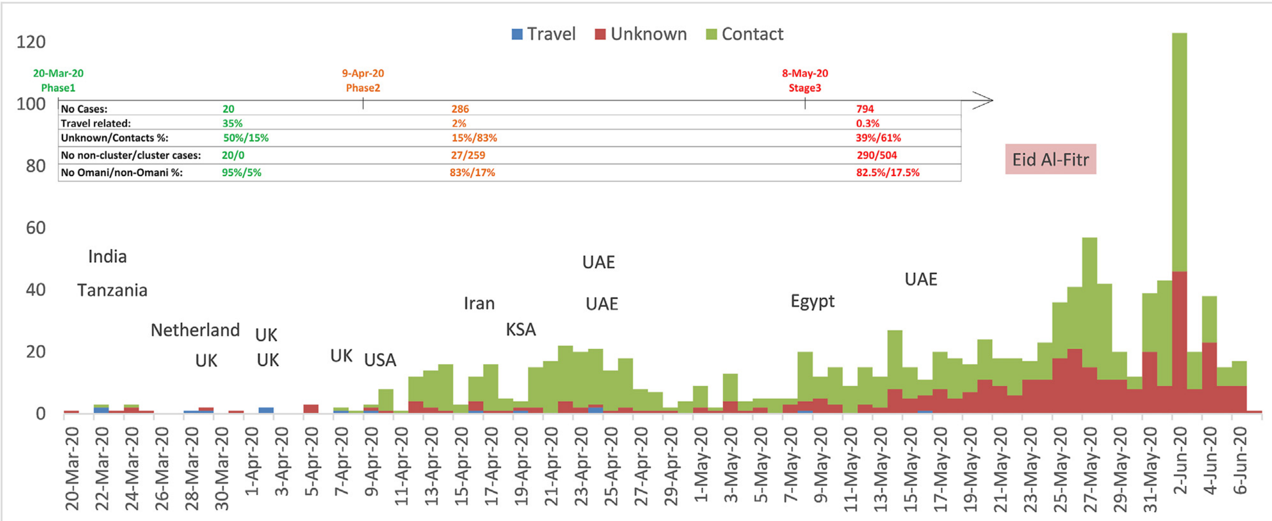


Figure 2: Epicurve of COVID19 cases in SBG distributed by the infection source and characteristics of clusters (travel related cases are colored in blue, with the corresponding countries of origin).

symptomatic. The median patient age was 31, and the IQR was 24–40. A total of 508 (46.2%) patients were under 30 years of age, 317 (28.8%) patients were 30–39 years of age, and 74 (25%) patients were 40 years of age or older. A total of 716 (65.1%) patients were males, and 912 (82.9%) were Omanis. Most cases 880 (80%) were in Barka (43.4%), followed by Musanaah (22.9%) and Rustaq (13.7%). A total of 89 clusters were identified, containing 763 (69.4%) patients.

The median duration of symptoms was 5 days (IQR, 3–9), the median time from symptom onset to sample collection was 1 day (IQR, 1–3), and the median time from sample collection to result release was 2 days (IQR, 1–3). Among 47 admitted patients, 11 died during the study period. The median time from symptom onset to admission and to death was 7 days (IQR, 4.5–10) and 16 days (IQR, 11–37), respectively. Most patients (42.3%) were not working. The most likely sources of infection for the index cases were the workplace (24.5%), homes with sick family members (9.5%), or homes with household members who went out to work (4.7%). Table 1 provides further details. Figures 1 and 2 show the epidemic curves displayed by sources of infection and by SBG district. The epidemic curves classified the pandemic into three phases, each associated with the stage of the response plan used in SBG.

Phase 1 started on 20 March, when the first case was identified but had an unknown source, and lasted until 8 April, by which time 20 cases had been diagnosed. Among these cases, 10 (50%) had unknown sources, 7 (35%) were travel-related, and 3 (15%) had identified contacts. Phase 2 started on 9 April, when clusters appeared in the Awabi and Barka districts. These clusters were reasonably well controlled, owing to sufficient information to identify contacts, trace, monitor, and take other preventive measures. A total of 286 cases were identified in phase 2: 238 (83%) with identified contacts, 43 (15%) from unknown sources, and only 5 (2%) related to travel. The third phase started on 8 May, and was characterized by cases spreading more widely and clusters forming in all SBG districts. During this phase, 794 cases were identified; the proportion associated with unknown sources increased to 39%, and the proportion with identified contacts decreased to 61%. The peak of reported cases on 24 May 2020 clearly corresponded to the Eid Al-Fitr on 24 May 2020. Travel-related cases were mainly from India, Tanzania, the Netherlands, the United Kingdom, the United States, KSA, the United Arab Emirates, and Egypt.

Figures 3 and 4 provide details on the chronological expansion of clusters throughout the six districts in SBG. A total of 736 patients were identified in 89 clusters. The numbers of cases in transmission generations 1–6 were 411, 154, 56, 30, 22, and 1, respectively.

The clusters and related characteristics are shown in Figures 5, 6, and 7. Age, cluster size, fever, body ache, fatigue, shortness of breath, and vomiting tended to be associated with higher likelihood of admission. However, only age and fever were significant variables in the multivariate analysis. Patients in the age categories of 30–39, 40–49, and $\geq$50 years had ORs of 2.86 (95% CI 1.07–7.65), 5.57 (95% CI 1.93–16.08), and 12.85 (95% CI 5.13–32.19), respectively. Patients with fever had an OR of 2.53 (95% CI 1.24–5.17) of admission, as compared with those with no fever. The findings also indicated that age, gender, district, and the presence of symptoms were significantly associated with a higher likelihood of forming clusters. Patients 30–39 years of age were 30% less likely than younger patients to form clusters OR = 0.70 (95% CI 0.51–0.96). However, female gender, absence of symptoms, and residence in the Awabi district were associated with

