REVIEW ARTICLE

Emergence of Mosquito-borne Viruses in Iran and Adjacent Countries: The Case of Chikungunya

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Abstract

Background: Scientific overwhelming evidence confirms that the prevalence and incidence of mosquito-borne viruses such as chikungunya (CHIK) are dramatically increasing in Middle-Eastern countries including Iran.

Methods: In this review article, using relevant keywords ("Chikungunya" OR "CHIKV" OR "*Aedes albopictus*" OR "*Aedes aegypti*"), available literature was searched to collect data related to the reports of CHIK and its main vectors, *Aedes albopictus* and *Ae. aegypti*, in Iran and 15 neighboring countries: Pakistan, Afghanistan, Turkmenistan, Russia, Azerbaijan, Armenia, Turkey, Iraq, Kuwait, Bahrain, Qatar, United Arab Emirates (UAE), Oman, Saudi Arabia, and Yemen.

Results: CHIK was reported in neighboring countries such as Pakistan, Turkey, Russia, Saudi Arabia, Yemen, Oman, Qatar, and Iraq. Furthermore, presumably introduced in 2019, CHIK was reported in 11 provinces in Iran with overall seropositivity of 17.23% in humans over the past three years. The mosquitoes, *Ae. albopictus* and *Ae. aegypti*, have recently been reported in the southeast and south of Iran.

Conclusion: Given the change in climate, even if the density of the vectors is still limited, there is no guarantee that their population will not spread much more in the coming years. This emphasizes the urgent need to strengthen the surveillance system for the vectors, and sustained surveillance of CHIK infections in mosquitoes and humans, preferably in a collaborative international project.

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Keywords: Vector borne diseases, Chikungunya fever, *Aedes*, Middle East, Iran

Introduction

Zoonotic diseases account for about 73% of emerging infectious diseases worldwide, causing high mortality rates and substantial economic burden[1] like malaria.[2] Among these zoonoses, several arboviral (arthropod-borne viral) diseases have caused serious public health concerns in the last decades due to their major emergence and/or re-emergence.[3] These infections range from asymptomatic to incapacitating and febrile conditions, leading to physical disability, mental impairment, and even death.[4, 5] Chikungunya (CHIK) is caused by the *chikungunya virus* (CHIKV) which is an *Alphavirus* (Family: *Togaviridae*), transmitted through the bites of infected female mosquitoes of the Culicidae family, mainly by *Aedes albopictus* and *Ae. aegypti*.[6, 7] The CHIKV is mainly divided into four genotypes according to phylogenetic analysis: ECSA (East/Central/South

African), West African, Asian,[7] and recently reported Indian Ocean Lineage (IOL).[8]

In the vertebrate host, CHIKV directly enters the subcutaneous capillaries and then multiplies in macrophages, fibroblasts, and endothelial cells.[9] The more common symptoms are headache, febrile exanthema, joint pain, persistent myalgia, recurrent fevers, macular and maculopapular rashes, tenosynovitis, diarrhea, and vomiting.[10, 11] Furthermore, some patients may suffer from cardiovascular, neurological, pulmonary, and renal dysfunctions.[12] Although CHIKV infection is not usually fatal, it can damage the central nervous system (CNS).[13, 14] The fatality rate is around 1 in 1,000 with most deaths occurring in infants, the elderly, and individuals with comorbidity.[15] One of the largest outbreaks of CHIK was reported in India and Sri Lanka in 1962 which infected about 100,000 people and caused 200 deaths.[16] Because CHIK develops similar symptoms to those caused by dengue and Zika viruses, its diagnosis is complicated; therefore, CHIKV is often under-reported.[5, 17, 18] CHIKV has a large distribution. This virus has been reported in at least 60 countries and has caused more than 6 million cases.[19] During the last decade, CHIK outbreaks have been reported repeatedly in Africa and Asia with inter-epidemic periods of 2 to 20 years.[20] Meanwhile, estimation of the real burden of CHIKV is challenged by considering the large proportion of asymptomatic patients.[18, 21, 22]

Countries of the Middle East are not an exception from the emergence of vector-borne pathogens such as Crimean-Congo hemorrhagic fever virus (CCHFV) and CHIKV. Among these countries, Iran offers diverse bioclimatic regions suitable to different mosquito vectors and pathogens to be introduced from neighboring countries with poor public health facilities.

