Heliyon 10 (2024) e37562

Contents lists available at ScienceDirect

Heliyon

journal homepage: www.cell.com/heliyon

Research article

# Diarrhea and cholera surveillance for early warning and preparedness to prevent epidemics among Rohingya Myanmar nationals in Cox's Bazar, Bangladesh

Ashraful Islam Khan [a,1], Md. Taufiqul Islam [a,1], Nabid Anjum Tanvir [a], Zahid Hasan Khan [a], Mohammad Ashraful Amin [a], Md. Golam Firoj [a], Md. Mokibul Hassan Afrad [a], Yasmin Ara Begum [a], Abu Toha M.R.H. Bhuiyan [b], ASM Mainul Hasan [c], Tahmina Shirin [d], Firdausi Qadri [a,*]

[a] *Infectious Diseases Division, International Centre for Diarrhoeal Disease Research Bangladesh (icddr,b), 68, Shaheed Tajuddin Ahmed Sarani, Mohakhali, Dhaka, 1212, Bangladesh*
[b] *Refugee Health Unit, Office of the Refugee Relief and Repatriation Commissioner, Cox's Bazar, Bangladesh*
[c] *Health Section, The United Nations Children's Fund (UNICEF), Dhaka, Bangladesh*
[d] *Institute of Epidemiology Disease Control and Research (IEDCR), Dhaka, Bangladesh*

A B S T R A C T

Diarrheal diseases, especially cholera, can be a serious threat to Rohingya refugees in Cox's Bazar due to overcrowding and inadequate hygiene infrastructure. Assessing the risk, cholera surveillance network was established with the aim to identify the outbreak of diarrhea and cholera and help to take appropriate preventive measures including a vaccination campaign. The surveillance network has been ongoing for 6 years (2017–2023) in 17 health facilities. Diarrhea patients from Rohingya Myanmar nationals matched with case definition were enrolled and stool samples were tested by Rapid diagnostic test (RDT) for early cholera detection Multiple Logistic regression models were fitted to examine the associations of risk factors among cholera cases. A total of 17,252 stool samples were collected through surveillance. Among the tested samples, 588 (3.5 %) were detected positive by RDT, and 239 (1.4 %) *Vibrio cholerae* were isolated by microbiological culture. Between 2021 and 2023, the number of culture-confirmed cases exceeded that in the period from 2017 to 2020. In addition to *V. cholerae*; high positivity was identified for ETEC (11.8 %) followed by *Salmonella* (3.9 %) and *Shigella* (2.7 %). Most of the cholera cases were presented with vomiting, dehydration and loose watery and rice watery nature of stool ($p$ value = <0.001). Major risk factors for cholera were 2–4 years age group (OR = 5.72; 95 % CI, 3.84–8.53.14; $P$ = .001), process of water treatment (OR = 1.54; 95 % CI, 1.01–2.37; P = .046) and hand washing with soap before taking meals (OR = 0.6; 95 % CI, 0.39–0.92; $P$ = .020. This study highlights the epidemiology of cholera among the Rohingya population and underscores the effectiveness of integrating surveillance data with early warning, alert, and response systems (EWARS) system, along with oral cholera vaccine (OCV) campaigns, in preventing major cholera outbreak.

## 1. Introduction

Diarrheal diseases including cholera is a significant public health threat and are regarded as a serious threat to refugee populations [1,2]. *Vibrio cholerae* is a highly transmissible bacterium, which can cause a rapidly dehydrating, watery diarrheal disease known as cholera [3]. In the 69 endemic countries, an estimated 2.86 million cholera cases occur annually, resulting in approximately 95,000

* Corresponding author.
*E-mail address:* fqadri@icddrb.org (F. Qadri).
[1] Joint first author.

https://doi.org/10.1016/j.heliyon.2024.e37562
Received 1 February 2024; Received in revised form 5 September 2024; Accepted 5 September 2024
Available online 6 September 2024

deaths. Moreover, around 1.3 billion people are at risk for cholera, including Bangladesh [4]. It has been observed that huge cholera outbreaks occur in countries like Yemen, South Sudan, Haiti where public health care facilities including water sanitation and hygiene (WASH) become critical because of humanitarian crises [5]. Foodborne illness surveillance, conducted in collaboration with the Institute of Epidemiology Disease Control and Research (IEDCR) and the icddr,b reported 8 % culture-confirmed cholera cases in Cox's Bazar. This finding designates Cox's Bazar as a high-risk area for cholera. In August 2017, Bangladesh perceived a sudden influx of an estimated over 700,000 refugees including the large number of children from neighboring Rakhine state in Myanmar in the coastal area of Cox's Bazar, Bangladesh. This population have faced decades of systematic discrimination, statelessness, and targeted violence and such oppression has forced these people of all ages and genders into Bangladesh especially in 2017 [6]. These refugees, commonly known as 'Rohingya' had to live in spontaneous makeshift settlements. The current crisis has been regarded as the most extensive and rapid migration event in modern history [7]. The hurriedly built makeshift camps were vulnerable to monsoon flooding and storm surges. Nevertheless, due to the influx of a substantial number of displaced populations and inadequate provision of essential sanitation infrastructures such as latrines and safe waterpoints, the surrounding environment swiftly transformed into a conducive breeding ground for waterborne illnesses, encompassing acute watery diarrhea, cholera, and various enteric diseases [8–10]. Cholera outbreaks exhibit a high frequency and extended duration in regions where the disease is prevalent, characterized by recurring seasonal patterns [11]. The phenomenon described also manifests in non-endemic regions, triggered by the introduction of exogenous toxins from *V. cholerae*. This is frequently observed in conjunction with complicated emergencies, which give rise to infrastructure deterioration or population relocation [12]. Cholera is known to impact individuals across all age groups, including young children under the age of five, who are particularly susceptible to catching the disease in areas where it is endemic [13]. The Bangladeshi host population who are vulnerable to the disease also live in close proximity to the camps [14–16].

Cholera disease surveillance can furnish up-to-date data on the population's health condition, thereby aiding in the prevention of morbidity and mortality, detection of outbreaks, improvement of health service provision, and guidance of appropriate interventions [17,18]. In order to enhance the timely identification of disease outbreaks and maintain effective disease surveillance during crises, the implementation of early warning, alert, and response systems (EWARS) that encompass both surveillance and water, sanitation, and hygiene (WASH) components has proven to be highly efficacious. The purpose of this surveillance was to identify and prevents outbreaks of diarrhea as well as cholera early so as to take immediate control measures including vaccination which is crucial for reduction of mortality and morbidity due to the disease.