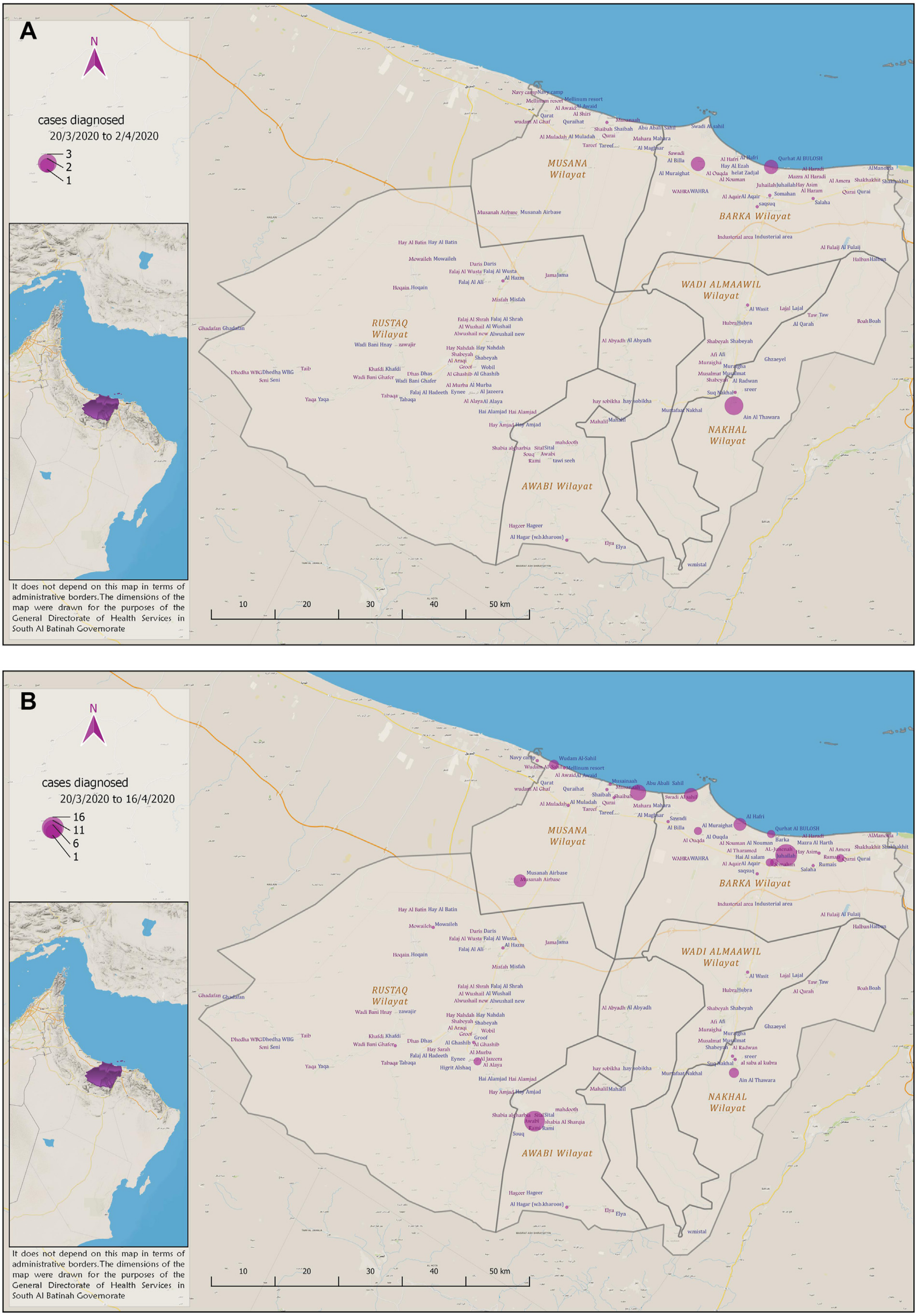
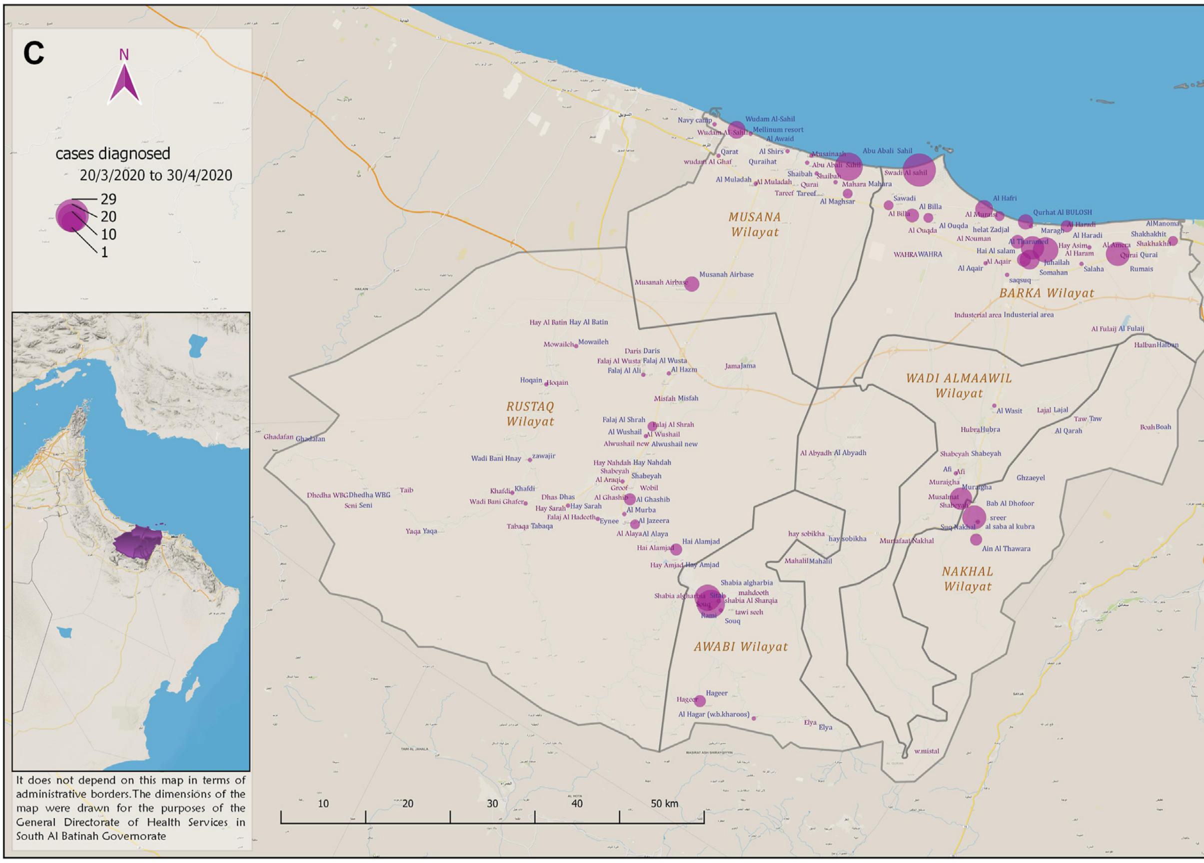
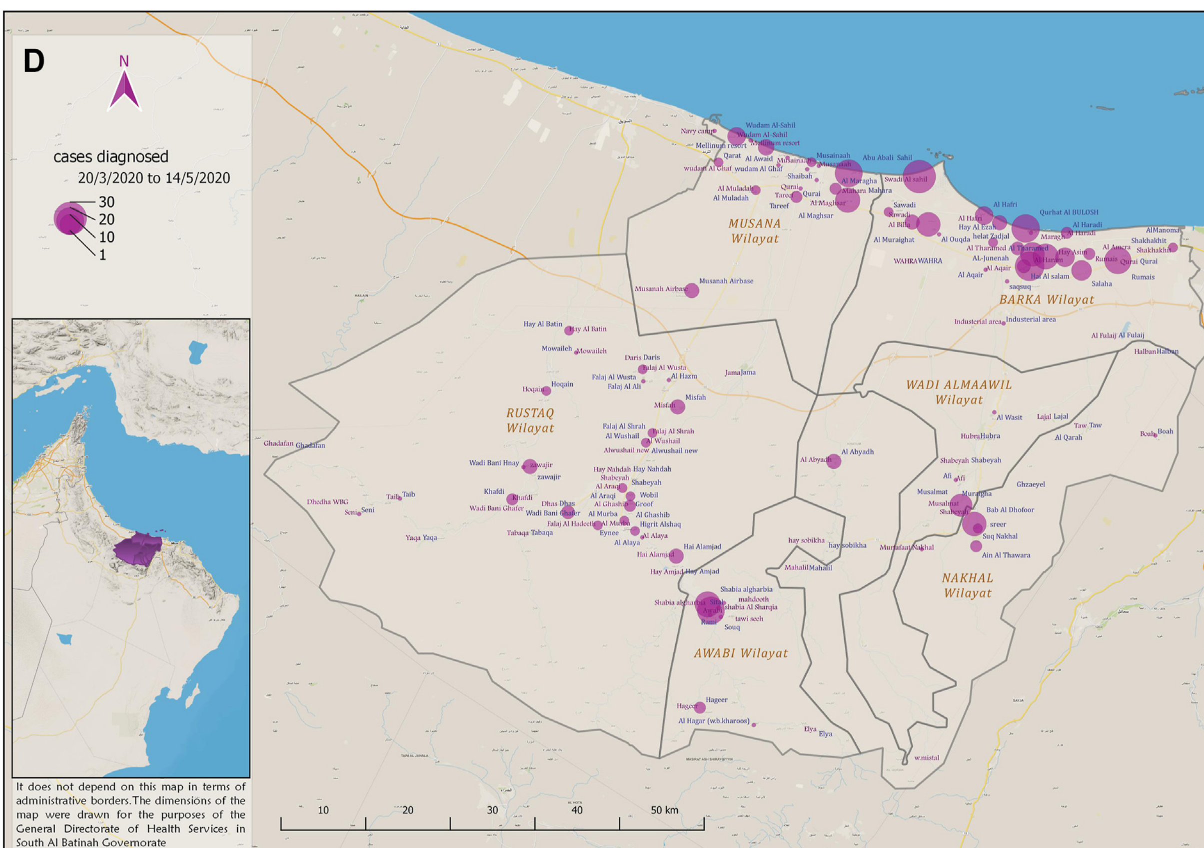


Figure 3: The chronological distribution of cases and clusters across the SBG, (A) 20/Mar-2/April, (B) 20/March-16/April, (C) 20/March-30/April, (D) 20/March-14/May, (E)20/March-28/May, (F) 20/March-7/June.





