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A second local dengue fever outbreak: A field experience from Muscat Governorate in Oman, 2022

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ABSTRACT

Background: Dengue fever is an infectious disease of global health concern. This study aimed to describe the epidemiology and field experience of a locally transmitted outbreak of dengue fever in Muscat Governorate, Oman from mid-March to mid-April 2022, and the multi-sectoral approach to control the outbreak.
Methods: Data were collected from an electronic e-notification system, active surveillance and contact investigations.
Results: Of 250 suspected and probable cases, 169 were confirmed as dengue fever with DENV-2 serotype. Of these, 108 (63.9%) were male and 94 (55.6%) were Omani. The mean age was 39 years (standard deviation 13 years). Fever was the most common symptom and occurred in 100% of cases. Haemorrhagic manifestations occurred in 10% (n=17) of cases. Hospitalization was required for 93 cases (55.1%). The field investigation included 3444 houses and other suspected sites. Breeding sites for *Aedes aegypti* were identified in 565 (18.5%) sites visited. Interventions to control the outbreak included environmental and entomological assessment of the affected houses and surrounding areas (400 m radius of each house).
Conclusion: Outbreaks are expected to continue, with the possibility of severe cases due to antibody-dependent enhancement. More data are required to understand the genetics, geographical spread and behaviour of *A. aegypti* in Oman.

Background

Dengue fever is a mosquito-borne viral disease caused by a positive single-stranded RNA virus that belongs to the family Flaviviridae. There are four distinct, closely related, dengue virus serotypes (DENV1–4) [1]. Recovery from infection by one serotype provides lifelong immunity against that serotype; however, cross-immunity to the other serotypes after recovery is only partial, and subsequent infections by other serotypes increase the risk of developing severe dengue fever due to antibody-dependent enhancement (ADE) [2].

According to the International Health Regulations (2005), dengue fever has the potential to cause serious public health impact and to spread internationally [3]. Dengue fever is currently the most common mosquito-borne disease in the world. The virus is estimated to cause 390 million (range 284–528 million) infections per year [4], and almost 3.9 billion people are at risk of infection [5]. Before 1970, only nine countries reported severe dengue epidemics, but the disease is now endemic in more than 100 countries [6]. The Americas, South-East Asia and the Western Pacific Region are the most seriously affected areas [1]. In the Eastern Mediterranean Region, nine countries have reported dengue epidemics and four serotypes have been identified [7].

The virus is transmitted mainly by female mosquitoes of the species *Aedes aegypti* and, to a lesser extent, *Aedes albopictus*; these are the same mosquito vectors that transmit chikungunya, yellow fever and Zika infections [7]. Dengue fever can also be transmitted from mother to child during pregnancy or breastfeeding [8]. Healthcare workers are at risk

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of acquiring dengue infection through needlestick injury and mucocutaneous exposure [9].

Dengue fever ranges from mild febrile illness to potentially fatal but rare dengue haemorrhagic fever (DHF) and dengue shock syndrome (DSS). Almost three-quarters of cases of dengue fever are asymptomatic [10]. Younger children usually have milder illness than older children and adults. DHF usually manifests 2–7 days after fever onset, and unless properly managed, DSS follows [11]. During the early stages of the disease, virus isolation, nucleic acid or antigen detection can be used to diagnose the infection. At the end of the acute phase of infection, serology is the method of choice for diagnosis [7].

The Omani Ministry of Health (MoH) established a communicable disease surveillance and control programme in 1991. Dengue fever and DHF are notifiable diseases in Group A diseases and syndromes, respectively, which require notification and investigation within 24 h for immediate action [12]. The total number of travel-related cases of dengue fever reported from 2001 until the end of 2017 was 173. From 1 January to mid-December 2018, 30 travel-related cases of dengue fever were reported at national level, including nationals who travelled to areas affected by the disease [12,13]. From establishment of the programme in 1991 until November 2018, no local transmission of dengue was reported.

Surveillance data from 1 November 2018 until 15 May 2019 detected 71 laboratory-confirmed cases. Of these, 59 were indigenous and 12 were travel-related [14]. Following that outbreak, the MoH and Muscat municipality conducted an elimination campaign for the breeding sites of *A. aegypti* from 8 to 23 January 2019, aiming to eliminate all potential vector breeding sites and raise community awareness about the importance of sustaining vector control activities after the campaign. No locally transmitted confirmed cases of dengue fever were reported after 15 March 2019 until the current outbreak.

The aim of this study was to describe the locally transmitted (indigenous) outbreak of dengue fever in Baushar and As-Seeb districts in Muscat Governorate from mid-March to mid-April 2022, and the multisectoral approach used to control the outbreak.