Methods

In this review, we summarize up-to-date relevant researches available in Google Scholar, PubMed, Scopus, and Science Direct databases related to CHIK and its main vectors, *Ae. albopictus* and *Ae. aegypti*, in Iran and 15 neighboring countries: Pakistan, Afghanistan, Turkmenistan, Russia, Azerbaijan, Armenia, Turkey, Iraq, Kuwait, Bahrain, Qatar, United Arab Emirates (UAE), Oman, Saudi Arabia, and Yemen. We made an attempt to cover the most recent articles for this literature review (up to March 1, 2022). To identify the potentially related articles in terms of virus epidemiology and geographical distribution, we applied the following keywords and search terms in combination: ("Chikungunya" OR "CHIKV" OR "*Aedes albopictus*" OR "*Aedes aegypti*" AND "Iran" OR "Pakistan" OR "Afghanistan" OR "Turkmenistan" OR "Russia" OR "Azerbaijan" OR "Armenia" OR "Turkey" OR "Iraq" OR "Kuwait" OR "Bahrain" OR "Qatar" OR "United Arab Emirates" OR "UAE" OR "Oman" OR "Saudi Arabia" OR "Yemen"). Screening of the titles and abstracts was conducted by two different researchers. Then, the full text of the relevant publications was read and the eligible references were also determined. Any disagreements were discussed and resolved. In addition to the geographical distribution of CHIKV and its main vectors, our purpose was to indicate the presence or absence of the virus and their vectors in the studied countries. As a result, some of the data related to the distribution of CHIKV and its main vectors were not reviewed.

The Risk of CHIK Transmission in Iran and Adjacent Countries

In the study area, rise in temperature has contributed to the spread of multiple arboviral infections.[23] Recently, CHIK has been reported in Iran,[24, 25] and after the prevalence of the disease in Pakistan,[23, 26] Iraq,[27] Yemen,[28, 29] Saudi Arabia,[30] Turkey,[10, 11] Oman,[31] Russia,[32] and Qatar,[33] the threat of large CHIK outbreaks in the Middle East has been posed.

Increasing reports of the main vectors of CHIKV, *Ae. aegypti* and *Ae. albopictus*, in Iran and neighboring countries over the past decades have led to a high potential risk of CHIK emergence as well as cross-border virus spread among different countries in this part of the world.[34] *Ae. albopictus* has spread rapidly throughout the world and is considered a competent vector for at least 22 arboviruses including CHIKV.[35-38] It is an invasive species found in temperate and tropical climates.[39, 40] The other main vector of CHIKV, *Ae. aegypti*, can be found in tropical and subtropical environments near the human settlements.[41] It has been reported that *Ae. aegypti* and *Ae. albopictus* have occurred in almost 10 countries of the Middle East.[42] Multiple factors such as industrialization, poor hygiene, immigration, war, and economic disruption foster the spread of *Aedes*-borne viruses, posing the risk of CHIKV in such countries[43-45] (Table 1).

Afghanistan

During a vector surveillance program carried out in Afghanistan in 2018, both *Ae. aegypti* and *Ae. albopictus* were reported.[47] The presence of these two main vectors of CHIKV combined with frequent travels of people to endemic areas in Pakistan poses the risk of the emergence of CHIK in Afghanistan. However, in addition to the legacy of years of war and destruction of the health infrastructure, surveillance of this disease seems to be not fully functional. Further studies are needed to gather sufficient data on the prevalence of CHIKV and its vectors in Afghanistan.

Table 1: Different contributing factors of chikungunya such as the report of vectors and disease, risk of an outbreak, and necessity for vector control in Iran and 15 adjacent countries

Factors	Report of vectors		Report of chikungunya	Risk of outbreak	Current potential distribution of vectors*
	Aedes albopictus	*Aedes aegypti*			
Afghanistan	Yes	Yes	No	Yes	Yes
Armenia	Yes	No	No	Yes	Yes
Azerbaijan	No	No	No	Yes	Yes
Bahrain	No	No	No	Yes	Yes
Iran	Yes	Yes	Yes	Yes	Yes
Iraq	No	Yes	Yes	Yes	Yes
Kuwait	No	No	No	No	No
Oman	No	Yes	Yes	Yes	Yes
Pakistan	Yes	Yes	Yes	Yes	Yes
Qatar	No	Yes	Yes	Yes	Yes
Russia	Yes	Yes	Yes	Yes	Yes
Saudi Arabia	No	Yes	Yes	Yes	Yes
Turkey	Yes	Yes	Yes	Yes	Yes
Turkmenistan	No	No	No	Yes	Yes
United Arab Emirates	No	Yes	No	Yes	Yes
Yemen	No	Yes	Yes	Yes	Yes