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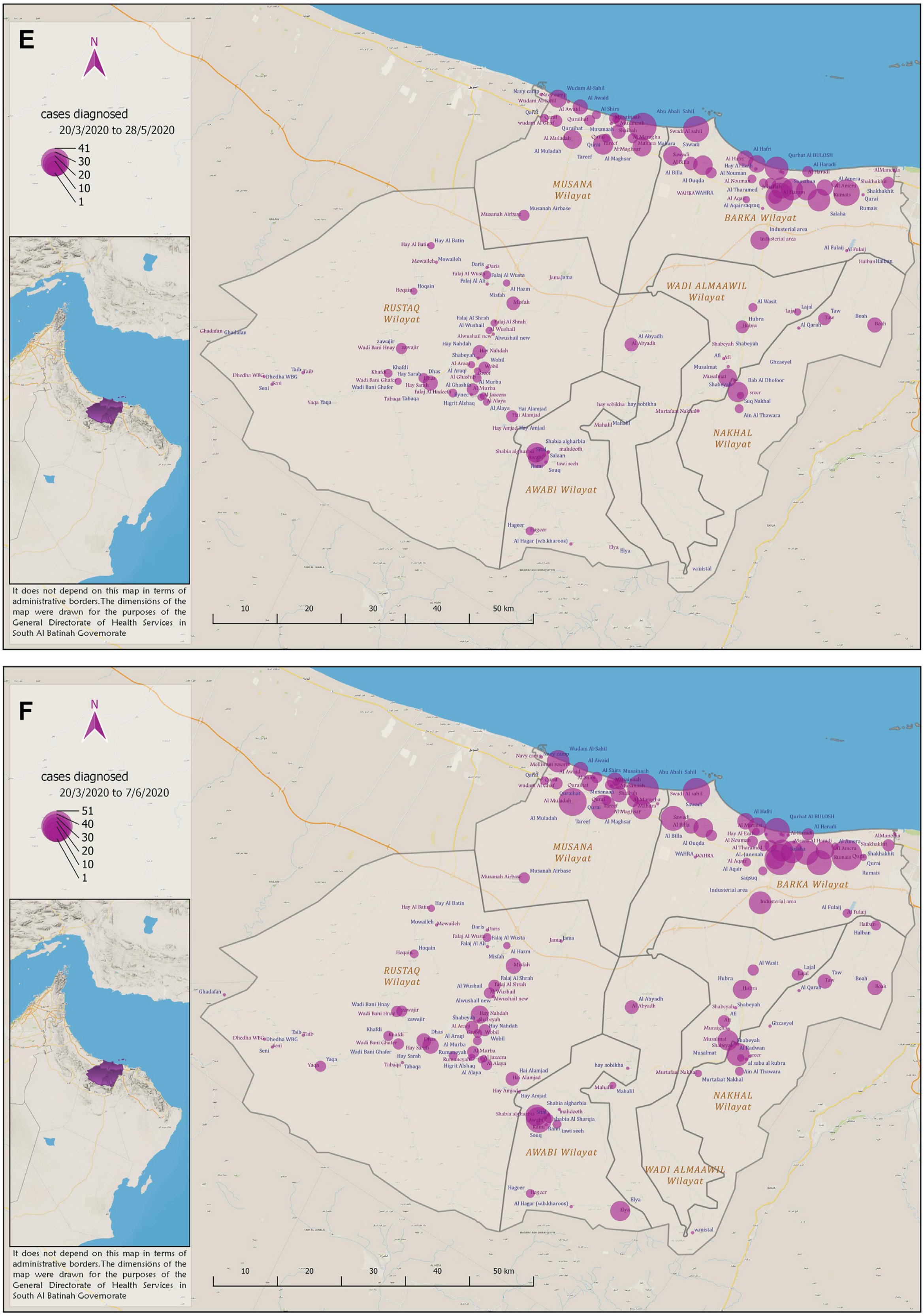

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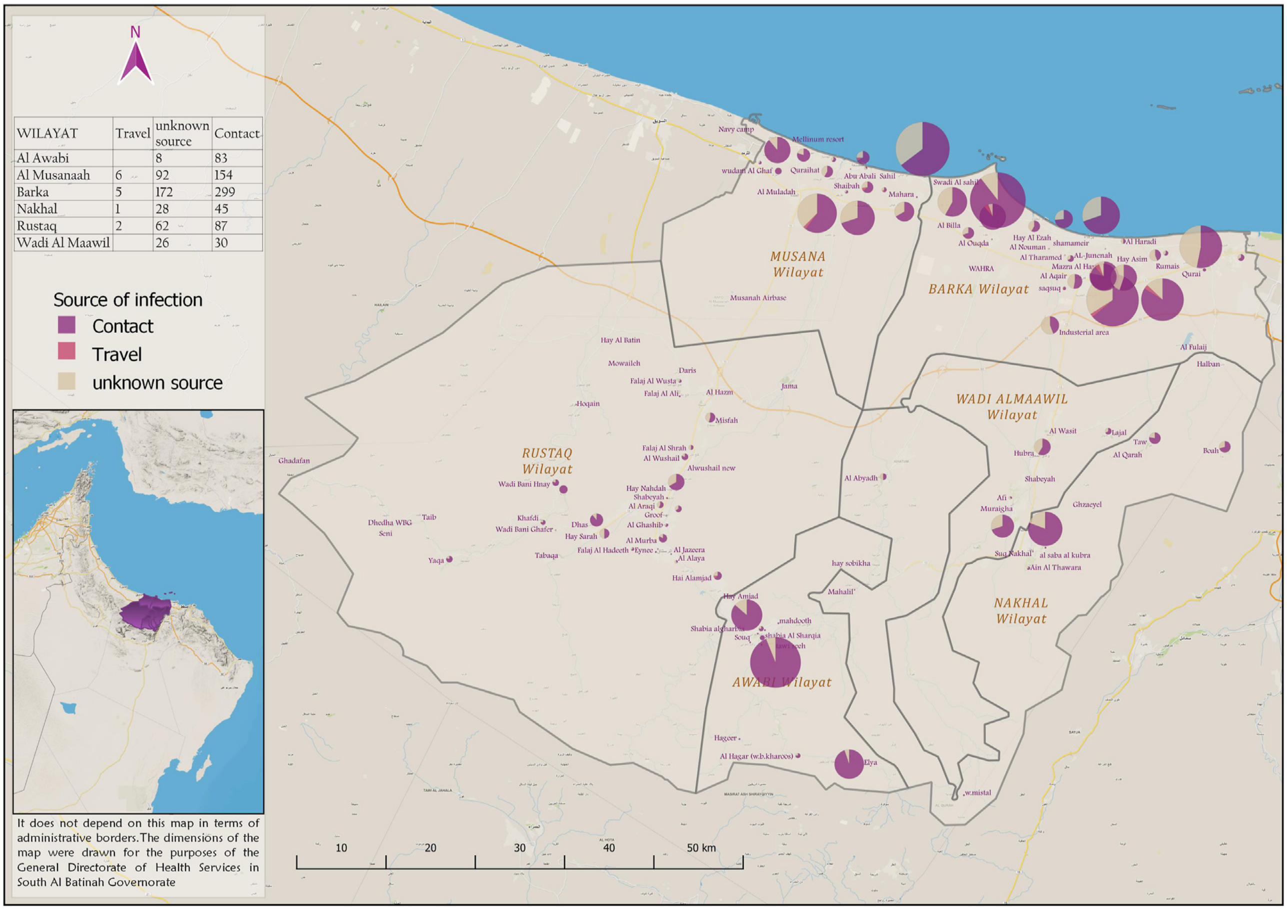


Figure 4: Mapping of all COVID-19 cases across SBG throughout the study period, demonstrated by the proportions of travel related cases, contacts and cases with unknown sources.

higher likelihoods of cluster formation: OR = 2.3 (95% CI 1.7−3.1), 6.39 (95% CI 2.33−17.2), and 3.54 (95% CI 2.06−6.07), respectively. Tables 2 and 3 show additional details of the analysis. Symptomatic patients were more likely than asymptomatic patients to be the index patient in the clusters: OR = 3.86 (95% CI 1.25−11.92). Patients who worked in the police and defense sectors had relatively higher odds of being an index patient: OR = 7.88 (95% CI 3.35−18.52), followed by patients working in companies and health care workers: OR = 7.26 (95% CI 3.52−15.00) and 5.72 (95% CI 1.81−11.92), respectively (see Table 4).