## 2. Methods

### 2.1. Surveillance sites

Surveillance activities was conducted in 14 settings in Ukhiya and 3 places in Teknaf Upazilla of Cox's Bazar district which covered most of the geographical areas of these two Upazila. The locations encompass two Upazilla Health Complexes located in Ukhiya and Teknaf, as well as the Kutupalong and Balukhali makeshift camps situated in Ukhiya. Additionally, the Leda and Nayapara camps in Teknaf are included in this analysis. In total, there are 34 camps within these areas [17]. To gain a complete understanding of the epidemiology of pathogen-specific diarrhea among the Rohingya Myanmar nationals and the surrounding host communities, a variety of healthcare facilities, including both government and private establishments, were chosen for surveillance purposes in proximity to the camps and shown in Thematic map of surveillance sites (Fig. 2). These sites were chosen for conducting surveillance activities based on geographical location and population density, weekly diarrheal patient flow, easily accessibility for the community, and well-structured including accessible sanitation facilities for the patients. Along with this, all the surveillance sites had oral rehydration therapy (ORT) corner and indoor admission facilities for severely dehydrated patients. The health infrastructure consisted of primary health care centers, hospitals operated by the International Organization for Migration (IOM), clinics managed by Medecins Sans Frontieres (MSF), Primary health care centers of Gonoshasthaya Kendra, hospitals operated by other non-governmental organizations (NGOs), and Upazila health complexes.

### 2.2. Operational definition of diarrhea

Patients who presented at a treatment center and experienced three or more loose or liquid stools during a 24-h period, or less than three loose/liquid stools resulting in dehydration, were deemed potentially eligible for inclusion in the surveillance.

### 2.3. Ethics Statement

The participants' informed agreement was obtained prior to their inclusion in the study so that data and biological samples could be collected. For participants and legal guardians of children younger than 11 years old, informed consent was acquired, and assent was gained from participants and legal guardians of children aged 11–17 years old according to the 'Declaration of Helsinki' regulation and guidelines. The International Center for Diarrheal Disease Research in Bangladesh (icddr,b) has a Research Review Committee and an Ethical Review Committee (PR 20002), and both of these committees have given their permission to the surveillance protocol.

### 2.4. Surveillance

This surveillance was conducted among patients suffering from diarrheal disease seeking treatment in NGO-assisted health facilities and Upazila Health Complex of Ukhia and Teknaf upazila in Cox's Bazar district to observe any epidemic and prevalence of *V. cholerae* and other enteric pathogens. Diarrhea patients with matched case definitions and had no other severe co-morbidity (e.g., severe acute respiratory illness, acute cardiovascular symptoms, or severe acute neurological disorder) were enrolled in the surveillance. Trained staff were assigned to each of the facilities who were dedicated only for this surveillance. Fecal specimen was collected from a random subset of diarrheal patients of all age groups for testing *V. cholerae*, ETEC, *salmonella spp. and shigella spp*. We targeted ten diarrheal patients from each surveillance site per week for testing for *V. cholerae* irrespective of age and sex. Additionally, for other pathogens (ETEC, Salmonella and Shigella spp.), we tested 2 samples (targeted one sample from $<5$ years and one from $\geq5$ years patient) per week per site.

After obtaining informed consent, the researchers collected data on patients' sociodemographic variables, including age, gender, occupation, medical history, sanitation practices, and hygiene information, using a standardized questionnaire. A fecal specimen was obtained from every person who was included in the study. The early detection of cholera was facilitated through the utilization of a Rapid Diagnostic Test (RDT) specifically designed for the identification of *Vibrio cholerae*. All the collected fecal samples were preserved in Cary-Blair transport media within the field office located in Ukhiya, maintaining an ambient temperature. Samples that are stored in Cary-Blair transport media at room temperature have the capability to be preserved for a duration about 20 days [19]. All the samples that were collected were carried to the Mucosal Immunology and Vaccinology Laboratory at the International Centre for Diarrhoeal Disease Research, Bangladesh (icddr,b) in Dhaka on a weekly basis. The samples were conveyed using Cary-Blair transport media [20]. Upon the arrival of the specimens at the icddr,b laboratory, prompt processing was initiated to determine the presence *of V. cholerae* O1, enterotoxigenic *Escherichia coli* (ETEC), Salmonella, and Shigella spp.

The reports of all the RDT positive and culture confirmation cases were disseminated to the EWARS system operated WHO. The system in question is an online platform specifically developed to augment disease surveillance and facilitate the detection of outbreaks in emergency scenarios, with the ultimate goal of promptly responding to and managing the spread of the disease.

### 2.5. Laboratory procedures

To facilitate the identification of *V. cholerae*, the specimens were streaked onto a culture medium known as taurocholate-tellurite gelatin agar (TTGA) and thereafter incubated at a temperature of 37 °C for a period of one night. In addition, the specimens underwent incubation in alkaline peptone water for the purpose of enrichment. Following this, they were further cultured for a duration of 18–24 h and subsequently plated on TTGA [15,21]. The colonies under suspicion were subjected to serotyping using monoclonal antibodies that are specifically designed to target the *V. cholerae* O1 (Ogawa and Inaba) and O139 serogroups [22,23]. To identify *Escherichia coli* strains that cause enterotoxigenic infections (ETEC), fecal samples were evenly distributed onto MacConkey agar plates and thereafter placed in an incubator set at a temperature of 37 °C for an overnight duration. The presence of Enterotoxigenic *Escherichia coli* (ETEC) was verified using a multiplex polymerase chain reaction (PCR) technique that specifically targeted the gene sequences associated with ETEC toxins LT and ST. This analysis was conducted on colonies capable of fermenting lactose [15,23]. To detect the presence of Salmonella and *Shigella* spp., the specimens were streaked onto Salmonella-Shigella agar and subsequently incubated at a temperature of 37 °C for a period of one night. This was followed by a series of systematic biochemical and serological testing methods, specifically employing the Denka Seiken technique.