*Current potential distribution of *Aedes aegypti* and (or) *Aedes albopictus*, predicted by;[46] available at: https://doi.org/10.1371/journal.pone.0210122.g002).

Iran

To date, four studies have reported the evidence of CHIKV circulation in Iran. The first report of CHIKV was notified in Sistan and Baluchistan province. The investigators examined 159 serum samples from CHIK-suspected individuals, exhibiting clinical signs of fever and arthritis, collected between April 2017 and June 2018, in 10 cities across Sistan and Baluchistan province. After examining the patients using serological and molecular techniques, 40 CHIKV-positive samples (25.2%) were identified. All of the positive cases declared recent travel records to Pakistan. Furthermore, phylogenetic analysis of five samples revealed that the virus was identical to the recently isolated subtype of the Pakistan epidemic belonging to the ECSA genotype, Indian Ocean sub-lineage. These findings provide strong evidence of CHIKV transmission from Pakistan to Iran. Most of the positive samples came from patients infected during spring and summer when the activities of mosquitoes were at their peak.[25] In another investigation, researchers analyzed 1,212 mosquitoes collected in Mazandaran, North-Khorasan, and Fars provinces in Iran; the Asian CHIKV genotype was identified in six different mosquitoes, 5 collected in North Khorasan and 1 in Mazandaran, suggesting that CHIKV is circulating in the north of Iran.[24] In another study, the seropositivity of IgG antibodies against CHIKV in 180 blood samples obtained from Iranian children under 14 years old was evaluated. Four blood samples (2.2%) were found to be seropositive for CHIKV in Tehran province, the capital city of Iran.[48] In another investigation, the risk of CHIK infection among measles and rubella IgM negative individuals in Iran from December 2016 to November 2017 was investigated, showing that among 1,306 serum samples, 210 were positive for CHIKV.[45] Collectively, 11 provinces, out of 31, reported the evidence of CHIKV based on molecular detection method in mosquitoes (Mazandaran (0.08%), and North Khorasan (0.41%); humans (Sistan and Baluchistan; 13.75%); and serological surveys in humans (15% and 31.12% in Sistan and Baluchistan, 17% in South Khorasan, 23% in Kerman, 18% in Hormozgan, 22% in Fars, 13% in Bushehr, 9% in Khuzestan, 22% in Ilam, and 2.2% in Tehran provinces, with overall seropositivity of 17.23% in nine provinces).[25, 45, 48]

With more than 600km border and close cultural relations with Pakistan, the risk of transboundary diseases in Iran is fearful. Additionally, low health indices and inadequate health facilities in bordering eastern regions have resulted in a more serious threat to the southeast and northeast areas in Iran.[1] Introduction of exotic mosquitoes from countries surrounding Iran pose a significant threat to the emergence of CHIK.[1] In Iran, the inventory of *Ae. albopictus* is still incomplete. Five larvae of this species were initially detected in Sistan and Baluchistan province, during a six-year entomological surveillance program in 2009. Four years later, seven mosquito adults were also identified in this province.[49] As the density of this invasive vector is low, it has a limited chance for being established.[50] However, there is no guarantee that the population of this species will not increase and spread in the coming years.[49] Ships arriving from Karachi, a city in Pakistan, are likely to introduce *Ae. albopictus* in the southeast provinces.[49] Vehicles coming from Turkey may also import this species into Iran. Recently, investigators used the analytical hierarchy process (AHP) method to model and predict the possible risk-prone zones of *Ae. albopictus* in

Iran. Five coastal areas in Gilan province in the north and six coastal counties in Khuzestan province in the southwest of Iran were labeled as main sites suitable to *Ae. albopictus*, due to the semi-tropical climate.[51] Using Geographic Information Systems (GIS) and remote sensing (RS), investigators demonstrated that the southern areas of Iran are favorable for *Ae. albopictus* populations, and the southern parts are at the highest risk of *Ae. albopictus* colonization.[39] In addition, Iran is at risk of increasing colonization of *Ae. Aegypti*. In a recent investigation, *Ae. aegypti* has been detected in Hormozgan province located near the Persian Gulf in the southern part of Iran and also in the seaports of Bandar Khamir and Bandar Lengeh.[41] Because of the warm climate, the chance of establishment of *Ae. aegypti* and CHIKV in this area is relatively high (Figure 1).