Discussion

This is one of the first studies in the country and the GCC focusing on the detailed progressive formation of the initial clusters of the COVID-19 pandemic. The study explored the first 1100 COVID-19 cases in SBG, including the clinical symptoms associated with an increased risk of cluster initiation (i.e., of an individual being the likely source or index patient in localized outbreaks), and of hospital admission. The epidemiological and geographic graphs reflect the dynamics of case transmission over the first 2.5 months of the outbreak in SBG, and the progression through three escalating stages.

Three phases

Most of the initial cases (apart from those related to travel) had no identified sources, thus indicating that infectious foci were already present within the country, and might or might not have been detected or properly controlled. Although the first imported case in Oman was detected in Muscat on 24 February, other clusters and major outbreaks were subsequently detected in congested places in Muscat, such as Souq Matrah, an old market and famous tourism site.[13,15,16] In addition, the field investigation revealed that many cases with unknown sources were likely to be associated with these outbreak sites in Muscat, which have a high influx and outflux of people, particularly workers, tourists, and relatives visiting friends and family members. The first case in SBG was in a health care worker in Muscat, who had a history of visiting Souq Matrah at the time of the outbreak. Her husband was also a member of the airport staff. However, other case influxes across ground borders were observed, in which the affected people were neither screened nor quarantined. One of our own cases was in a non-Omani truck driver, who was granted temporary access to the country at a ground border and tested positive in Barka district. When the case numbers were still gradually increasing, the limited number of RRT personnel working

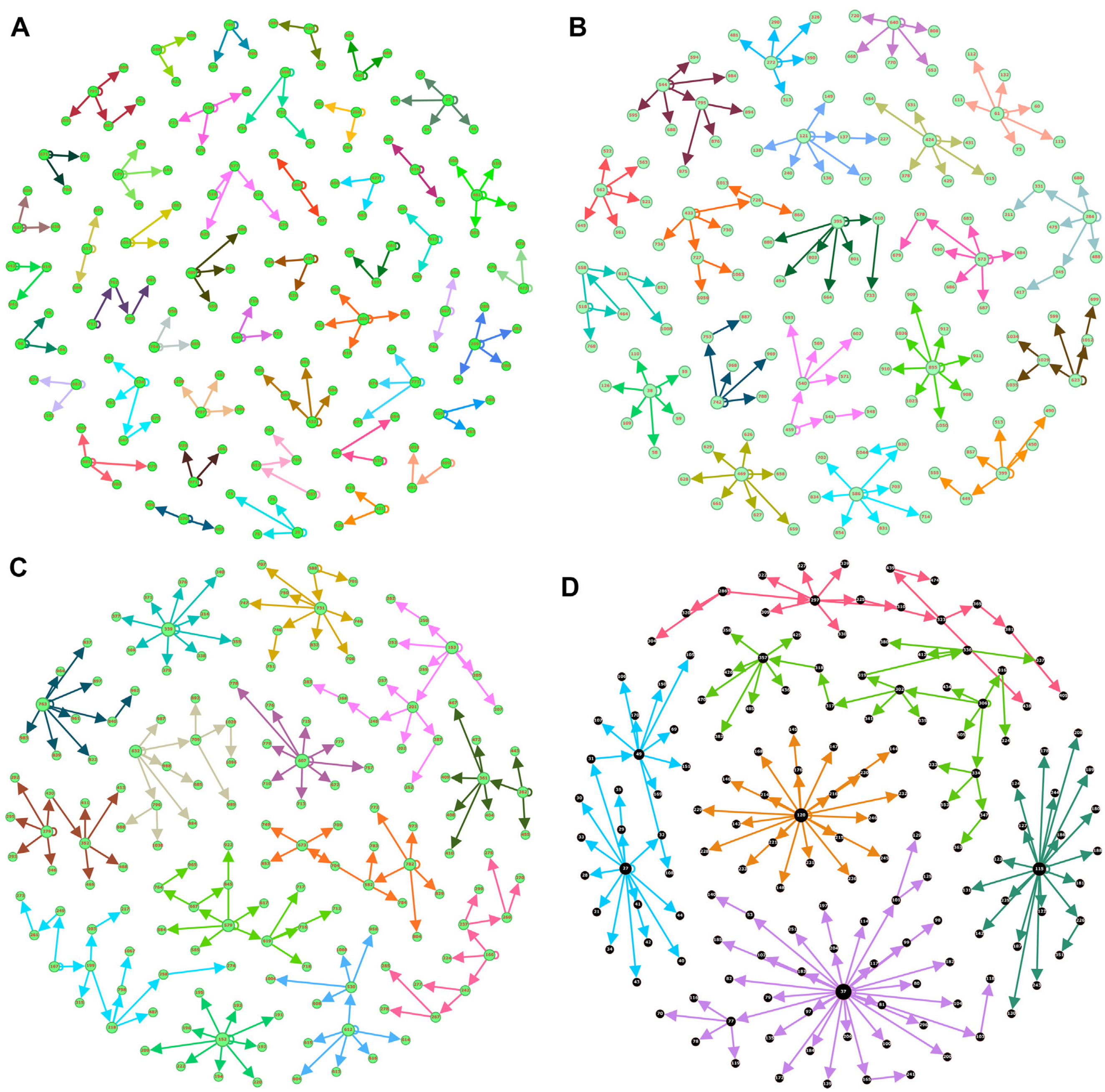


Figure 5: Transmission networks of the 89 COVID-19 clusters identified in SBG between March 20, 2020, and June 7, 2020. They are categorized in five groups by cluster size. Clusters are given different colors where arrows indicate the direction of transmission, and the index case can easily be identified. (A) 3-5 cases/cluster, (B) 6-9 cases/cluster (C) 10-15 cases/cluster (D) 16-41 cases/cluster, (E) $\geq$ 42 cases/cluster.

in disease surveillance and control were able to contain the cases, thus resulting in a remarkably small number of secondary cases. The definition of a suspected case was broadened and was made highly sensitive on 7 April. In the 2 days that followed, the increase in infections and cluster formation became much more apparent, thus marking the start of what we refer to as the second, or intermediate, stage.[11]

The initial extended clusters in SBG started in Barka and Awabi. Both clusters probably had sources of different outbreak foci in Muscat. The RRT began to become overwhelmed by daily investigation and case monitoring, thus prompting the gradual implementation of ground teams in the six districts. These teams continued the same daily operations, mainly through field investigations of individual cases, and with direct communication with the RRT in the DSC. Until the August 2020 pandemic, a designated institutional quarantine center existed, where the RRT and the ground teams had the authority to recommend institutional quarantine if home quarantine did not meet the minimum criteria. The ground teams were usually able to respond quickly to the increasing number of clusters, and to

