



Outbreak Investigation of Cholera in Kamaran Island, Hodeidah, Yemen: Ecological study

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Abstract

Background: Yemen, in particular, face challenges with compromised sanitation conditions, while maintaining a clean physical environment is the responsibility of local communities, ensuring adequate sanitation remains a pressing concern. **Objectives:** The study aimed to describe the ecological characteristics of cholera outbreak in Kamaran Island, Hodeidah, Yemen. **Methodology:** The research included descriptive observation ecological study and pilot experimental study that were carried out from July and August 2018 in Kamaran Island of Hodeidah, Yemen that is high war area and difficult to access. The study included 179 of suspected cases that were diagnosed clinically according to national and world health organization (WHO) guideline. 6/179 fecal samples of patients were diagnosed in laboratory. In addition, 7 of water samples were collected from the source and the coliform and cholera in water were isolated. On the other hand, the chlorine in water samples were detected. **Results:** The patients with diarrhea aged from 1 to 85 years (179 cases) were investigated. The males/ females ratio (%) was 44 % : 56 % (79/100). The attack rate (AR) was reported about 4.096 % and 1 case was dead with the case fatality rate (CFR) was 0.55 % (1 /179 cases). In addition, 6 fecal samples of severe cases were positive with *Vibrio cholerae* (*V. cholerae*), based on rapid test and 1 fecal sample of death case was confirmed using gold standard microbiological method. On the other hand, the fecal coliforms were confirmed in all water samples collected (7/7; 100 %) associated with zero chlorine detected. Also, the cholera was isolated and confirmed in drinking water (1/7; 14.42 %). **Conclusion:** Our findings highlight the urgent need to improve water infrastructure, sanitation, and access to clean water, water chlorination and vaccination campaign in Kamaran Island, Hodeidah, Yemen, to control and prevention of cholera outbreaks. Also, strengthening health awareness, surveillance, resource availability, and international collaboration, along with regular response evaluations, is essential for improving public health and combating the epidemic.

Keywords: Cholera, Outbreak, Ecological, Chlorine, Water, Kamaran Island, Yemen

1. Introduction

According to the World Bank, Yemen falls within the lower-middle-income category [1]. Since March 2015, an armed conflict has been ongoing and persists to the present day, leading to a profound humanitarian crisis affecting the population [2]. The protracted displacement of populations, disruptions in infrastructure, and deteriorating water and sanitation conditions have collectively played a role in escalating one of the most severe cholera outbreaks in recent history [3,4]. Cholera manifests as a disease characterized by severe watery diarrhea is, a result of infection by the bacterium *Vibrio cholerae* (*V. cholerae*), commonly spread through contaminated water sources [5,6]. Cholera is diagnosed clinically following the world health organization (WHO) case definition and is confirmed through laboratory tests identifying *V. cholerae* 01 or 0139 in a patient's diarrhea or vomit samples [7,8]. Cholera outbreaks continue to pose a significant public health threat due to their potential for rapid spread and high mortality rates if left untreated [9]. Ending Cholera: a Global Roadmap to 2030" was introduced in October 2017. Subsequently, it became evident that further evidence is necessary to support countries in cholera control efforts, emphasizing the need for a prioritized research agenda to target resources effectively towards addressing key issues relevant to Roadmap implementation [10]. The true extent of the global impact of cholera remains uncertain due to underreporting, which stems from various factors including insufficient resources for surveillance and laboratory testing [11]. As well as socio-political and economic barriers to reporting [12]. One such outbreak occurred in Yemen, 2017 [13]. The investigation into this outbreak was crucial to understanding the

epidemiology of cholera in this region and implementing effective control measures to prevent future occurrences. Through a detailed examination of patient demographics, clinical presentations, and laboratory findings. This research sheds light on the impact of cholera in vulnerable populations and underscores the urgent need for improved sanitation practices and access to safe drinking water [14,15]. By integrating lessons learned from this investigation, public health authorities can develop targeted interventions to mitigate the impact of cholera outbreaks and safeguard community health in resource-constrained settings [16]. The study aimed to describe the ecological characteristics of cholera outbreak in Kamaran Island, Hodeidah, Yemen.