Furthermore, the infection of *Anopheles maculipennis* s.l., *Culex triateniorhynchus*, and *Culiseta longiareolata* (engorged females) to CHIKV has been reported in the north of Iran, suggesting the possible role of other species of Culicidae mosquitoes in transmission of CHIKV.[24] Several records of CHIK positive samples in neighboring countries, in combination with the report of the current occurrence of *Ae. aegypti* and *Ae.* albopictus, pose a threat of emergence of this disease in Iran. Routine surveillance of the disease and screening the hosts and vectors are suggested.

Iraq

An investigation in Nasiriyah Governorate revealed a noticeable prevalence of vector-borne flaviviruses, phleboviruses, alphaviruses, and orthobunya viruses in adult volunteers. Of 399 blood samples tested, two (0.5%) were positive for CHIKV suggesting that CHIKV may be an underlying cause of febrile diseases in this area.[27]

Murayati reported the occurrence of *Ae. aegypti* in Bagdad city, the capital of Iraq, in 1956.[52] Furthermore, some investigators have included *Ae. aegypti* in the updated checklist of mosquitoes in Iraq;[53] however, to the best of our knowledge, the presence of *Ae. aegypti* and *Ae. albopictus* has not been reported in Iraq in recent decades.[54] CHIK has been reported in humans in Nasiriyah, located in the south of Iraq, in the vicinity of two marshes, providing an appropriate area for mosquito proliferation.[27] On the contrary, most of the regions in Iraq have a hot arid climate with subtropical influence and low precipitation. Climate change in Iraq, in combination with insufficient precipitation and decreasing water of its main rivers due to dam building in Turkey, is predicted to be unfavorable to mosquito breeding.