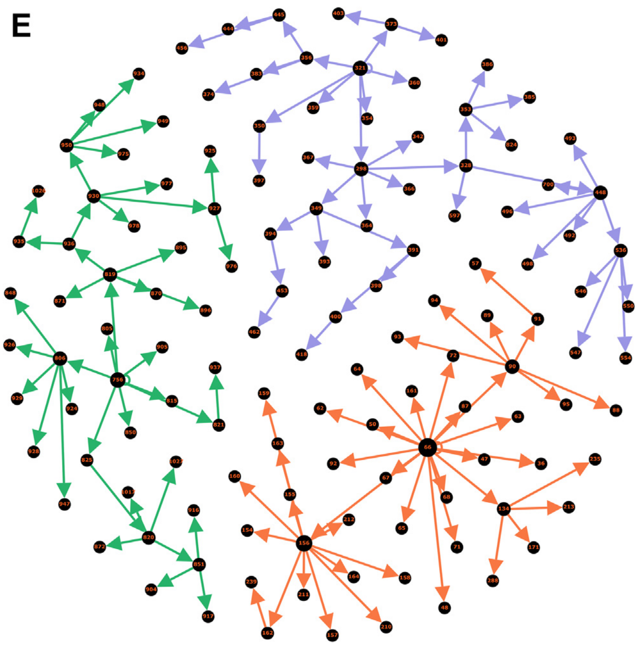


Figure 5: (*continued*).

adequately control the largest clusters (more than 40 secondary cases). During the intermediate phase, the SBG's secondary hospital was required to manage one of the earliest outbreaks in the entire sultanate, but the outbreak was successfully controlled. Remarkably, the epidemiology of this outbreak was associated with a possible SARS-CoV-2 transmission route other than respiratory droplets.[17] The third phase, in which clusters became more pervasive (50% more than those in the previous phase), was also characterized by a prominent increase in cases with unknown sources. This finding clearly indicated the beginning of community transmission throughout the SBG. Subsequently, the ground teams became overwhelmed and were unable to continue their efforts. The preventive measures taken at the national level were clearly unable to curb the spread of the SARS-CoV-2 virus.[3] Ultimately, the RRT work needed to be undertaken by the 21 primary health institutions in SBG, and the ground team members returned to their primary health institutions to provide support and help train additional staff. At that stage, the pandemic had already spread and coincided with the Muslim Eid Al-Fitr, during which a surge in diagnosed cases was observed. This situation overstressed the health system, exhausted the staff, and delayed the testing processes.[13] On 16 June 2020, the Ministry of Health upgraded the case definition and limited testing to severely symptomatic patients.[13] The tremendous work undertaken by the health system in the first two phases was reflected in a substantial delay in community transmission, thus giving the primary and secondary health institutions time to prepare technical and logistical operations. As the health system effectively accomplished surveillance and cluster control, as evidenced by the dramatic case decline on 29 April, the flow of cases from outside the SBG, according to the epidemiologic data, did not stop. The success of the public health response by the SBG indicated that the country would have been able to further mitigate the effects of the pandemic if the movement restrictions on people coming into the country from abroad, and moving between provinces, had been more effective. A modeling study has indicated that case-based interventions (e.g., contact tracing and quarantine) were not sufficient to control the epidemic in Taiwan.[18] In 2020, only several countries, such as Taiwan and Mongolia, were capable of substantially delaying the spread of the pandemic, or applied protective measures beyond social distancing and mask-wearing, particularly at borders, ports, and other vulnerable locations.[19,20] Other countries, such as Denmark and New Zealand, even implemented lockdowns as early as March 2020.[20,21] If such measures had been applied in Oman, they would have enabled far better control of infections and cluster formation, and ground teams could have practiced case-based interventions more thoroughly. However, countries have different geographies, demographics, politics, economies, and cultures, all of which make objective comparison extremely difficult. In addition, awareness, education, and compliance levels vary among and within populations. Our previous study in SBG, in patients diagnosed in the same period, indicated suboptimal compliance with self-isolation measures.[22]

Clinical manifestations

The prevalence of asymptomatic COVID-19 cases in this study was 13.1%, in agreement with the 4%−41% range reported in a meta-analysis.[23] In addition, in agreement with the current study, the resolution of symptoms has been reported to take 1 week, although some patients require several more weeks to return to normal health.[24] The time required to obtain test results exceeded 48 h, thereby reflecting the overwhelmed healthcare capacity, as described in detail in our previous article.[13] This finding is particularly notable, because minimizing testing delays has been reported to prevent up to 80% of transmissions.[25] Patients in this study had fever, cough, and dyspnea as the most common symptoms on presentation; however, the time from symptom onset to admission was 7 days, which was slightly longer than that in other studies.[26−28]

Admission vs. non-admission

Our findings, in agreement with the literature, indicated a direct relationship between admission and advanced age.[29,30] Indeed, our other laboratory and hospital-based studies in SBG have found that older patients are more likely than younger patients to acquire infections, to be admitted to the hospital, and to have poor prognoses.[13,26] Although the reporting of symptoms was subjective, particularly for fever, our findings, like those in other studies, showed that febrile patients were more likely to be admitted than those without fever.[31,32]

Cluster vs. non cluster

Both female and asymptomatic patients showed a significantly elevated tendency to form clusters. This finding was unsurprising, given the predominantly Arabic culture