### 2.6. Statistical analysis

Year wise cholera RDT and Culture positivity among Rohingya Myanmar nationals are provided with number and percentage along

**Table 01**
Year wise distribution of RDT positive and culture confirmed cholera cases stratified by age and sex among Rohingya Myanmar nationals.

| Year | RDT Positive, n (%) | | | | | | Culture Positive, n (%) | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Total | Age | | | | Sex | Total | Age | | | | Sex |
| | | <2 years | 2–4 years | 5–17 years | ≥18 years | Male | | <2 years | 2–4 years | 5–17 years | ≥18 years | Male |
| 2017 | 226 (25 %) | 142 (63 %) | 6 (3 %) | 18 (8 %) | 60 (27 %) | 112 (50 %) | 8 (1 %) | 4 (50 %) | 2 (25 %) | 0 (0 %) | 2 (25 %) | 4 (50 %) |
| 2018 | 76 (4 %) | 50 (66 %) | 1 (1 %) | 6 (8 %) | 19 (25 %) | 44 (58 %) | 8 (0 %) | 4 (50 %) | 2 (25 %) | 0 (0 %) | 2 (25 %) | 3 (38 %) |
| 2019 | 28 (1 %) | 13 (46 %) | 3 (11 %) | 4 (14 %) | 8 (29 %) | 18 (64 %) | 17 (1 %) | 9 (53 %) | 0 (0 %) | 0 (0 %) | 8 (47 %) | 8 (47 %) |
| 2020 | 3 (0 %) | 2 (67 %) | 0 (0 %) | 0 (0 %) | 1 (33 %) | 1 (33 %) | 1 (0 %) | 1 (100 %) | 0 (0 %) | 0 (0 %) | 0 (0 %) | 1 (100 %) |
| 2021 | 127 (4 %) | 61 (48 %) | 17 (13 %) | 7 (6 %) | 42 (33 %) | 72 (57 %) | 95 (3 %) | 49 (52 %) | 13 (14 %) | 5 (5 %) | 28 (29 %) | 43 (45 %) |
| 2022 | 70 (1 %) | 38 (54 %) | 9 (13 %) | 3 (4 %) | 20 (29 %) | 42 (60 %) | 51 (1 %) | 32 (63 %) | 10 (20 %) | 1 (2 %) | 8 (16 %) | 35 (69 %) |
| 2023 | 58 (2 %) | 22 (38 %) | 9 (16 %) | 7 (12 %) | 20 (34 %) | 31 (53 %) | 59 (3 %) | 30 (51 %) | 8 (14 %) | 6 (10 %) | 15 (25 %) | 33 (56 %) |

with the monthly distribution of cholera from September 2017 to April 2023. Isolation of other enteric pathogens e.g. Shigella, Salmonella and ETEC are also presented with count and percentages. Relationships between confirmed cholera and socio-demographic factors and disease characteristics have assessed by using Chi-square test and Fisher's exact test for sparse data. Bivariate and multiple Logistic regression models have been fitted to measure the association of socio-demographic factors with cholera among Rohingya Myanmar nationals. Covariates with $p < .20$ in the bivariate analysis have included in the multiple regression model. Exponential of the coefficients of the Logistic regression models have used and presented as odds ratios (OR) with a corresponding 95 % confidence interval. All tests were two-tailed, where p-value $<0.05$ has considered statistically significant.

The statistical analysis was conducted using R (version 4.2.1). For plots and figures "ggplot2" package have been used.

## 3. Results

### 3.1. Descriptive statistics

A total of 17,252 stool samples were collected for detection of *Vibrio cholerae* from diarrheal patients among Rohingya Myanmar Nationals who attended the sentinel sites seeking treatment from September 2017 to April 2023. Among the tested samples, 588 (3.4 %) samples were detected positive by RDT, and 239 (1.4 %) *Vibrio cholerae* were isolated through culture [Table 1]. The number of cultures confirmed cases were higher in 2021-23 than 2017–20 [Table 1]. In addition, the proportion of other enteric pathogens isolated from the stool samples were 2.7 % *Shigella*, 3.9 % *Salmonella,* and 11.8 % ETEC among the Rohingya Myanmar nationals [Table 2]. Between September and November 2019, we observed the first spike of confirmed cholera cases among the Rohingya Myanmar nationals following the influx. The next increase in cholera cases was observed in June 2021 and lasted until October 2021. In September 2022, another upsurge was detected. All three of these peaks occurred during the post-monsoon season. In 2023, the last cholera outbreak was observed in the month of March–April (pre-monsoon period) [Fig. 1(A and B)]. Geographical mapping of the culture confirmed cases according to GPS [Figs. 2 and 3]. Among the 34 camps, *V. Cholerae* transmission was identified in almost every camp except camp 22, 23 and 25 over time. The number of confirmed cholera cases was notably higher in Ukhia Upazila compared to Teknaf. Surveillance data revealed that the highest burden of culture-confirmed cholera cases occurred in camp 2 W, followed by camp 9. Both camps are located in Ukhia Upazila of Cox's Bazar. Additionally, increased numbers of culture-confirmed cases were reported in camps 1E, 2E, 6, 7, and 13, and all of which are also situated in Ukhia [Fig. 2].

### 3.2. Socio-demographic and disease characteristics according to confirmed cholera

Among the enrolled Rohingya diarrheal patients in surveillance, 8760 (51 %) were male and 8492 (49 %) were female. About 67 % (n = 11602) of the enrolled patients were under the age of 5 among the study population. Among the enrolled patients, 68.6 % (n = 164) were confirmed cholera cases in children under 5 years old. The majority of patients were illiterate. In addition, 65 % of the enrolled cases had family members of more than 4 and this group was at high risk for being confirmed cholera cases [Table 3].

During the enrollment, we found loose watery stool in 92 % (n = 15933) cases and rice watery stool in 7 % (n = 1242) cases. The majority of the enrolled Rohingya participants suffering from acute watery diarrhea presented with some (61 %; n = 10535) dehydration and about 3 % (n = 572) percentage of participants presented with severe dehydration. Among the severely dehydrated patients, 10 % became confirmed by microbiological culture. Approximately 48 % of Rohingya participants (n = 8279) visited health facilities with vomiting during the study period. Among the enrolled participants, it was reported that 15 % treated their drinking water after collection, 99 % used proper sanitary latrine, and 97 % wash their hands with soap after defecation and 84 % before taking meal. [Table 3].