Materials and methods

Initial alert and response

On 16 March 2022, the Disease Surveillance and Control Department of the Directorate General of Health Services, Muscat Governorate received two simultaneous notifications of two cases of confirmed dengue fever from two different districts in Muscat Governorate.

Case finding

To include as many cases of dengue fever as possible, the surveillance of acute febrile illness was activated in all districts of Muscat Governorate and the following case definitions were developed: (a) A suspected dengue case has acute febrile disease (temperature >38°C) lasting for 2–7 days, with two or more of the following manifestations: headache, back pain, retro-orbital pain, myalgia, arthralgia, rash and haemorrhagic manifestations. Blood samples were collected from all suspected cases to perform a full blood count.

(b) A probable dengue case is a suspected case with platelet count <100,000 mm^3.

(c) A confirmed dengue case is a suspected or probable case that is laboratory confirmed by polymerase chain reaction (PCR) or NS1 with or without immunoglobulin M (IgM), or positive for both IgM and IgG [15].

The above-mentioned case definitions, together with guidelines for diagnosis and management of cases of dengue fever, were distributed to all health institutions in Muscat Governorate. Serological testing using enzyme-linked immunosorbent assays for DENV NS1 antigen, IgM and IgG antibodies was conducted using a kit from Panbio Diagnostics (Abbott, Chicago, IL, USA). The method used has been described elsewhere [14]. Dengue PCR was undertaken using a Liferiver dengue virus general type real-time reverse transcriptase (RT)-PCR kit (Shanghai ZJ Bio-Tech Co., Ltd, Shanghai, China). Samples that were PCR-positive were subsequently typed using four different real-time RT-PCR kits (Liferiver); each kit detects genes that are specific for type I, II, III or IV dengue virus.

Data were collected from the following sources: (a) an e-notification system for cases examined by healthcare professionals at primary, secondary and tertiary health institutions; (b) active surveillance through field visits and reviewing health institution registries, looking for fever and low platelet count to discover possible missed cases; and (c) contact investigation for early diagnosis of cases.

Control measures

The rapid response team, from health services in Muscat Governorate, in collaboration with the national team and the Muscat municipality team, prepared a demographic map of the affected areas in both districts (Baushar and As-Seeb). The maps extended 400 m from patients' residences in each direction. Public health inspectors visited the patients' residences and met their families for risk assessment of the house and the surrounding environment. Immature stages of mosquitoes were evaluated and identified in all water-holding containers by an entomologist. In total, 308 samples of mosquito larvae were sent to the Central Public Health Laboratory (CPHL) for classification and testing for sensitivity to the pesticide used in the spraying process. Mosquito traps were set up by the central team in the affected areas. The municipality was directed to spray the affected areas by ultra-low-volume fogging with 5 g/L of D-phenothrin in the morning every second day for at least 10 days.

In parallel to the above-mentioned control measures, a community mobilization plan was developed and implemented. The plan focused on awareness and education, where knowledge about the disease, mode of transmission, and vector control were provided. Community members were approached through different media channels. Social influencers were among the tools used to approach the community. Awareness and social mobilization became a whirlwind of activity with multi-level community integration. Several education sessions were conducted at community gathering sites, such as primary healthcare facilities, women's society offices and mosques. Two tools were used to facilitate and enhance awareness, and thereby involve the public: (a) the 'Be the change' campaign, which aimed to bring about support and changes from within the community; and (b) electronic posters, printed leaflets and recorded messages with different language translations to reach most of the population, such as English, Hindi, Urdu and Bengali, in addition to the Arabic local language.

Results

The total number of reported suspected and probable cases of dengue fever from 1 February to 15 April 2022 was 250. Of these, 169 were confirmed cases with DENV-2 serotype. None of the cases had a history of travel overseas. Of the confirmed cases, 108 (63.9%) were male and 94 (55.6%) were Omani. Ages ranged from 4 to 82 years, with a median age of 36 years. Most cases were in the age group 21–40 years (46.7%, *n*=79). Table 1 shows the sociodemographic factors of cases of dengue fever. The first two cases were a 25-year-old Omani male from Baushar district and a 53-year-old Omani female from As-Seeb district. Both were admitted to a regional hospital with high-grade fevers not associated with recent travel. The initial entomological investigation for the two cases identified *A. aegypti* mosquitoes in their proximity.