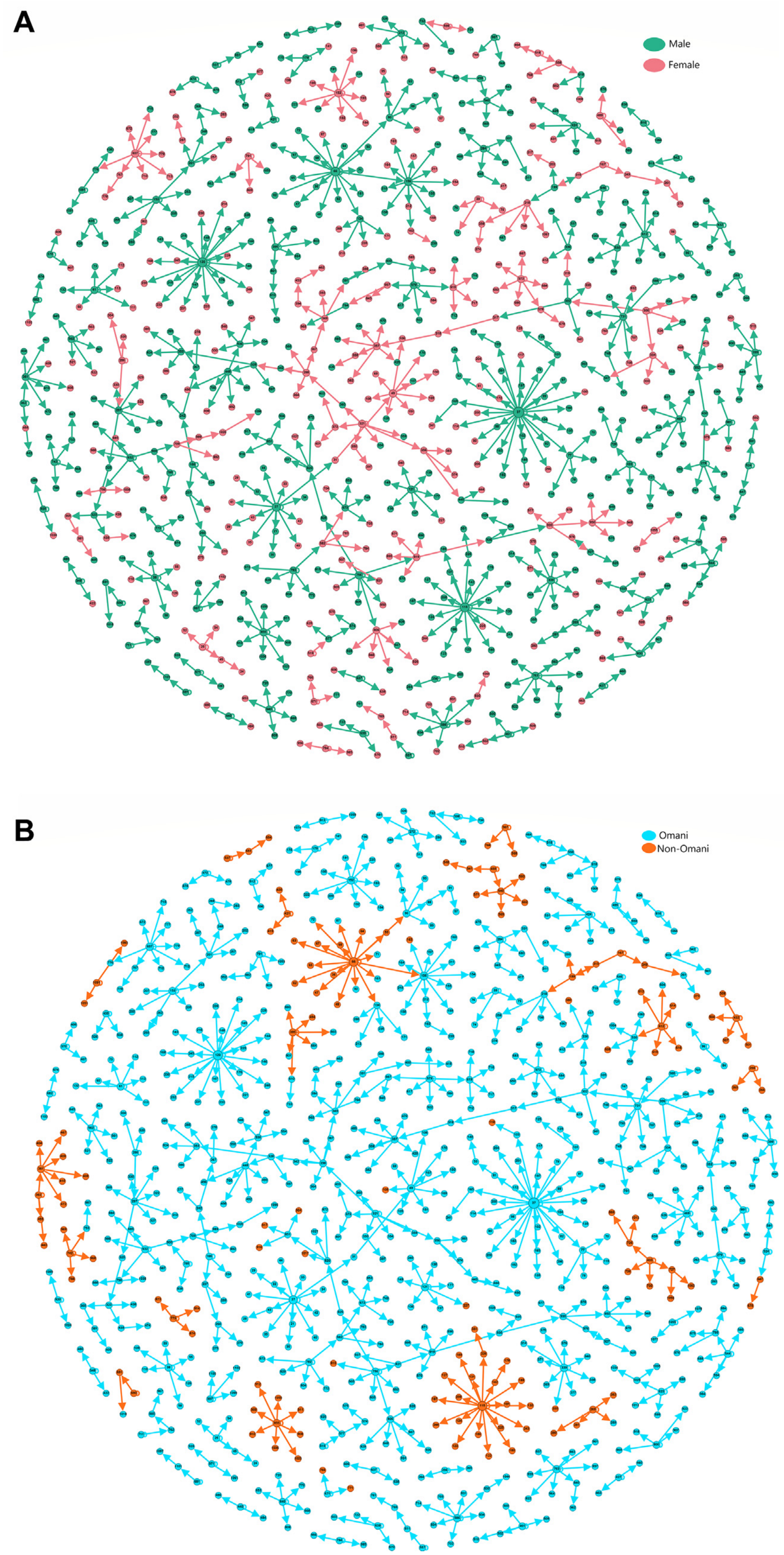
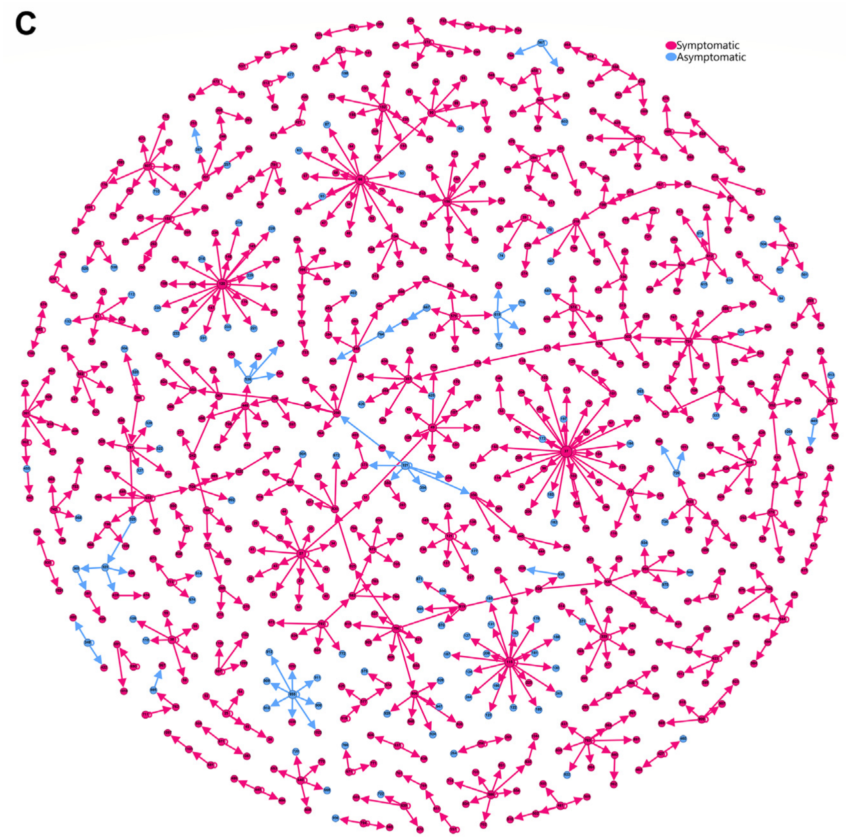
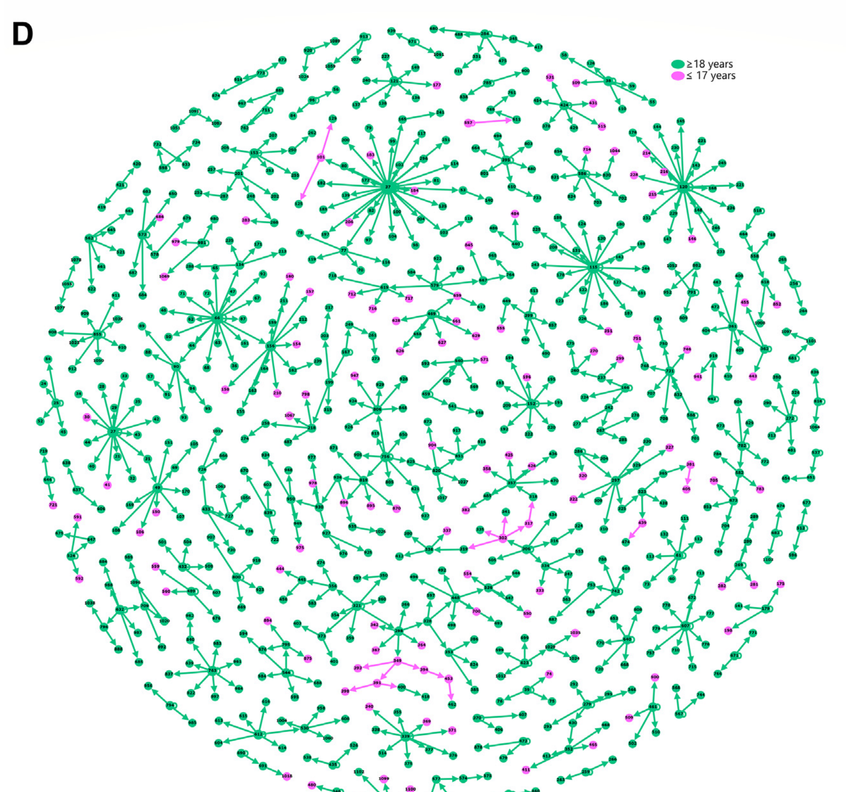


Figure 6: Demographical and clinical patterns of transmission networks of the 89 COVID-19 clusters. (A) Gender (B) Nationality (C) Symptoms (D) Age.





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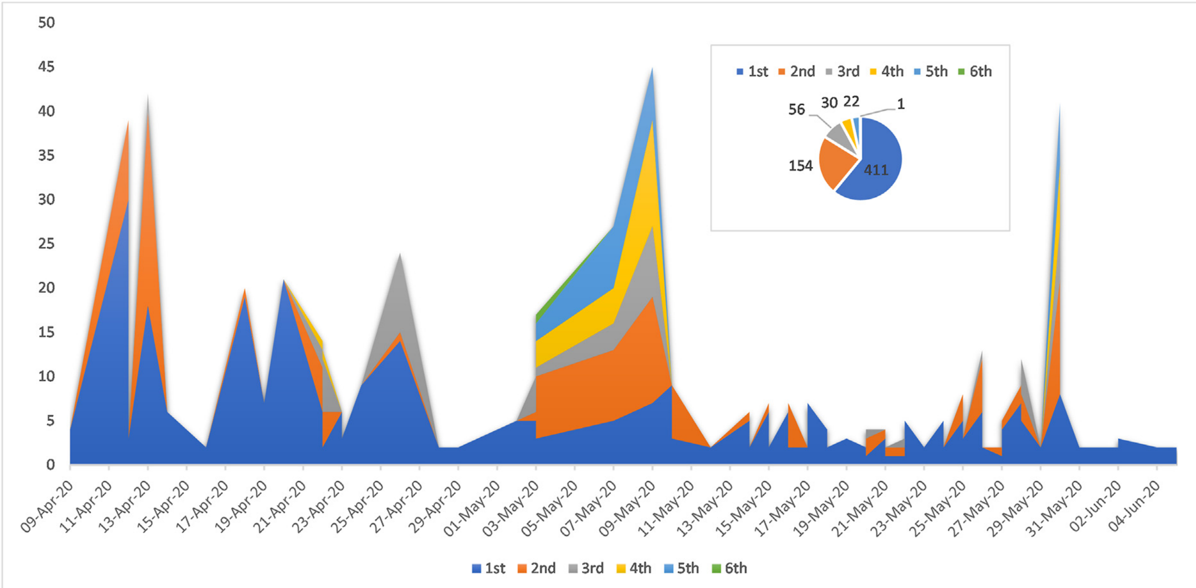

Figure 7: Demonstration of the number of infection generations among detected clusters throughout the study period.