### 3.3. Association of socio-demographic variables with cholera

Among the Rohingya participants, age group 2–4 years had odds of being confirmed cholera cases that were approximately 6 times higher (OR = 5.72; 95 % CI, 3.84–8.53.14; *P* = .001) than other age groups. Although it is not statistically significant, the odds of cholera positivity among people aged 5 to 17 is also around two times higher (OR = 1.91; 95 % CI, 0.97–3.75; P = .06). The rate of cholera detection was around two times high (OR = 1.54; 95 % CI, 1.01–2.37; P = .046) in the group of participants who did not use a water treatment system. Among the Rohingya participants, confirmed cholera cases had odds of hand washing with soap before taking

**Table 02**
Isolation of other enteric pathogens among Rohingya Myanmar nationals.

| Factors | | Shigella | Salmonella | ETEC |
|---|---|---|---|---|
| Total | | 130 (2.67 %) | 190 (3.90 %) | 575 (11.79 %) |
| **Age** | **<2 years** | 63 (48 %) | 108 (57 %) | 359 (62 %) |
| | **2 to 4 years** | 4 (3 %) | 3 (2 %) | 20 (3 %) |
| | **5 to 17 years** | 12 (9 %) | 5 (3 %) | 24 (4 %) |
| | **≥ 18 years** | 51 (39 %) | 74 (39 %) | 172 (30 %) |
| **Sex** | **Male** | 57 (44 %) | 88 (46 %) | 288 (50 %) |
| | **Female** | 73 (56 %) | 102 (54 %) | 287 (50 %) |

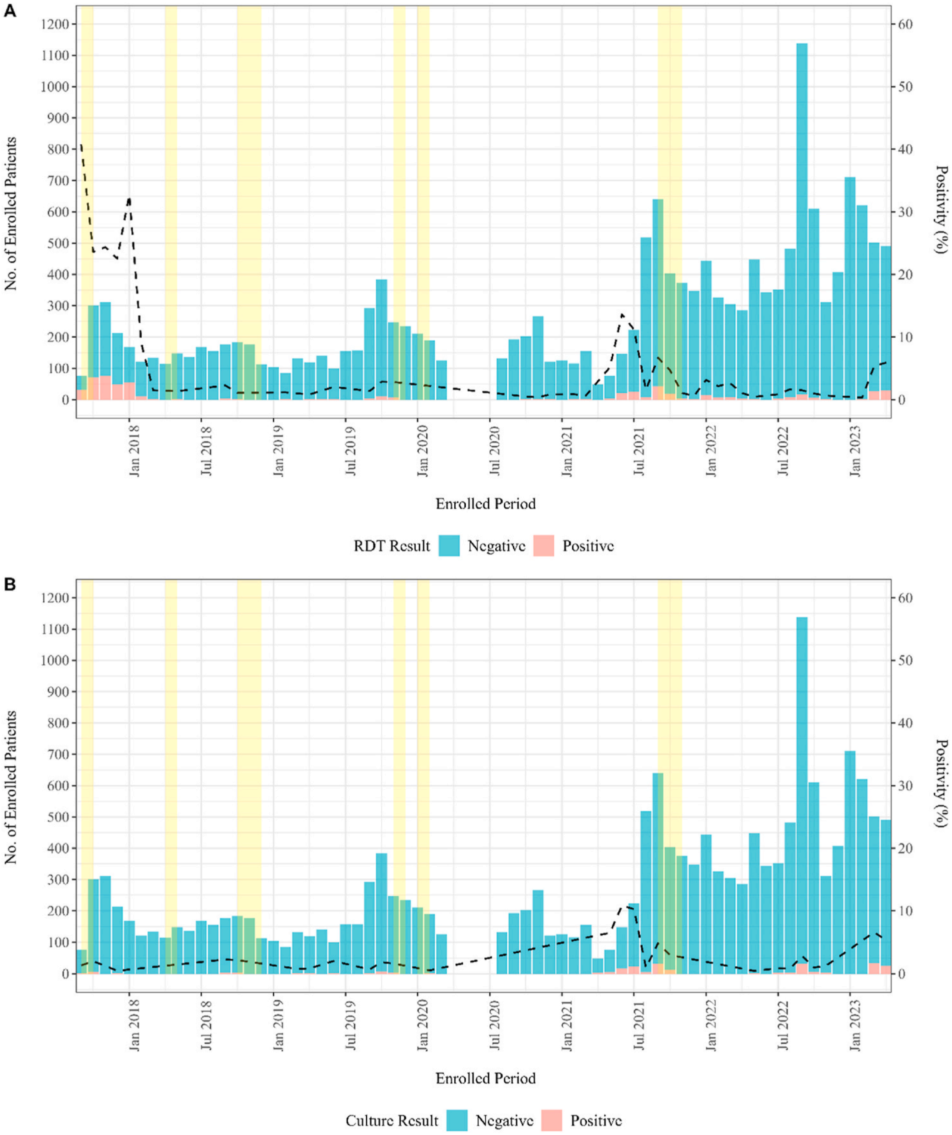


**Fig. 1. Monthly distribution of RDT positive (A) and culture confirmed (B) cholera cases (**Yellow highlighted part indicated the time of OCV campaigns).

meals (OR = 0.6; 95 % CI, 0.39–0.92; $P = .020$) in comparison to non-cases [Table 4].

## 4. Discussion

The study demonstrates the cholera prevalence and epidemiology among the Rohingya Myanmar nationals in Cox's Bazar, with the presence of other enteric bacterial pathogens. Cholera surveillance in camp areas allowed for early detection of any potential cholera epidemic and facilitated rapid response measures. The coordinated efforts of the monitoring system, oral cholera vaccine (OCV) usage, and water, sanitation, and hygiene (WASH) initiatives successfully prevented any significant outbreaks. More than 17,000 diarrheal patients attending government and NGO-assisted health facilities in refugee camps were enrolled and tested by RDT and microbiological culture. Among the enteric pathogens, the proportion of *E. coli* isolation is higher and *V. cholerae* isolation is the least among Rohingya Myanmar nationals. Similar findings were observed in the acute watery diarrhea surveillance conducted from 2017–19 in the same region [15]. However, the number of cholera cases detected in Haiti and Yemen is much higher, which also faced humanitarian crises [24,25].