Fever was the most common symptom, and occurred in 100% of cases (Figure 1). Other symptoms were myalgia (56%), fatigue (33%),

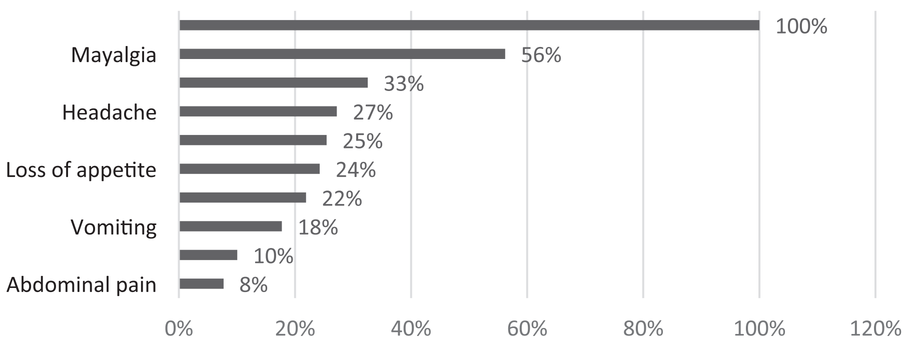

Figure 1. Clinical features of cases of dengue fever in Muscat Governorate, March–April 2022.

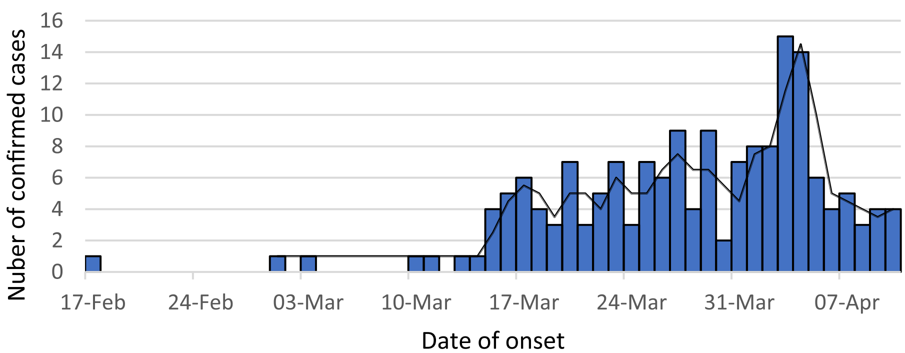

Figure 2. Epidemic curve of outbreak of dengue fever in Muscat Governerate, March–April 2022.

Table 1
Sociodemographic factors of cases of dengue fever in Muscat Governorate, March–April 2022.

Variable	*n*	%
Age (years)		
0–20	22	13.0
21–40	79	46.7
41–60	48	28.4
>61	20	11.8
Gender		
Male	108	63.9
Female	61	36.1
Nationality		
Omani	94	55.6
Non-Omani	75	44.4
District of residence		
Baushar	135	79.9
As-Seeb	25	14.8
Amerat	6	3.6
Mutrah	3	1.8

headache (27%) and arthralgia (25%). Haemorrhagic manifestations occurred in 10% (*n*=17) of cases. The proportions of IgG and IgM were 8.9% and 26.0%, respectively. Of all cases, 93 (55.1%) were hospitalized. No fatal cases were reported until mid-April 2022. There was no history of travel in any of the cases.

The epidemiologic curve is shown in Figure 2. Active surveillance traced back to three earlier cases with local transmission. One dated back to 17 February 2022, and the other two dated back to 3 and 4 March 2022. The outbreak started to peak on 15 March 2022, reached the maximum on 3 April 2022, and then declined gradually. Eighty percent of cases (*n*=146) had their date of onset between 5 March and 4 April 2022 (i.e. weeks 11–13).

Environmental and entomological investigations were conducted between 17 March and 7 April 2022 as part of public health intervention and control measures. The primary entomological investigation of the first case confirmed the presence of *A. aegypti* larvae in the area. The field of investigation was expanded to include all houses in the affected districts. In total, 3444 houses and other sites were visited in four districts, including the two affected districts; of these, 3059 (89%) were open sites (72.8%, *n*=2228 were in Baushar district). Most of the sites visited were houses (71%), commercial buildings and other sites accounted for 14% and 15%, respectively. Of 308 samples of larvae collected and sent to CPHL, 288 (93.5%) were positive for *A. aegypti*. Figure 3 shows a map of potential breeding sites identified during the entomological investigation. Breeding sites were identified in 565 (18.5%) of the open sites visited. Of these, 69.4% (*n*=392) were in Baushar district, 15% (*n*=128) were in As-Seeb district, and the remaining 8% (*n*=45) were in Amerat and Mutrah districts.