2. Methodology

The study involved observational ecological and pilot experimental studies in Kamaran Island, Hodeidah, Yemen that were carried out based on outbreak investigation in 10 steps:

- 1) **Preparation for field work:** team composition: professors and consultants in epidemiology, internal medicine specialists, epidemiologist and microbiologists.
- 2) **Establish the existence of an outbreak:** confirmed unusual increase in cases of cholera
- 3) **Verify the diagnosis:** Cholera diagnosis, samples collection, the stool specimens taken from patients, rapid test as primary screening, bacterial culture: cultured on Thiosulfate-Citrate-Bile-Sucrose (TCBS) agar to isolate and confirm *V. cholerae*, clinical findings supported by: reference hospital reports, hematological and biochemical analyses. The laboratories confirmed the cases were Center of Tropi-

cal Medicine and Infectious Diseases (CTMID) - Authority of Public AL Thawara Hospital, Hodeidah, Yemen, or National Center of Public Health Laboratories (NCPHL), Sana'a, The studies conducted in Kamaran Island, Hodeidah, Yemen, the data were collected from 179 suspected cases of cholera using WHO case definitions (acute watery diarrhea more than 3 times within 24 hours). The samples collection and questionnaires, fecal analysis, and water analysis were conducted to confirm cholera status.

- 4) **Construct a working case definition:** developed a national case definition based on WHO guideline categories: mild, moderate, severe, critical cases.
- 5) **Systematic case finding and information recording:** comprehensive data collection on identified cases, data were initially fed into excel and then imported for analysis.
- 6) **Perform descriptive epidemiology:** data summarized to characterize the outbreak: descriptive biostatistics used included range, median, percentage, case fatality rate (CFR %), and attack rate (AR %).
- 7) **Evaluate hypotheses epidemiologically:** descriptive study design: descriptive observations, ecological study design, and pilot experimental study.
- 8) **Implement control and prevention measures:** Chlorine Detection in Water: Residual chlorine Tests: Conduct DPD (N,N-diethyl-p-phenylenediamine) tests to measure chlorine concentration in water, chlorine Meters: use electronic devices to accurately measure chlorine levels, cholera in water: water sample collection: collect samples from suspected water sources, bacterial culture: culture samples to identify *V. cholerae*, control and prevention strategies executed, continued monitoring by CTMID, epidemiological surveillance and control diseases administration.
- 9) **Communicate findings:** reports presented orally and in writing to: AL Thawrah Public Hospital, Hodeidah, Public Health and Population Office, Hodeidah Governorate and Non - governmental organization (NGOs), medical reports of patients were also reviewed.
- 10) **Initiate or maintain surveillance:** both active and passive surveillance systems were established [17-19].

3. Results

3.1. Social determinants

179 of cholera cases were investigated and reported, comprising 79 males (44%) and 100 females (56%). Statistical analysis using a chi-square goodness-of-fit test yields a value of $\chi^2=2.464$ with a p -value of 0.116. The result indicated no significant association between gender and cholera incidence. The age of patients ranged from 1 to 85 years, with a median age of 40 years.

3.2. Morbidity, mortality and outcome

The severity of cases predominantly fell within the mild to moderate category namely 173 cases (96.7%) of cases. Severe cases constituted only 6 cases (3.3%) of the total. Outcomes were overwhelmingly positive, with a recovery rate was 178 cases (99.5%). Only one death was reported, resulting in a the attack rate (AR) in cholera outbreak of Kamaran Island was 4.09 % (179 cases out of a population of 4370). One the other mean, 40.9 cases per 1000 population. On the other hand, the case fatality rate (CFR) of 1/179 cases (0.5%).

Table 1. Epidemiological and clinical data of outbreak in Kamaran Island, Hodeidah, Yemen.

Variables	(n)	(%)	χ^2	p-value
Sex				
Males	79	44	2.46	0.116
Females	100	56		
Age				
Median	40		NA	
Range	1-85			

Severity			
Mild and Moderate	173	96.7	NA
Severe	6	3.3	
Outcome			
Recovery	178	99.5	NA
Death	1	0.5	
NA: Non - applicable, *: p -value (significant < 0.05)			

3.3. Environmental determinants

Samples of water was (7/7 ;100 %) was coliform contaminated. while 1/7 (14,28%) of water samples was contained by cholera. Samples collected (7/7 ;100 %) associated with zero chlorine detected.

