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# Control of emerging and re-emerging zoonotic and vector-borne diseases in countries of the Eastern Mediterranean Region

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Despite improvements in the detection and control of infectious diseases, many new pathogens are emerging and re-emerging in various parts of the world. Most of these emerging and re-emerging infections are of zoonotic origin, which highlights the importance of the human–animal interface. Similarly, the rate of vector-borne diseases has increased recently due to changes in human habitats, climate change, deforestation, changes in food production practices, and increased population movement. The risk of spread of these zoonotic and vector-borne diseases is higher in the Eastern Mediterranean Region (EMR) of the World Health Organization due to its topography and geopolitical situation, fragile health systems, complex humanitarian emergencies, and, in some countries, other socioeconomic risk factors. Many countries in the region have reported outbreaks of zoonotic and vector-borne diseases over the last few decades, and some of these diseases have spread to other WHO regions as well. Avian influenza A (H5N1) and Middle East respiratory syndrome coronavirus (MERS-CoV) are among the greatest threats to global health security and both viruses are endemic in the EMR. Countries in the EMR have made significant progress toward the control of zoonotic and vector-borne diseases in recent years, and prevention, preparedness, and response capacities have been improved. However, there are still many challenges associated with the control of these diseases in the EMR, particularly in countries facing humanitarian emergencies. In this paper, we present the current situation of emerging and re-emerging infections in the EMR and discuss progress, challenges, and ways forward.

## KEYWORDS

zoonotic diseases, vector-borne diseases, Eastern Mediterranean Region, emerging infections, MERS-CoV, avian influenza H5N1, COVID-19

## Introduction

Despite advances in the detection and control of infectious diseases, many new infections are emerging and re-emerging globally, including avian influenza viruses H5N1 and H7N9, Middle East Respiratory Syndrome coronavirus (MERS-CoV), severe acute respiratory syndrome coronavirus 1 (SARS-CoV1), and, more recently, severe acute respiratory syndrome coronavirus 2 (SARS-CoV2). The consequences of these emerging infections may be catastrophic, as people have very little or no immunity against these pathogens. Moreover, some existing infections are emerging in new geographical areas or have seen increased incidences recently; these include Ebola, monkeypox, West Nile virus (WNV), dengue, chikungunya, and Zika (1–3). Most of the emerging and re-emerging infections are of zoonotic origin, which highlights the importance of controlling these diseases not only in humans but also in animals (4). Vector-borne diseases (VBDs) are also a major public health issue and more than 80% of the world's population is at risk of developing one or more VBDs (5). Important factors contributing to the emergence and re-emergence of these zoonotic and vector-borne diseases include changes in human habitat and climate due to urbanization, deforestation, and reforestation; changes in food production and farming practices; increased poultry density and more frequent contact with animals; and an increase in travel, trade, and tourism (1, 6–8).

## Risk of zoonotic and vector-borne disease in the Eastern Mediterranean Region

The Eastern Mediterranean Region (EMR) of the World Health Organization (WHO) is sociopolitically diverse and includes countries from the Middle East, North Africa, the Horn of Africa, and Central Asia (9). The emergence risk of zoonotic and vector-borne diseases is high in this region due to its topography, complicated geopolitical situation, mass gatherings for religious and sporting events, and other socioeconomic factors (10–12). Four of the eight migratory birds' flyways pass through various countries of the EMR: Central Asia–India, East Atlantic, Mediterranean–Black Sea, and West Asia–Africa (13). These migratory wild birds are reservoirs for many avian influenza viruses and may transfer viruses to domestic birds, poultry, and subsequently, to humans as well. Climate change and other environmental factors also affect the survival and distribution of high-risk pathogens and their vectors and hosts. The complicated geopolitical situation and humanitarian emergencies have also resulted in the spread of infections due to huge population displacement, interruptions in health services, poor living conditions, weak surveillance and disease-detection capacities, and the lack of disease control measures (10).

## Important outbreaks and epidemics of zoonotic and vector-borne diseases in EMR

Over the last few decades, at least 11 countries in the EMR have reported major outbreaks and epidemics of zoonotic and vector-

borne diseases, which have had the potential to spread globally (Table 1) (14). Currently, there are approximately 50 active outbreaks ongoing in the region, with 70% of them related to vector-borne and zoonotic diseases. Avian influenza A (H5N1) and MERS-CoV are considered two of the greatest threats to global health security and both viruses are endemic in the EMR. Sporadic cases and outbreaks of monkeypox, sandfly fever, Alkhurma hemorrhagic fever (AHF) (20–22), and plague are also occurring in a few countries, but there is limited information on other rare zoonotic diseases such as Q fever, and tularemia (23). In addition to these outbreaks and epidemics, many zoonotic and vector-borne infections are endemic in the region, such as rabies, brucellosis, leishmaniasis, Ebola, other food-borne zoonotic infections, and malaria.