Table 2: Study characteristics and comparison between admitted and non-admitted patients with COVID-19.

	Total	Unadjusted OR				Adjusted OR			
	N (%)	OR	95% CI		P-value	OR	95% CI		P-value
Age									
Median, IQR	31 (24–40)								
≤30 years	508 (46.2)	1	–	–	–	1	–	–	–
30–39 years	317 (28.8)	2.57	0.99	6.71	0.53	**2.86**	**1.07**	**7.65**	**0.036**[a]
40–49 years	136 (12.4)	**4.47**	**1.59**	**12.56**	**0.004**[a]	**5.57**	**1.93**	**16.08**	**0.002**[a]
≥50 years	138 (12.6)	**12.74**	**5.29**	**30.67**	**<0.001**[a]	**12.85**	**5.13**	**32.19**	**<0.001**[a]
Gender									
Male	716 (65.1)	1	–	–	–				
Female	384 (34.9)	1.28	0.70	2.32	0.418				
Nationality									
Omani	912 (82.9)	1	–	–	–				
Non-Omani	188 (17.1)	0.423	0.29	1.67	0.423				
Wilayat									
Al Awabi	91 (8.3)	0.95	0.26	3.53	0.943				
Al Musanaah	252 (22.9)	0.73	0.23	2.34	0.601				
Barka	477 (43.4)	0.47	0.15	1.45	0.189				
Nakhal	71 (6.5)	0.19	0.02	3.53	0.146				
Rustaq	151 (13.7)	0.66	0.18	2.33	0.66				
Wadi Al Maawil	58 (5.3)	1	–	–	–				
Cluster size									
≤2	337 (30.6)	1	–			1	–	–	–
3–7	230 (20.9)	**2.36**	**1.00**	**5.55**	**0.049**[a]	1.82	0.74	4.49	0.195
8–18	266 (24.2)	1.87	0.79	4.45	0.155	1.97	0.79	4.88	0.145
≥19	267 (24.3)	1.57	0.64	3.84	0.327	1.48	0.56	3.89	0.428
Fever									
Yes	626 (56.9)	**2.28**	**1.17**	**4.44**	**0.015**[a]	**2.53**	**1.24**	**5.17**	**0.011**[a]
No	474 (43.1)	1	–	–	–	1	–	–	–
Cough									
Yes	348 (31.6)	1.36	0.74	2.48	0.317				
No	752 (68.4)	1	–	–	–				
Sore throat									
Yes	264 (24.0)	0.97	0.48	1.93	0.922				
No	836 (76.0)	1	–	–	–				
Headache									
Yes	201 (18.3)	0.77	0.34	1.76	0.541				
No	899 (81.7)	1	–	–	–				

Table 2 (*continued*)

	Total	Unadjusted OR				Adjusted OR			
	N (%)	OR	95% CI		P-value	OR	95% CI		P-value
Body ache/fatigue									
Yes	203 (18.5)	**0.09**	**0.01**	**0.67**	**0.018**[a]	**0.06**	**0.01**	**0.45**	**0.006**[a]
No	910 (81.5)	1	–	–	–	1	–	–	–
Runny nose									
Yes	174 (15.8)	0.93	0.41	2.1	0.859				
No	926 (84.2)	1	–	–	–				
Anosmia									
Yes	94 (8.5)	0.46	0.11	1.94	0.294				
No	1006 (91.5)	1	–	–	–				
Diarrhea									
Yes	59 (5.4)	2.20	0.84	5.79	0.109	2.48	0.84	7.32	0.100
No	1041 (94.6)	1	–	–	–	1	–	–	–
Ageusia									
Yes	50 (4.5)	0.45	0.06	3.30	0.428				
No	1050 (95.5)	1	–	–	–				
SOB									
Yes	20 (1.8)	**6.03**	**1.93**	**18.8**	**0.002**[a]	2.23	0.59	9.19	0.231
No	1080 (98.2)	**1**	**-**	**-**	**-**	1	–	–	–
Vomiting									
Yes	17 (1.5)	**5.06**	**1.40**	**18.25**	**0.013**[a]	3.28	0.63	17.05	0.158
No	1083 (98.5)	1	–	–	–	1	–	–	–
Sneezing									
Yes	13 (1.2)	1.89	0.24	14.82	0.546				
No	1087 (98.8)	1	–	–	–				
Chest pain									
Yes	5 (0.5)	5.70	0.62	52.03	0.123	3.13	0.27	35.68	0.358
No	1095 (99.5)	1	–	–	–	1	–	–	–
Abdominal pain									
Yes	4 (0.4)	0.00	0.00	0.00	0.999				
No	1096 (99.6)	1	–	–	–				

[a] Significant results ($P \leq 0.05$).

Table 3: Study characteristics and comparison between cluster and non-cluster groups.

	Total	Unadjusted OR				Adjusted OR			
	N (%)	OR	95% CI		P-value	OR	95% CI		P-value
Age									
≤30 years	508 (46.2)	1	–	–	–	1	–	–	–
30–39 years	317 (28.8)	**0.70**	**0.52**	**0.95**	**0.022**[a]	**0.70**	**0.51**	**0.96**	**0.027**[a]
40–49 years	136 (12.4)	0.68	0.46	1.01	0.058	0.68	0.45	1.03	0.070
≥50 years	138 (12.6)	1.50	0.95	2.36	0.079	1.34	0.84	2.14	0.224
Gender									
Male	716 (65.1)	1	–	–	–	1	–	–	–
Female	384 (34.9)	**2.17**	**1.63**	**2.91**	**<0.001**[a]	**2.3**	**1.7**	**3.1**	**<0.001**[a]
Nationality									
Omani	912 (82.9)	1	–	–	–				
Non-Omani	188 (17.1)	0.99	0.70	1.39	0.944				
Wilayat									
Al Awabi	91 (8.3)	**8.04**	**3.00**	**21.55**	**<0.001**[a]	**6.39**	**2.33**	**17.52**	**<0.001**[a]
Al Musanaah	252 (22.9)	1.27	0.70	2.30	0.440	1.24	0.67	2.30	0.136
Barka	477 (43.4)	1.24	0.70	2.19	0.464	1.17	0.65	2.30	0.500
Nakhal	71 (6.5)	0.92	0.45	1.90	0.831	0.91	0.43	1.90	0.459
Rustaq	151 (13.7)	0.99	0.53	1.86	0.977	0.92	0.48	1.77	0.808
Wadi Al Maawil	58 (5.3)	1	–	–	–	1	–	–	–
Symptoms									
Yes	956 (86.9)	1	–	–	–	1	–	–	–
No	144 (13.1)	**3.76**	**2.23**	**6.35**	**<0.001**[a]	**3.54**	**2.06**	**6.07**	**<0.001**[a]

[a] Significant results ($P \leq 0.05$).

Table 4: Study characteristics and comparison between index and contacts among clusters with at least three members.