According to the last six years of surveillance data, the seasonality of cholera cases trend remains the same. Previously, most of the upsurge or outbreak happened in the post-monsoon season (September–October), but in 2023, the upsurge was detected in pre-monsoon monsoon (March–April). Similar seasonality (pre-monsoon and post-monsoon) of the cholera cases was observed in the

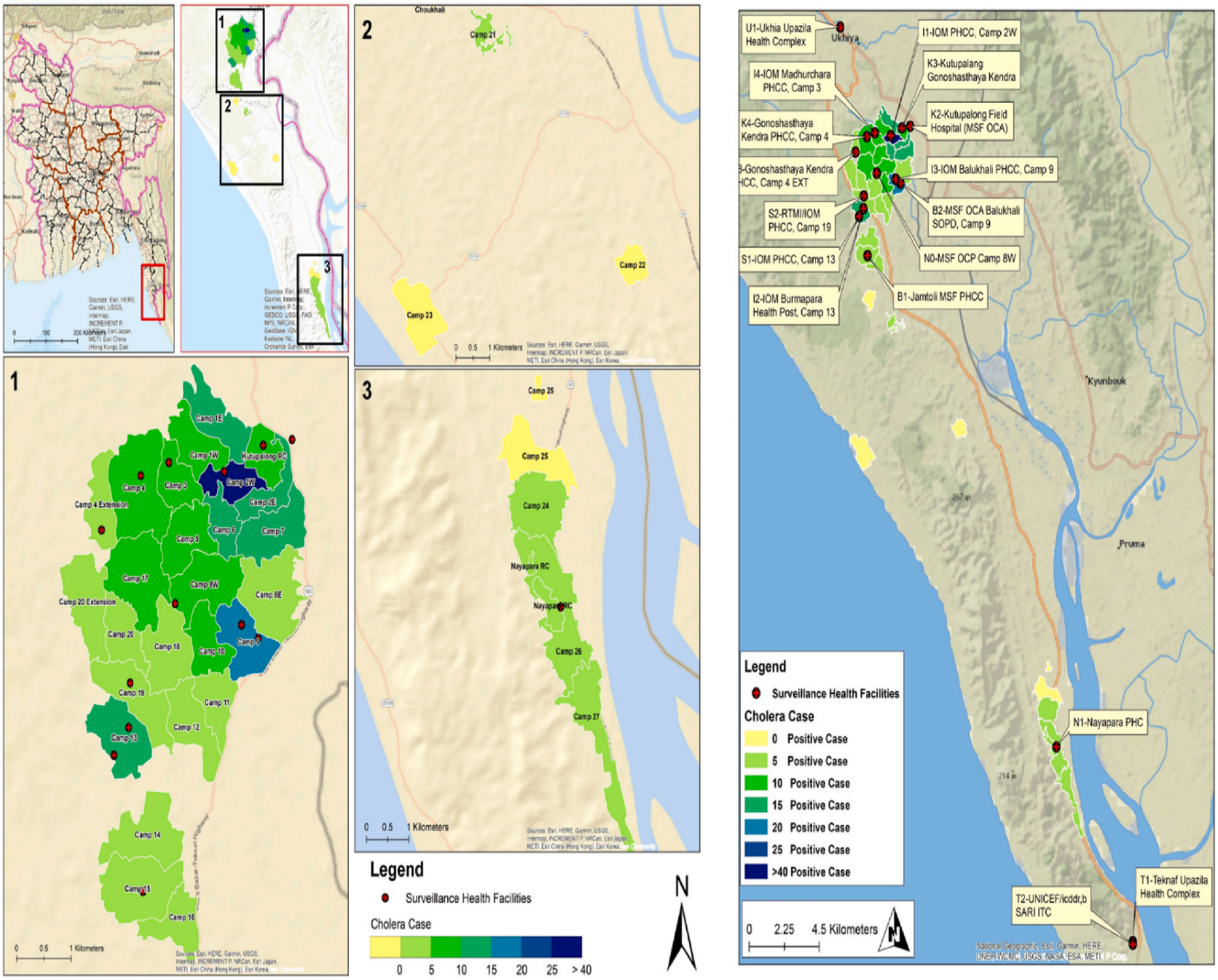


**Fig. 2.** Geographical mapping of the culture confirmed cases according to GPS.

nationwide cholera surveillance conducted in Bangladesh [14,16].

We identified that major risk factors for cholera were age (<5 years), patients presenting with vomiting, dehydration, the process of water treatment, and hand washing behavior. Children aged less than 5 years were at the highest risk of cholera than other age groups [26,27]. Similar risk of cholera among this age group were also found in a hospital based surveillance conducted in Matlab and icddr,b Dhaka hospital [27]. A study conducted in Kolkata, India, also revealed the same cholera risk factor in under 5 children [28]. Similar findings were observed in a study conducted in Sierra Leone and Haiti during a cholera epidemic. The study identified consuming unsafe water and street-vented water as significant risk factors for cholera infection. These risk factors highlight the importance of safe water sources and hygiene practices in preventing cholera outbreaks [29,30]. People who did not treat their drinking water were more likely to be affected by cholera. Due to the extensive promotion of WASH behavior and awareness sessions in camp settings, almost all the Rohingya participants used sanitary latrines, and majority of the participants were more used to using soap after defecation [31]. But they were lagging behind in terms of handwashing by using soap before meals. More awareness sessions are needed to increase handwashing behavior with soap, not only after defecation, but also before meals.

There is a threat of cholera outbreaks in Rohingya refugee camp settings where public health care facilities including WASH become critical [32]. Nationwide surveillance study of cholera conducted by icddr,b and IEDCR, also shows that cholera is circulating in Cox's Bazar and affects the population of this district every year [16]. Establishing cholera surveillance in Rohingya refugee camps just after the influx helped to identify the transmission of *V. cholerae* among Rohingya Myanmar nationals since 2017. Considering the risk and evidence of cholera transmission by surveillance system, there were seven rounds of OCV campaign that were carried out over time among the Rohingya Myanmar nationals and over 4.5 million doses of OCV were delivered in this region, and a clear declining trend of AWD and cholera was found after each round of the OCV campaign [6]. Whenever the surveillance system detected signs of a cholera upsurge, an oral cholera vaccine (OCV) campaign was promptly organized and conducted, leading to significant success in controlling the disease [6,33].