Table 2. Ecological data of outbreak in Kamaran Island, Hodeidah, Yemen

Samples	chlorine	Coliform	Cholera
1	Zero	Positive	Negative
2	Zero	Positive	Negative
3	Zero	Positive	Negative
4	Zero	Positive	Negative
5	Zero	Positive	Positive
6	Zero	Positive	Negative
7	Zero	Positive	Negative

4. Discussion

The study involved observational ecological study and pilot experimental studies, given the challenging circumstances of the conflict-affected area and limited accessibility to healthcare facilities by collecting epidemiological data, analyzing fecal samples for diagnosis, and testing water sources for the presence of *V. cholerae* [14]. Our finding suggested that cholera's spread was unrelated to gender differences, highlighting the need for universal preventive measures and interventions. The age of affected individuals ranged widely, from 1 to 85 years, with a median age of 40 years. This broad range illustrates that cholera did not disproportionately impact any specific age group, underscoring the vulnerability of all demographics in areas with poor water and sanitation conditions. However, statistical analysis focusing on age vulnerability was not conducted due to the absence of comparative data. Although this indicates a favorable prognosis for most patients, it also raises questions about potential underlying factors contributing to disease severity in the minority of severe cases. This low fatality rate demonstrates the efficacy of medical responses during the outbreak, due to less than 1 %. While, the CFR of untreated cases was 25 – 50 % [20].

Environmental changes also contribute significantly to the situation. Heavy rainfall, floods, and impactful weather patterns such as El Niño intensify water source contamination in Yemen, facilitating the migration of cholera-affected insects (chironomids) from the Horn of Africa to Yemen [21]. Improved sanitation, and enhanced healthcare services have revolutionized living conditions in many parts of the world. Despite these advancements, cholera is still believed to have an ongoing presence in 69 countries, with the majority of Yemen being included in this category [22]. To mitigate the ongoing pandemic and prevent its spread, implementing a sustainable solution is essential. In addition, conducting cholera vaccination campaigns is essential for preventive measures [23,24]. In Yemen, the destruction of water networks due to frequent air strikes has increased the risk of widespread infection since water sources have been compromised. In the absence of a comprehensive cholera preparedness and response plan, humanitarian groups quickly developed response strategies when discovered. However, these initial plans failed to prioritize essential actions. On the other mean, the crisis-focused groups and the incident management system dedicated to the pandemic were not coordinated effectively. The current health strategy has been primarily crisis-oriented, with a central focus on functioning health facilities, which may lead to the neglect of hard-to-reach areas. Given the delay in integrating vaccination into preparedness efforts, consensus on its use has been slow. At

the height of the second wave, critical actions such as community-focused water, sanitation, and hygiene (WASH) interventions to reduce transmission, epidemiological analysis, and laboratory monitoring, data management, and the establishment of diarrhea treatment centers for fluid rehydration (both oral and intravenous) and vaccination were still pending [25]. Water and sanitation play a crucial role in cholera prevention and are key considerations in setting priorities for National Cholera Plans (NCPs). The Global Task Force on Cholera Control (GTFCC) provides guidance on how to prioritize locations for comprehensive interventions, with a primary focus on historical suspected cholera cases. However, the lack of reliable data on water and sanitation access at the operational level poses a significant challenge to incorporating these factors systematically into prioritization efforts. Moreover, conflicts and natural disasters can result in diminished access to water and sanitation facilities, thereby increasing the risk of cholera outbreaks in regions previously unaffected by the disease [26]. Additionally, the airstrikes result in water contamination, restricted transportation options, and delays in treating cholera patients promptly. The air raids also contribute to extensive displacement, creating challenges in accessing adequate WASH [27].

Severe rainfall can overwhelm or damage sewage systems, exposing communities to contaminated water and human waste, often triggering disease outbreaks. This contrasts with endemic cholera, where outbreaks are typically caused by the intrusion of bacteria-laden seawater into coastal and island regions due to tidal movements [28]. In regions prone to cholera outbreaks, a variety of effective measures can be implemented, including community-led initiatives to eliminate open defecation, the construction of adequate sanitation facilities, ensuring access to clean household water, strengthening water quality monitoring, promoting the use of sodium hypochlorite for water disinfection, improving fecal waste management systems, and expanding the availability and use of handwashing facilities [29].

5. Conclusion

Our finding obtained concluded an urgent need to improve water infrastructure and sanitation conditions to ensure the health and safety of the community. And access to clean water and vaccination and vaccination campaign in Kamaran Island, Hodeidah, Yemen to effectively control cholera outbreaks. Also to increase health awareness, strengthen surveillance systems, provide health resources, collaborate with international organizations, conduct regular response evaluations by implementing these recommendations, significant progress can be made in controlling the cholera epidemic and improving the health of the population in Yemen.

Data Availability

No data were used to support this study.

Conflicts of Interest

The authors declare that they have no conflicts of interest.

Acknowledgments

This work was conducted during our work at CTMID – Al Thawara Public Hospital Authority, Hodeidah, Yemen.

Ethical Approval

The studies involving human participants were reviewed and approved by Ethics Committee of Tropical Medicine and Epidemiology Studies of Hodeidah University (CTMES-HU) Hodeidah, Yemen.

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