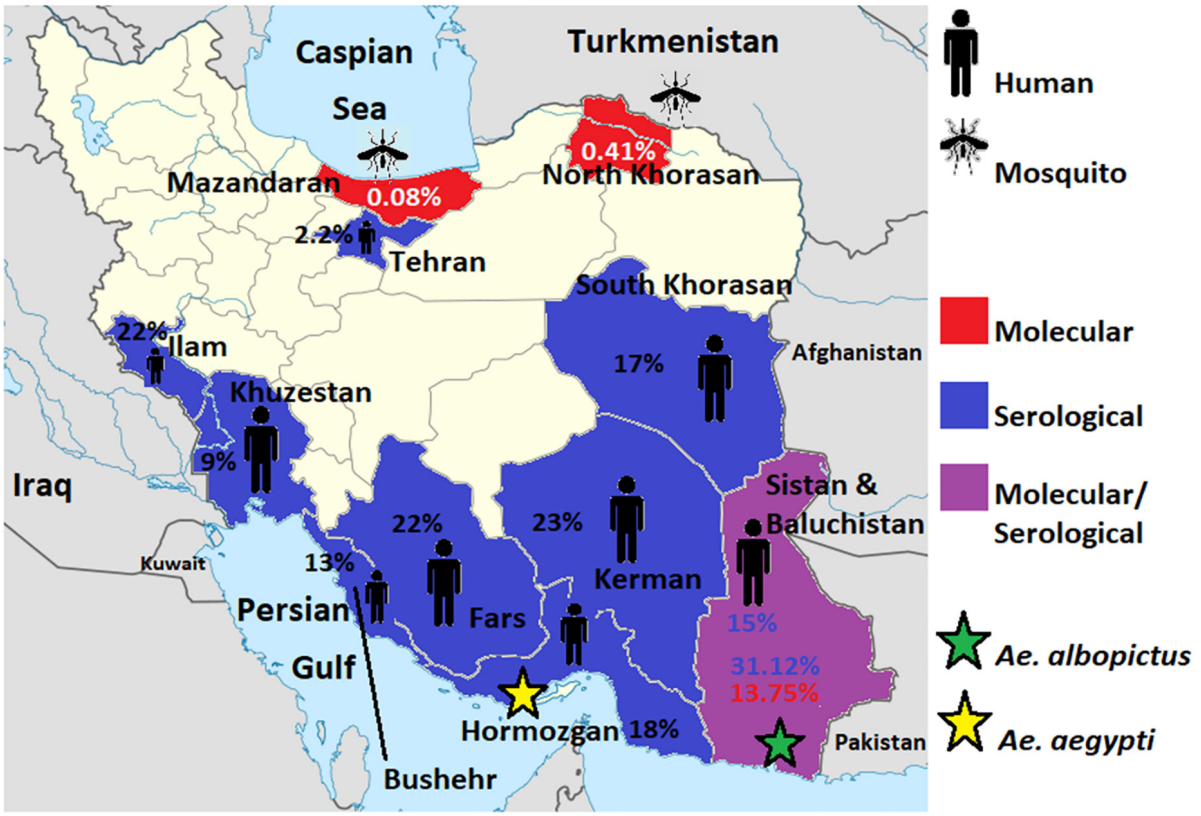

Figure 1: Molecular and serological prevalence of chikungunya fever in different provinces of Iran.[24, 25, 41, 45, 48, 49] Red: provinces where chikungunya infections were detected using molecular tools; Blue: provinces with evidence of chikungunya infection using serological method; and Purple: provinces with evidence of chikungunya infections using molecular and serological methods. Green stars indicate places with *Aedes albopictus* and yellow stars, places with *Aedes aegypti*. (The map was built using the open source map site https://commons.wikimedia.org/wiki/Category:Maps_of_Iran#/media/File:Gergeri_location_map.png).

Oman

Increasing international travels between Oman and CHIK-endemic countries like India and Pakistan may promote the introduction of CHIKV to this country. Nine Non-Omani people returning from India have been found to be infected with CHIKV.[55] The other confirmed imported case was reported with an Omani traveler from Pakistan. RT-PCR was negative for dengue virus but positive for CHIKV.[31]

Ae. aegypti has been reported in the south of Oman since 2008.[54] Further surveillance revealed the occurrence of this species along the coastline from Seeb to Muscat, located in the north of the country, where the risk of the establishment of this species is high.[56] The *Ae. aegypti* elimination campaign (2019) implemented 1,000 people in 200 teams for identifying the breeding sites, applying Temephos to stagnant water, fogging the areas with D-phenothrin where the species was found, and educating inhabitants for sustaining the control strategy.[56]

Pakistan

The first case of CHIKV detected in the Middle East was from Pakistan in 1981. There is some evidence that CHIKV has been circulating in rodents in Pakistan since 1983.[57] Pakistan experiences harsher weather in summers and milder winters, resulting in expanding arthropod-vector breeding seasons and increasing the probability of CHIK epidemics.[23] In recent years, several outbreaks have been reported in Pakistan.[23, 58] Despite the successive alerts from the National Institute of Health, Pakistan experienced its first CHIK epidemic in Karachi, infecting thousands of people. This epidemic was related to a recent outbreak in India.[58] During a dengue fever outbreak in 2011 in Lahore, cases of CHIK were reported.[59] In 2017, CHIK hit Karachi again, where more than 30,000 people were infected. This epidemic was closely related to the hot climate and insufficient level of hygiene in the region.[23, 60] From December 2016 to May 2017, Badar and colleagues tested 584 serum samples of CHIK-suspected individuals using RT-PCR method. Most of the CHIK cases were patients over 20 years of age, and ECSA was the predominant genotype. They reported a CHIKV incidence of 70%.[61] CHIK was also reported in Rawalpindi, Pakistan, where among 129 individuals tested, 28 (17 men and 11 women) were positive.[62]