In total, 167 houses and apartments of confirmed cases were visited between 24 March and 10 April 2022, and were assessed for breeding sites and risk factors. Of these, potential breeding sites were found in 98 (58.7%) houses/apartments. Plastic waste was found outdoors and indoors at 37.4% (*n*=58) and 43.4% (*n*=67) of houses/apartments, respectively. Insecticides were only used in 45.8% (*n*=71) of the visited sites, 132 (85.2%) did not use insect repellents, and 56 (63.8%) did not have screens on the windows.

Discussion

Since the establishment of communicable disease surveillance, Muscat Governorate has witnessed two locally transmitted outbreaks of dengue fever. The first outbreak started in late 2018 and continued through early 2019, while the second (current) outbreak started in early March 2022. Notably, prior to 2018, all reported cases of dengue fever were imported. However, the hot humid weather throughout Muscat Governorate, high levels of rainfall in some regions, and the high population density in some urban areas, in addition to behavioural factors such as water storage, may facilitate the endemicity of dengue fever in the future if proper control measures are not sustained.

Most affected cases in the second outbreak were male, Omani and aged 21–40 years. Almost 80% of cases lived in Baushar district, 15% lived in As-Seeb district, and the remaining cases lived in Amerat and Mutrah districts and were epi-linked to the cases in Baushar district. The low number of cases with DHF can be explained by a study carried

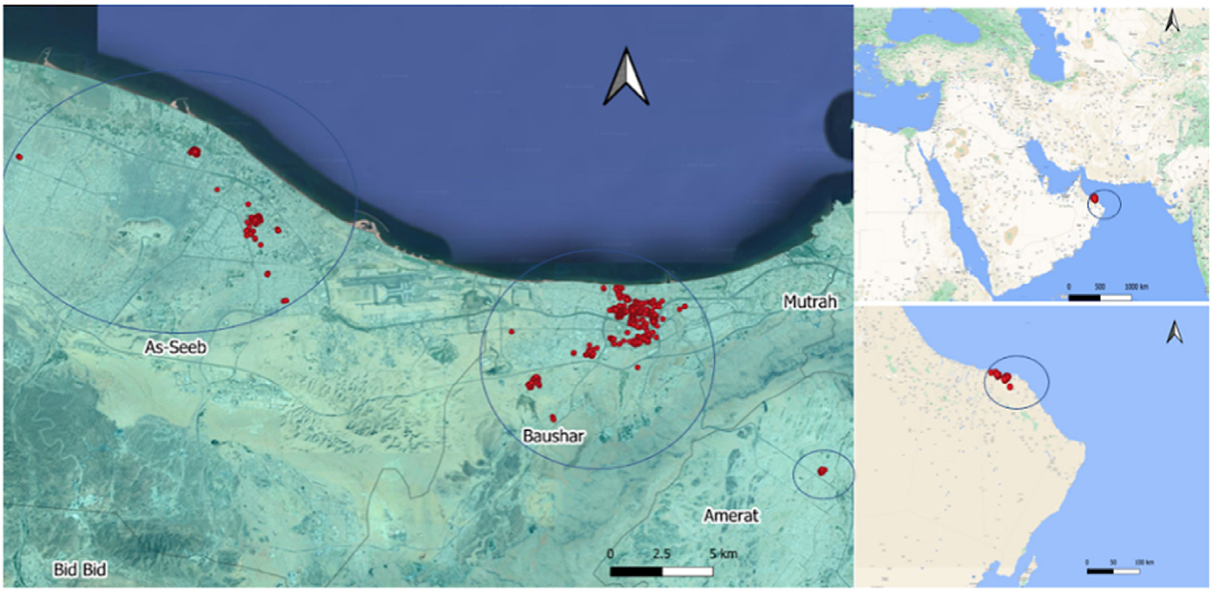

Figure 3. Map of Greater Muscat from As-Seeb district to Mutrah districts. Red dots indicate the breeding sites identified by entomological investigations in As-Seeb, Baushar, Amerat and Mutrah districts.

out in Thailand, which concluded that the incidence of DHF is maximized above 80% maximum humidity. 75% mean humidity, and 55% minimum humidity [16]. The mean relative humidity levels in Muscat Governorate in March and April 2022 were 70% and 66%, respectively [17].

There were more hospitalizations in the second outbreak than in the first outbreak (55.1% vs 47.5%, respectively). Although more than half of the cases in the current outbreak were hospitalized, no cases of DSS or severe dengue were reported, and all cases recovered with rehydration and supportive treatment. There were no reported deaths until mid-April 2022. This may be explained by the primary infection of most reported cases, in addition to the male predominance and the secondary infection with the same serotype (i.e., DENV-2). It is worth noting that female gender and secondary infection (with two sequential infections by different serotypes) were associated with increased risk for severe dengue [18]. During secondary infection, the dominant IgG is detected at high levels, even in the acute stage. IgM antibody levels are significantly higher in primary infections than in secondary infections [7]. In the current outbreak, most cases were primary infections, as indicated by the seroprevalence of IgM and IgG (26.0% and 8.9%, respectively). However, in subsequent outbreaks, more severe cases may occur due to ADE, where antibodies enhance viral entry into cells instead of neutralizing the virus [7].