	Total	Unadjusted OR				Adjusted OR			
	N (%)	OR	95% CI		P-value	OR	95% CI		P-value
Age									
≤ 30 years	364 (47.7)	1	–	–	–				
30–39 years	203 (26.6)	1.57	0.93	2.65	0.094				
40–49 years	86 (11.3)	1.52	0.76	3.08	0.240				
≥50 years	110 (14.4)	1.26	0.64	2.48	0.503				
Gender									
Male	458 (60.0)	**3.16**	**1.82**	**5.48**	**<0.001**[a]	1.36	0.67	2.77	0.393
Female	305 (40.0)	1	–	–	–	1	–	–	–
Nationality									
Omani	633 (83.0)	1	–	–	–				
Non-Omani	130 (17.0)	0.73	0.42	1.25	0.251				
Wilayat									
Al Awabi	85 (11.1)	0.30	0.06	1.42	0.130				
Al Musanaah	174 (22.8)	1.52	0.50	4.63	0.937				
Barka	327 (42.9)	1.15	0.39	3.42	0.802				
Nakhal	44 (5.8)	1.06	0.26	0.26	1.06				
Rustaq	96 (12.6)	0.96	0.28	3.27	0.947				
Wadi Al Maawel	37 (4.8)	1	–	–	–				
Symptoms									
Yes	636 (83.4)	**4.74**	**1.71**	**13.18**	**<0.003**[a]	**3.86**	**1.25**	**11.92**	**0.019**[a]
No	127 (16.6)	1	–	–	–	**1**	**-**	**-**	**-**
Occupation									
HCW	29 (4.2)	**4.93**	**1.65**	**14.71**	**0.004**[a]	**5.72**	**1.81**	**18.11**	**0.003**[a]
Government	41 (5.9)	**3.29**	**1.13**	**9.57**	**0.029**[a]	2.64	0.84	8.32	0.097
Police and Defense	64 (9.2)	**9.26**	**4.37**	**19.62**	**<0.001**[a]	**7.88**	**3.35**	**18.52**	**<0.001**[a]
Company	190 (27.4)	**6.72**	**3.61**	**12.48**	**<0.001**[a]	**7.26**	**3.52**	**15.00**	**<0.001**[a]
Not working	370 (53.3)	1	–	–	–	**1**	**-**	**-**	**-**
Fever									
Yes	405 (53.1)	**1.67**	**1.05**	**2.64**	**0.029**[a]	1.07	0.62	1.83	0.819
No	358 (46.9)	1	–	–	–	1	–	–	–
Cough									
Yes	241 (31.6)	**1.73**	**1.10**	**2.71**	**0.017**[a]	1.65	0.97	2.80	0.063
No	522 (68.4)	1	–	–	–	1	–	–	–
Sore throat									
Yes	176 (23.1)	1.03	0.61	1.74	0.900				
No	587 (76.9)	1	–	–	–				
Headache									
Yes	137 (18.0)	1.49	0.88	2.52	0.142	1.50	0.80	2.81	0.206
No	626 (82.0)	1	–	–	–	1	–	–	–
Body ache/fatigue									
Yes	123 (16.1)	1.49	0.86	2.57	0.156	1.36	0.71	2.61	0.352
No	640 (83.9)	1	–	–	–	1	–	–	–
Runny nose									
Yes	121 (15.9)	0.81	0.43	1.53	0.515				
No	642 (84.1)	1	–	–	–				
Anosmia									
Yes	61 (8.0)	0.98	0.43	2.23	0.962				
No	702 (92.0)	1	–	–	–				
Diarrhea									
Yes	37 (4.8)	1.83	0.78	4.31	0.165	1.44	0.53	3.94	0.473
No	726 (95.2)	1	–	–	–	1	–	–	–
Ageusia									
Yes	28 (3.7)	0.91	0.27	3.06	0.873				
No	735 (96.3)	1	–	–	–				
SOB									
Yes	16 (2.1)	1.08	0.24	4.85	0.916				
No	747 (97.9)	1	–	–	–				
Vomiting									
Yes	14 (1.8)	0	0	0	0.999				
No	749 (98.2)	1	–	–	–				

Table 4 (*continued*)

	Total	Unadjusted OR				Adjusted OR			
	N (%)	OR	95% CI		P-value	OR	95% CI		P-value
Sneezing									
Yes	9 (1.2)	3.88	0.5	15.81	0.058	2.59	0.50	13.49	0.258
No	754 (98.8)	1	–	–	–	1	–	–	–
Chest pain									
Yes	3 (0.4)	0	0	0	0.999				
No	760 (99.6)	1	–	–	–				
Abdominal pain									
Yes	3 (0.4)	3.82	0.34	42.54	0.276				
No	760 (99.6)	1	–	–	–				

[a] Significant results ($P \leq 0.05$).

in Oman, in which social gatherings are frequent within families and neighborhoods, particularly among women. Similarly, a study from Malaysia has found that Female household contacts were more were remarkably associated with increased risk for COVID-19.[33] The Awabi district showed an elevated tendency to form clusters, possibly because of several factors, including a small population size, limited geographical area, and low population dispersal. The RRT and ground team were able to respond easily and promptly in the area, and therefore were able to identify most clusters. Although most (60%) infections were found to be first generation secondary infections, a substantial number involved multiple infection generations; we suspect that these were from the same cluster families or from people working in the same environment. The extended chain of infection hindered determination of the typical time taken for infection to spread within households or dwellings, because cases were continually diagnosed, and the residents all lived together. A previous study from Taiwan proposed a 2-month quarantine duration.[34]

Index vs. contact

Although symptomatic patients appeared to be more likely to be the index patients in clusters, this interpretation might be skewed, because all clusters were traced back to the person who first developed symptoms. However, from the first few weeks of the pandemic, clusters were clearly initiated mainly by Police and Defense staff, company workers, and health care workers. Asymptomatic transmission of COVID-19 has already been reported in many previous studies. A systematic review has reported an overall transmission rate of 24.51% in all studied population groups.[35] Moreover, a study from China has estimated that approximately 23% of transmissions in Shenzen could have originated from pre-symptomatic infections.[36]

Limitations

This study had several limitations. The testing data were incomplete, including the dates of symptom onset, and details of the symptoms. In addition, the RRT needed to be recruited quickly and consequently had differences in background, skill level, and experience. The assessment of symptoms and complications was also subjective. However, we worked to verify the data retrospectively by checking the electronic data systems, or by directly calling the ground response teams. The index case was assumed to be the one that developed symptoms first, but because transmission also occurs asymptomatically, the case could have been in an asymptomatic individual, thus further decreasing the importance placed on asymptomatic transmission dynamics. Limited testing capacity was another challenge, and testing was offered to only symptomatic patients. Nonetheless, the RRT was able to screen asymptomatic patients during some of the early outbreaks.

Recommendations

The transmission dynamics in SBG mirror those in the other governorates, with limited differences. The regional surveillance and response were effective, particularly during the first two phases. The country should consider more stringent population-wide measures and tighter movement restrictions for future events, in addition to prompt responses and case-based measures to be taken when initial clusters are detected. Establishing public preventive health units with sufficient qualified staff in the districts would be highly valuable. Alternatively, the roles of primary health care institutions could be expanded to include the continual prevention of communicable diseases in their catchment areas. To prepare for new or emerging viruses, examining the transmission routes into the country, the duration required for safe and effective quarantine, and transmission through asymptomatic cases is also extremely important. More attention must be paid to the risks unique to specific occupational categories. This study highlighted that transmission and subsequent cluster formation were associated with cases in people who worked in the military, police, healthcare, and large companies with multiple subsidiary centers across the country. Interventions should always be prioritized for the sectors of the population most vulnerable to infection and mortality. Community health education should be seriously considered, because the efficacy of many preventive measures ultimately resides in communities' awareness and willingness to comply and cooperate.

Conclusion

Case based interventions in SBG effectively delayed community transmission within the governorate. However, the interventions should have been supported by strict and swift population-wide measures and movement restrictions at the national level. The enhancement of the ground response team and primary health institutions will be important for the control of future pandemics, and vulnerable populations should always remain a priority in prevention.

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Conflict of interest

The authors have no conflict of interest to declare.

Ethical approval

Because surveillance data were used, ethical approval and consent were not required.

Authors' contributions

Conceptualization, ZKA; Data Collection, ZKA, NAS, AAH, DAS, SMA, FAG, KAD, MAK; Methodology, ZKA; Formal Analysis, ZKA; Investigation, ZKA, SMA, NAS, NAH, AAH, YAG, NAA, ZAK, NAJ, AAM, MAS, HAN, HAS, ASA, IAN, SAK, MAN, AAS, AAJ, YAJ, SAH, NAG, SAM, AAK, MAK, MAB, RAM; Validation, ZKA; Writing Original Draft Preparation, ZKA; Writing, Review & Editing, ZKA, SMA, RAM, NAS; Supervision, ZKA; Project Administration, ZKA. All authors have critically reviewed and approved the final draft and are responsible for the content and similarity index of the manuscript.

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