Different studies have suggested that CHIK emerged in Pakistan in the 19th century but was misdiagnosed as other arboviral diseases.[63] The outbreak of CHIKV ECSA lineage occurred in 2016 in Karachi located in Sindh province. *Ae. aegypti* has a wide distribution in this province, and the people in this area enjoy rapid travelling facilities.[64] *Ae. albopictus* has been established in Pakistan where it behaves as a pest mosquito species in Karachi.[65] This mosquito is spread throughout Pakistan, exposing the country to possible future emergences of CHIK.[66, 67] The other main vector, *Ae. aegypti*, can be involved in CHIK epidemics in different areas of Pakistan.[67] Thus, the two main CHIKV vectors, *Ae. aegypti* and *Ae. albopictus,* are well-established species in the Indian subcontinent and several studies have reported the occurrence of these two vectors in Pakistan.[68]

Qatar

Using commercial microplate ELISA, Humphrey and colleagues examined the seroprevalence of anti-CHIKV antibodies in blood donors residing in Qatar. Compared to residents from the Middle East, North Africa (MENA), and Qatar, the Asian population had a greater chance of being anti-CHIKV positive. CHIKV exposure was lower in Qataris and MENA nationalities than in Asians, implying a lower burden of CHIK disease in the MENA. Except for Iran, each country in the region had at least detected anti-CHIKV IgG in one sample. The overall seroprevalence of anti-CHIKV IgG varied from 0% in Iranian blood donors to 17.7% in Filipinos.[33]

In Qatar, the concerns regarding vector-borne diseases have risen due to the attribution of the soccer 2022 FIFA World Cup Qatar™.[69] Most areas in Qatar are plains, covered with sand, and it has very hot summers. However, the occurrence of *Ae. aegypti* was reported in Qatar in 1999,[69] and the establishment of this species should be a concern because the anti-CHIKV IgG positive cases among expatriate workers and travelers have been reported in 2016.[27] Furthermore, no national plan exists for the surveillance of vector-borne diseases, especially for arboviruses such as CHIKV.

Russia

Recently, a human case of CHIK has been reported in Moscow. The virus was isolated from an Indonesian visitor, and the viral strain belonged to the Asian genotype.[32]

Different studies have reported the prevalence of *Ae. aegypti* and *Ae. albopictus* in Russia. In 2005, investigators detected *Ae. aegypti* in Sochi city.[70] Furthermore, in 2016, *Ae. albopictus* was identified in the humid subtropical climate zone, and *Ae. aegypti* in regions with the typically semi-dry Mediterranean climate on the coasts of the Black Sea.[71] Moreover, *Ae. aegypti* and *Ae. albopictus* have been reported in Caucasian coast of the Black Sea located in the south of Russia since 2011,[72] while *Ae. albopictus* has spread from the Black Sea coast in the Caucasus into the European part of this country,[73] increasing the risk of CHIK outbreaks in Europe. Control measures and entomological and arboviral surveillance are suggested to reduce the possible risk of CHIK in Russia.

Saudi Arabia

The first laboratory-confirmed case of *indigenous* CHIK infection in Saudi Arabia was reported in 2011.[74] In 2019-2020, Hakami and colleagues used ELISA and PCR methods to measure the CHIK prevalence in the southern region of Saudi Arabia; among 40 patients, one had anti-CHIKV IgG antibodies.[75]

To date, *Ae. aegypti* has been reported in Saudi Arabia, while *Ae. albopictus* is still absent.[54] In a study in Makkah, 12% of water sources were positive for *Ae. aegypti*.[76] Furthermore, hundreds of adults and larvae of this species have been collected in Riyadh province.[77] CHIK can be considered a neglected viral disease in Saudi Arabia;[75] however, due to recent reports of *Ae. aegypti*, a significant risk of epidemics exists in this country.

Turkey

The first laboratory-confirmed CHIK case in Turkey was reported in 2012 which was related to a traveler from New Delhi, India. The patient had a sudden onset of fever, as well as skin rash and arthralgia. Serum samples were negative for Hantavirus and dengue virus but presented specific CHIKV IgM and IgG antibodies.[10] Furthermore, 500 random sera of healthy individuals in central Anatolia have been screened, showing that 0.4% of the samples were positive for CHIKV.[11]