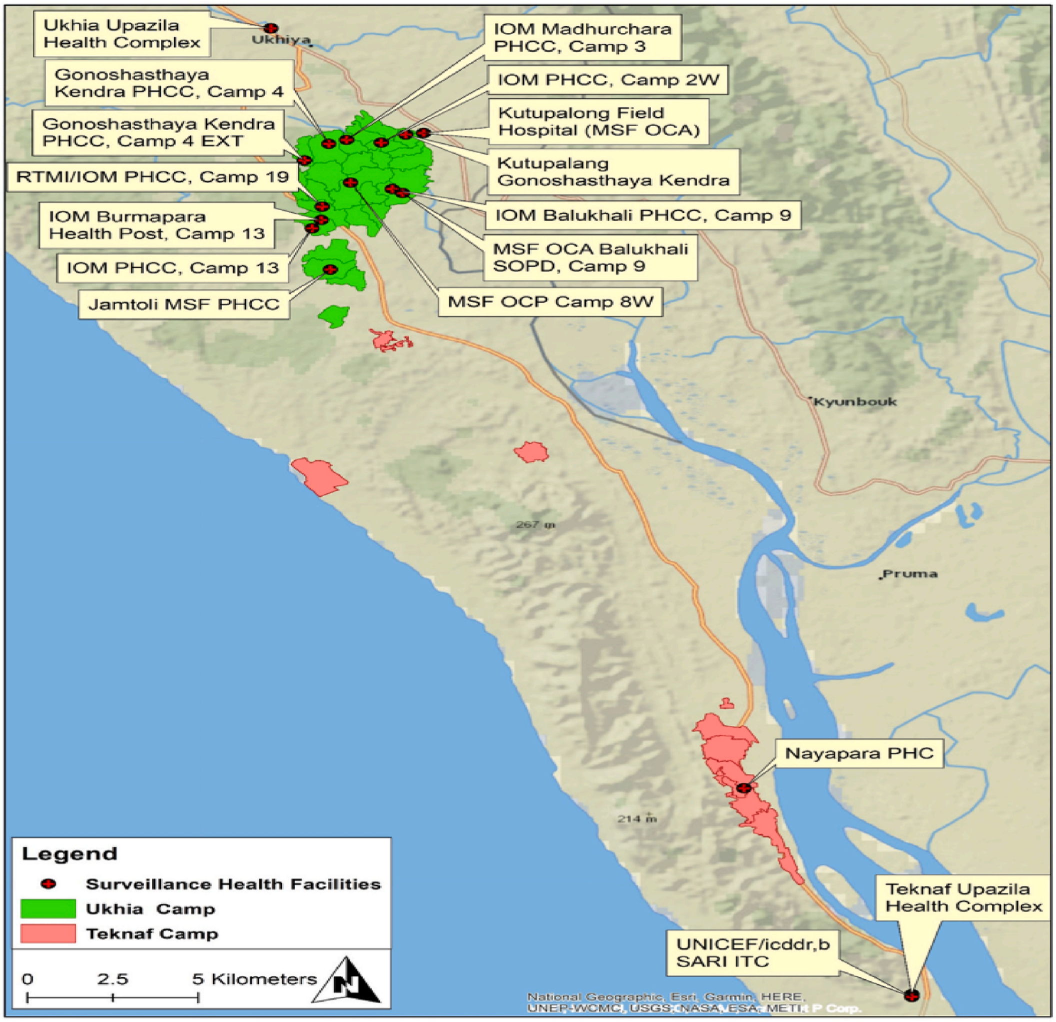


**Fig. 3.** Spatial data Source: Humanitarian Data Exchange" RRRC, Inter Sector Coordination Group (ISCG), Site Management Sector, UNHCR, IOM" https://data.humdata.org/dataset/outline-of-camps-sites-of-rohingya-refugees-in-cox-s-bazar-bangladesh?. GPS location collected by icddr'b Basemap esri open source map.

This cholera surveillance system played a crucial role in developing targeted interventions to prevent cholera outbreaks in the makeshift camps by providing evidence of *V. cholerae* transmission, real-time reporting of every RDT positive and culture-confirmed cases in EWARS system, regular reporting to health authorities of Government of Bangladesh and other stakeholders, helping local rapid response team to the breakdown the spread of the disease and aiding policymakers in decision making of conducting OCV campaign. In response to the upsurge of cholera cases detected in the surveillance system in 2019, two rounds of reactive OCV campaigns were conducted among Rohingya Myanmar national children aged less than five years from 8 to 14 December 2019, and 15 to 20 February 2020 [6]. In addition, the last round of the OCV campaigns was conducted in response to the surge in cholera cases in October–November 2021 [6]. Thus, the cholera detection rate decreased significantly. In 2022 and also in the first quarter of 2023, two peaks of cholera cases were again observed through this cholera surveillance network. Based on continuous monitoring of the sentinel cholera surveillance data, another round of OCV campaigns can be planned in 2024 prior to pre-monsoon ~~season~~ or post-monsoon season.

In situations where there is limited access to modern facilities, a rapid diagnostic test can be useful potential enteropathies like cholera [34]. Using cholera RDT in facility level in the Rohingya camp settings helped in early detection in facility level which helped in better case management and establishing referral pathway for cholera cases in health facilities having diarrhea isolation and treatment centers. The surveillance system implemented in the Rohingya camps in Cox's Bazar has profound implications for public health policy and practice in similar refugee or crisis settings. Its success underscores the importance of early detection and response mechanisms for cholera and other enteric diseases, facilitating timely interventions that can prevent widespread outbreaks. The robust data collection supports evidence-based policy formulation, highlighting the ongoing investment in water, sanitation, and hygiene (WASH) infrastructure. By refining targeted vaccination strategies using surveillance data, we can enhance the effectiveness of oral