A multi-sectoral approach was utilized during the control efforts, where teams from the MoH, Muscat municipality, civil society and volunteers collaborated. In addition to the fogging process, residents were directed to change the water in water tanks, fountains and swimming pools every 5 days; dispose of water collected from air conditioners; dispose of used tyres and damaged utensils; and cover various water reservoirs. In addition, the public were given awareness messages about measures to avoid mosquito bites, such as wearing long-sleeved wraps, using mosquito repellent on exposed body parts, using bed nets and spraying household pesticides.

However, these measures may be institutionalized, not merely reactive to outbreaks of dengue fever. Sequential surveys are warranted to calculate vector indices for the prediction of future outbreaks, because the likelihood of *A. aegypti*-mediated outbreaks can be predicted using risk indices such as the house index (HI), container index and Breteau index (BI) [19]. The BI establishes a relationship between positive containers and the number of houses. It is, therefore, considered the most useful single index for estimating the density of *A. aegypti* in a location [20]. For epidemiological purposes, the HI is important and indicates the potential spread of the virus through an area once an infected case becomes established. HI >5% and/or BI >20% for any locality indicates that the locality is prone to dengue fever [11].

Despite all vector control measures implemented by health authorities and other concerned stakeholders, the elimination of *A. aegypti* remains challenging for three main reasons:

(a) The adult female mosquito is active within a wide range of environmental temperatures. The lower threshold for development of the mosquito is 16°C, while the upper limit is 34°C [21]. Moreover, immature stages have been found to survive through a short exposure to an environmental temperature of up to 45°C [22]. Typically, the mosquito does not survive winter as an adult, but rather over winters at the egg stage, and adult mosquitos sometimes take advantage of a subterranean habitat to survive winter [23].
(b) Inadequate human and vector surveillance during and following the coronavirus disease 2019 (COVID-19) pandemic. It is thought that many cases of dengue fever in Muscat Governorate may have passed unnoticed as negative COVID-19 cases during the pandemic. Moreover, passive surveillance systems alone cannot capture all dengue infections because primary infection is more likely to cause mild or inapparent forms of dengue fever, and these individuals may not seek medical care [24]. The treatment-seeking behaviour itself can vary considerably depending on cost, accessibility and availability of care and, as a result, will differ in different areas and at different times [25].
(c) Some genotypes of the same serotypes of the dengue virus have different virulence in different geographic areas [26]. The recent exponential increase in international travel and trade also favoured the spread of dengue fever due to increased mobility of both vector and human populations [27].

In the absence of effective vaccines against several viruses transmitted by *A. aegypti* and *A. albopictus*, vector control remains an essential component of vector management [28]. Oman adopted the World Health Organization's integrated approach to vector control, which targets the ecological, biological and social driving factors for dengue transmission, in addition to educational programmes promoting behaviours that reduce vector spread and proliferation [28]. A 3-year trial was conducted in Indonesia, involving the release of *A. aegypti* infected with a bacteria called Wolbachia, which competes with viruses within the mosquito, in and around the dengue-endemic city of Yogyakarta. This intervention proved to be effective in significantly reducing both the number of cases of dengue fever and the number of hospitalizations in the intervention cluster compared with the control cluster [29,30]. The intervention also proved to be effective in Aedes vector control in China, Brazil, Singapore, parts of America, and one district in Saudi Arabia [31,32].

Limitations

Although this study relied on various sources for data collection, the real number of cases in the outbreak may have been underestimated due to the possibility of inapparent infections, and the differing treatment-seeking behaviours of infected persons, especially among the expatriate population.

Conclusion

Elimination of *A. aegypti* remains a challenge. Future outbreaks are expected and may show more severe cases due to ADE. Efforts of concerned authorities should, therefore, be directed towards the utilization of geographic information systems for the prediction of future outbreaks. Vector surveillance should be established as a routine public health service. New innovative interventions such as Wolbachia-infected mosquitoes are recommended in Oman.

Conflict of interest statement

None declared.

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Ethical approval

This study was approved by the Ethics Committee of the Directorate General of Health Services, Muscat Governorate. Data were gathered from existing health information systems, and disease surveillance and control reports.

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