The prevalence of *Aedes* species was investigated in 32 urban locations of northeast Turkey from 2016 to 2017 using a catch method, showing that *Ae. albopictus* and *Ae. aegypti* were the most prevalent species which comprised 89.6% and 7.8% of all collected samples, respectively. This suggests that these two species have been established in northeastern Turkey, coastal Black Sea region. Meanwhile, none of the collected samples was found to be infected with CHIKV.[78] The most recent investigation has suggested that the vector *Ae. albopictus* has expanded its distribution in recent years and has the potential to extend more throughout Turkey, as a temperate country in Europe, in a few coming years. Thus, coastal regions of Turkey are conducive for *Ae. albopictus* spread.[79] *Ae.* aegypti was reported in 1930s and 1961.[79, 80] Recently, this species was reported again in Turkey, suggesting that the distribution of *Ae. aegypti* may remain limited to the northeastern regions of the country.[81] Meanwhile, this species is suggested to be spreading along the Black Sea coast of Turkey.[82]

Yemen

CHIKV is considered a serious public health problem in Yemen. In 2011, an outbreak of a dengue-like disease was reported in Al-Hodayda, and the first CHIK epidemic was mentioned in this province,[83, 84] causing about 15,000 infected cases and 104 deaths.[43] CHIKV in human serum samples was confirmed during February-March 2011 using molecular and serological methods. In 2012, 400 individuals hospitalized during a dengue outbreak in Al Hudaydah were examined and 49 cases of CHIK were identified.[85] In 2020, CHIKV infected thousands of people in the provinces of Aden and investigators documented 50 CHIKV-infected patients at Al-shafa and Algamaheer medical centers.[50]

Ae. aegypti is associated with dissemination of CHIKV in Yemen.[43, 83, 84, 86] In 2012, investigators found that 8 out of 30 captured mosquitoes from the Eritrean Camp of Yemen were CHIKV-positive using RT-PCR method.[84] In 2012, CHIK fever hit the Southern Yemen where CHIKV-infected *Ae. aegypti* mosquitoes were detected;[86] based on phylogenetic analysis, the CHIKV isolate belonged to the ECSA genotype from the Indian Ocean.[28, 29] Because Al Hodayda is the major port in the Red Sea region, CHIK was likely to spread to other parts of Yemen and neighboring countries.

Conclusion

Aedes aegypti and *Ae. albopictus* are associated with dissemination of CHIKV and some other mosquito-borne viruses in different parts of the world. The introduction of these two vectors in Iran in recent years may result in introduction of new mosquito-borne viruses. Iran offers diverse bioclimatic areas that are suitable to *Aedes* mosquito vectors and pathogens which emerge from some neighboring countries with poor public health facilities. The first and most important point is to prevent the establishment of these two main vectors, especially in the southern and eastern provinces. This can be achieved by controlling the mosquito breeding sites, conducting systematic entomological surveillance and raising public awareness of vector-borne diseases. Monitoring patients and identifying infected individuals are also critical.[58] Most of the countries in the region lack an early screening system for CHIKV. One strategy to control CHIKV transmission is to limit mosquito densities. This relies on the elimination of water containers that serve as mosquito breeding sites. Minimizing skin exposure by complete clothing protection (long sleeves and tight pants) and usage of repellents are helpful. There is a triangle of fear for CHIK in Iran. The first angle refers to the detection of CHIKV in both humans and vectors. The second angle is the detection of CHIKV in neighboring countries such as Pakistan, Qatar, Yemen, Saudi Arabia, Oman, Iraq, Russia, and Turkey. The last angle is the risk of establishment of the main mosquito vectors, *Ae. albopictus* and *Ae. aegypti*. Collectively, this emphasizes the undeniable requirement for increasing the surveillance system for *Ae. albopictus* and *Ae. aegypti* and sustained surveillance of CHIK infection in vectors and humans, alongside preventive measures

for keeping track of the geographical spread of the virus and its vectors, and implementation of the appropriate measures in the region. Local health authorities in Iran and its neighboring countries are suggested to establish an active surveillance with an early detection of CHIK infection in field-collected mosquito vectors, preferably in a collaborative international project.

Authors' Contribution

Conceptualization: H.B., N.D.D., and A.B.F.; writing-original draft preparation: A.M.J.N., and H.B.; writing-reviewing and editing: H.B., K.A., M.F., M.S., H.G., and A.B.F.; visualization: N.D.D., and A.B.F.; funding acquisition: A.B.F. All authors provided feedback and were involved in drafting the manuscript. All authors read and agreed to the published version of this manuscript.

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