**Table 03**
Socio-demographic and Disease Characteristics of Rohingya Myanmar nationals according to confirmed cholera.

| Factor | Levels | Enrolled diarrheal cases | Culture Test | | |
|---|---|---|---|---|---|
| | | (N = 17,252) | Negative (N = 17,013) | Positive (N = 239) | p value |
| Socio-demographic factors | | | | | |
| Age group | <2 years | 11074 (64 %) | 10945 (99 %) | 129 (1 %) | 0.000 |
| | 2–4 years | 528 (3 %) | 493 (93 %) | 35 (7 %) | |
| | 5–17 years | 725 (4 %) | 713 (98 %) | 12 (2 %) | |
| | ≥18 years | 4924 (29 %) | 4861 (99 %) | 63 (1 %) | |
| Sex | Male | 8760 (51 %) | 8633 (99 %) | 127 (1 %) | 0.503 |
| | Female | 8492 (49 %) | 8380 (99 %) | 112 (1 %) | |
| Educational status | Child or No Education | 16138 (94 %) | 15907 (99 %) | 231 (1 %) | 0.338 |
| | Up to V | 458 (3 %) | 456 (100 %) | 2 (0 %) | |
| | VI to X | 265 (2 %) | 262 (99 %) | 3 (1 %) | |
| | XI & Above | 59 (1 %) | 58 (98 %) | 1 (2 %) | |
| Occupational status | Child or Student | 12855 (76 %) | 12670 (99 %) | 185 (1 %) | 0.287 |
| | Unemployed | 601 (4 %) | 597 (99 %) | 4 (1 %) | |
| | Employed | 3463 (20 %) | 3415 (99 %) | 48 (1 %) | |
| Family member | ≤4 | 5979 (35 %) | 5910 (99 %) | 69 (1 %) | 0.064 |
| | >4 | 10956 (65 %) | 10790 (98 %) | 166 (2 %) | |
| **WASH behavior** | | | | | |
| Water treatment | | 2406 (15 %) | 2382 (99 %) | 24 (1 %) | 0.081 |
| Use latrine | | 16214 (99 %) | 15983 (99 %) | 231 (1 %) | 0.130 |
| Use soap after defecation | | 15946 (97 %) | 15719 (99 %) | 227 (1 %) | 0.348 |
| Use soap before taking food | | 13849 (84 %) | 13642 (99 %) | 207 (1 %) | 0.031 |
| **Disease characteristics** | | | | | |
| Diarrhea type | Acute watery | 16335 (99 %) | 16105 (99 %) | 230 (1 %) | 1.000 |
| | Invasive | 103 (1 %) | 102 (99 %) | 1 (1 %) | |
| Nature of stool | Loose watery | 15933 (92 %) | 15741 (99 %) | 192 (1 %) | 0.000 |
| | Rice watery | 1242 (7 %) | 1195 (96 %) | 47 (4 %) | |
| | Bloody | 55 (1 %) | 55 (100 %) | 0 (0 %) | |
| | Semi solid | 21 (0 %) | 21 (100 %) | 0 (0 %) | |
| | Solid | 1 (0 %) | 1 (100 %) | 0 (0 %) | |
| Vomiting | | 8279 (48 %) | 8100 (98 %) | 179 (2 %) | 0.000 |
| Dehydration | | | | | 0.000 |
| | Some | 10535 (61 %) | 10397 (99 %) | 138 (1 %) | |
| | Severe | 572 (3 %) | 514 (90 %) | 58 (10 %) | |
| Abdominal cramp | | 10025 (61 %) | 9897 (99 %) | 128 (1 %) | 0.093 |
| Fever | | 8152 (47 %) | 8046 (99 %) | 106 (1 %) | 0.401 |

cholera vaccine (OCV) campaigns. Integrating these surveillance systems with existing health infrastructure and engaging the community are critical steps. Utilizing local languages and culturally aware community health workers can further enhance participation and effectiveness. In our study, 3.5 % RDT positivity rate represents the detection of cholera in a high-risk environment, such as a refugee camp, where living conditions can accelerate the spread of infectious diseases. Even a small percentage of positive cases can lead to substantial morbidity and mortality if not promptly and effectively managed. Therefore, despite the seemingly nominal percentage, the situation warrants serious attention and action to prevent a larger outbreak.

The major strength of this study is that the surveillance team has expertise and experience in conducting nationwide hospital-based cholera surveillance since 2014. All the surveillance sites were selected for their geographical location which covers almost entire geographical area of all the camps and these sites were located within 30 min distance of households. All the results of this study were incorporated with WHO EWARS system. In response to any notification of cholera cases from the surveillance team, triggered to activate a joint assessment and response team (JART) to follow up the cases, identify the sources and restrict the transmission. This surveillance has been the only source of culture confirmed cholera data and by using this data reactive OCV campaigns were carried out among the Rohingya population. Surveillance was conducted with the support of the government and national and international NGOs and data generated from this also helps policymakers initiate cholera preparedness and response plan including the implementation of the OCV campaign. Significantly, our study stands out as one of the pioneering efforts to establish a comprehensive, long-term cholera surveillance system within a major refugee crisis context. Over a span of six years, our research has provided invaluable real-time data. Unlike previous studies, which often focus on short-term outbreaks or limited datasets, our research offers a detailed epidemiological analysis of cholera and other enteric pathogens among the Rohingya in Cox's Bazar.

Despite facing numerous challenges during the COVID-19 lockdown in camp areas, we persevered in conducting cholera surveillance among the Rohingya refugee camps in Ukhia and Teknaf for over five years. Unfortunately, surveillance had to be temporarily halted for three months (April to June 2020) due to pandemic-related restrictions. The major challenge was communication with the Rohingya community and understanding their local language which is not similar to Bangla. To overcome this challenge, we hired surveillance staff from the local Bangladeshi community who could understand the Rohingya language. Another limitation of this study is that we didn't follow up on the mortality due to confirmed or suspected cholera cases. As the vaccination cards wasn't readily available during the enrollment period, we were unable to incorporate the enrolled patients' vaccination records into the analysis.

**Table 04**
Association of socio-demographic variables with cholera among Rohingya Myanmar Nationals.

| | | RDT Test | | | | Culture Test | | | |
|---|---|---|---|---|---|---|---|---|---|
| Factors | Levels | Crude OR (95%CI) | p value$ | Adj. OR# (95%CI) | p value | Crude OR (95%CI) | p value$ | Adj. OR& (95%CI) | p value |
| Age group | <2 years | Ref. | | | | | | | |
| | 2–4 years | 3.05 (2.21, 4.22) | 0.000 | 4.24 (2.97, 6.05) | 0.000 | 6.02 (4.1, 8.85) | 0.000 | 5.72 (3.84, 8.53) | 0.000 |
| | 5–17 years | 2.17 (1.57, 2.99) | 0.000 | 3.09 (1.99, 4.81) | 0.000 | 1.43 (0.79, 2.59) | 0.242 | 1.91 (0.97, 3.75) | 0.060 |
| | ≥18 years | 1.17 (0.97, 1.41) | 0.099 | 2.09 (1.49, 2.94) | 0.000 | 1.1 (0.81, 1.49) | 0.539 | 1.53 (0.91, 2.55) | 0.105 |
| Sex | Male | Ref. | | | | | | | |
| | Female | 0.86 (0.73, 1.01) | 0.073 | 0.73 (0.59, 0.91) | 0.004 | 0.91 (0.7, 1.17) | 0.462 | 0.91 (0.69, 1.19) | 0.491 |
| Educational status | Child or No Education | Ref. | | | | | | | |
| | Up to V | 0.7 (0.37, 1.32) | 0.274 | – | – | 0.3 (0.08, 1.22) | 0.092 | 0.28 (0.07, 1.16) | 0.080 |
| | VI to X | 0.85 (0.4, 1.82) | 0.682 | – | – | 0.79 (0.25, 2.48) | 0.684 | 0.73 (0.23, 2.35) | 0.598 |
| | XI & Above | 1.1 (0.27, 4.53) | 0.891 | – | – | 1.19 (0.16, 8.61) | 0.865 | 1.05 (0.14, 7.76) | 0.959 |
| Occupational status | Child or Student | Ref. | | | | | | | |
| | Unemployed | 0.75 (0.44, 1.26) | 0.276 | 0.63 (0.35, 1.14) | 0.127 | 0.46 (0.17, 1.24) | 0.124 | 0.4 (0.14, 1.17) | 0.095 |
| | Employed | 0.66 (0.51, 0.84) | 0.001 | 0.55 (0.38, 0.79) | 0.001 | 0.96 (0.7, 1.33) | 0.815 | 0.82 (0.48, 1.39) | 0.459 |
| Family member | ≤4 | Ref. | | | | | | | |
| | >4 | 1.01 (0.84, 1.21) | 0.937 | – | – | 1.32 (0.99, 1.75) | 0.056 | 1.2 (0.9, 1.6) | 0.222 |
| Water treatment | Yes | Ref. | | | | | | | |
| | No | 1.22 (0.9, 1.65) | 0.211 | – | – | 1.49 (0.97, 2.27) | 0.068 | 1.54 (1.01, 2.37) | 0.046 |
| Use latrine | Yes | Ref. | | | | | | | |
| | No | 0.37 (0.09, 1.5) | 0.163 | 0.32 (0.08, 1.33) | 0.118 | 0 (0, Inf) | 0.960 | – | – |
| Use soap after defecation | Yes | Ref. | | | | | | | |
| | No | 1.6 (0.99, 2.59) | 0.055 | 1.77 (1.08, 2.9) | 0.023 | 0.57 (0.21, 1.53) | 0.263 | – | – |
| Use soap before taking food | Yes | Ref. | | | | | | | |
| | No | 1.06 (0.81, 1.39) | 0.669 | – | – | 0.62 (0.4, 0.94) | 0.026 | 0.6 (0.39, 0.92) | 0.020 |

$ Factors having p value < 0.20 in bivariate analysis have been considered for multivariate analysis; # Adjusted for age, sex, occupation, using latrine and using soap after defecation; & Forcibly adjusted for age and sex with education, occupation, number of family member, water treatment and using soap before taking food.

Potential barriers include resource constraints, which can be mitigated through sustainable funding, partnerships with NGOs. Ensuring data privacy and security is paramount, requiring robust policies and secure digital platforms. The system's modular design allows for scalability and adaptability to various humanitarian contexts, making it a versatile model for crisis settings globally.

Overall, our study advances the understanding of cholera dynamics in refugee populations, offering practical solutions and policy recommendations to mitigate future outbreaks. Furthermore, our study demonstrates the effectiveness of integrating rapid diagnostic tests (RDTs) with microbiological culture confirmation, enhancing early detection and case management.

## 5. Conclusion

In Cox's Bazar, the surveillance system has played a pivotal role in detecting and responding to cholera outbreaks among the Rohingya refugees. By integrating this system with existing health infrastructure, it has facilitated timely public health responses and informed targeted vaccination strategies. These findings highlight the critical role of robust surveillance in managing public health crises and offer a blueprint for similar humanitarian settings globally.

## Funding

This research was funded by the United Nations Children's Fund (UNICEF) (BGD/PCA201840/PD2019319).

## Data availability statement

The raw data supporting the conclusions of this article will be made available by the authors, with some reservation and priority base.

## CRediT authorship contribution statement

**Ashraful Islam Khan:** Writing – review & editing, Writing – original draft, Visualization, Validation, Supervision, Resources, Project administration, Methodology, Investigation, Conceptualization. **Md. Taufiqul Islam:** Writing – review & editing, Writing – original draft, Visualization, Validation, Supervision, Software, Project administration, Methodology, Investigation, Formal analysis, Conceptualization. **Nabid Anjum Tanvir:** Writing – review & editing, Writing – original draft, Visualization, Methodology, Investigation, Data curation. **Zahid Hasan Khan:** Writing – review & editing, Writing – original draft, Visualization, Supervision, Project administration, Investigation. **Mohammad Ashraful Amin:** Writing – review & editing, Writing – original draft, Visualization, Validation, Data curation. **Md. Golam Firoj:** Writing – review & editing, Visualization, Software, Methodology, Formal analysis, Data curation. **Md. Mokibul Hassan Afrad:** Writing – review & editing, Project administration, Investigation, Formal analysis, Data curation. **Yasmin Ara Begum:** Writing – review & editing, Writing – original draft, Visualization, Validation, Supervision. **Abu Toha M.R.H. Bhuiyan:** Writing – review & editing, Visualization, Project administration. **ASM Mainul Hasan:** Writing – review & editing, Visualization, Project administration, Investigation, Funding acquisition, Conceptualization. **Tahmina Shirin:** Writing – review & editing, Visualization, Validation, Supervision, Project administration, Conceptualization. **Firdausi Qadri:** Writing – review & editing, Visualization, Supervision, Project administration, Investigation, Conceptualization.

## Declaration of competing interest

The authors declare the following financial interests/personal relationships which may be considered as potential competing interests:Dr. Firdausi Qadri reports administrative support and statistical analysis were provided by International Centre for Diarrhoeal Disease Research Bangladesh. If there are other authors, they declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

## Acknowledgements

The icddr,b is grateful to the governments of Bangladesh, and Canada for providing core/unrestricted support. We would like to thank the participants and all study staff for supporting the surveillance and to the physicians, administration, and health officials at each recruitment sites who generously provided facilities and support to carry out the surveillance.

## Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.heliyon.2024.e37562.

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