## Avian influenza

Avian influenza A (H5N1) remains a major concern in the EMR and, according to a recent study, approximately 10,000 outbreaks due to various types of avian influenza were reported in birds and other species in the EMR from 2011 to 2021 (24). The majority of these avian outbreaks were reported in Iran, Egypt, and Iraq, whereas most other countries either reported no outbreaks or very few outbreaks in avian species. From January 2003 to 31 May 2023, 876 cases and 458 deaths (CFR of 52%) have been reported worldwide due to avian influenza H5N1 in humans, and of them, 366 cases (42%) and 123 deaths (27%), were reported in the EMR (25, 26). Most of these cases and deaths were reported in Egypt, and a few cases and deaths were also reported in Djibouti, Iraq, and Pakistan (27).

The number of avian influenza H5N1 cases in Egypt is the largest globally, and Egypt is the only country with both a large number of H5N1 outbreaks among poultry and a large number of cases among humans. Some serologic studies showed that H5N1 cases in Egypt are underreported, and the actual number may therefore be larger than this (28–30). One study showed that approximately 2% of Egyptians exposed to poultry had been infected with H5N1 (29). The virus has become enzootic in Egypt and a low level of transmission is reported throughout the year (31). The upsurge in avian influenza H5N1 cases in Egypt had been attributed to uncontrolled poultry farming practices, lack of awareness, and engagement in high-risk behaviors and failure to take adequate personal protection measures while in contact with poultry (32). The risk of a major outbreak of H5N1 in poultry is high in Egypt, owing to the presence of more than 40,000 poultry farms with low-biosecurity and a high prevalence of backyard farming (33). An outbreak of the H5N1 subtype was also reported in a backyard poultry farm in an eastern region of Libya in 2014 (34). Avian influenza H5N1 is still a risk to regional and global health security, given that the virus has recently been detected among many new land and sea mammals including farmed mink, seals, sea lions, and cats in several countries (35). These mammals are biologically closer to humans than birds; therefore, it is likely that the virus might adapt to infect humans more easily in future.

TABLE 1 Emerging and epidemic-prone zoonotic and vector-borne disease outbreaks in the Eastern Mediterranean Region since 2000.

Outbreak/epidemic	Country (year)
MERS-CoV	Bahrain (2016), Egypt (2014), Iran (2014), Jordan (2012), Kuwait (2013), Lebanon (2014 and 2017), Oman (2013–2023), Qatar (2012–2022), Saudi Arabia (2012–2023), Tunisia (2013), United Arab Emirates (2013–2021), and Yemen (2014)
Influenza A (H5N1)	Iraq (2006), Djibouti (2006), Pakistan (2007), and Egypt (2006–2017)
Influenza A (H9N2)	Egypt (2016)
Influenza A (H1N1) pdm09	All countries (2009)
Ebola	Sudan (2004)
Monkeypox	Bahrain (2022–2023), Egypt (2022–2023), Iran (2022–2023), Jordan (2022–2023), Lebanon (2022–2023), Morocco (2022–2023), Pakistan (2023), Qatar (2022–2023), Saudi Arabia (2022–2023) Sudan (2005, 2022, and 2023), and United Arab Emirates (2022–2023).
Rift Valley fever	Yemen (2000), Saudi Arabia (2000 and 2010), Somalia (2006), and Sudan (2003, 2007, 2019, and 2020)
Sandfly fever	Lebanon (2007)
Ebola hemorrhagic fever	Sudan (2004)
Dengue fever	Afghanistan (2019–2023) Djibouti (2011–2012), Egypt (2015 and 2017), Oman (2014, 2018, and 2022), Pakistan (2004–2005, 2008, 2010–2013, and 2017–2023), Yemen (2012 and 2016–2019), Sudan (2005, 2010, 2013–2017, and 2019–2022), and Saudi Arabia (2004–2006, 2008–2009, and 2023)
Plague	Libya (2009)
Chikungunya	Yemen (2010, 2011), Pakistan (2016–2018), Somalia (2016), and Sudan (2018–2020)
Yellow fever	Sudan (2003, 2005, 2007, and 2011–2013)
Crimean-Congo hemorrhagic fever	Afghanistan (2002, 2007–2012, 2016–2019, and 2022–2023), Iran (2000–2012), Pakistan (2000–2014 and 2016–2023), Sudan (2004, 2008, and 2007–2011), Iraq (2010, 2018, and 2022–2023), and Oman (2019)
Q fever	Afghanistan (2011)
West Nile virus fever	Tunisia (2003, 2012, and 2018)
COVID-19	All countries (2020–2023)

Adapted from Buliva E, et al. (14), Malik M et al. (15), and WHO EMR (16–19).

## Middle East respiratory syndrome coronavirus

Most MERS cases are reported in EMR countries—those in Saudi Arabia alone constitute more than 84% of the global cases of MERS (36). MERS cases have also been reported in many other countries in the region, including the United Arab Emirates, Jordan, Qatar, Oman, Iran, Kuwait, Tunisia, Yemen, Bahrain, Egypt, and Lebanon (37). The number of cases in the region has decreased since the start of the COVID-19 pandemic, likely due to a reduction in testing and the adoption of various control measures such as mask-wearing, hand hygiene practices, improved ventilation, and social distancing.

However, MERS is still a threat in the region as cases are regularly being reported in Saudi Arabia and, currently, there is no vaccine or MERS-specific treatment available. According to a WHO risk assessment, additional cases of MERS-CoV infection will continue to be reported in countries in the Middle East, particularly when routine surveillance activities resume after the

acute phase of the COVID-19 pandemic has passed (38). The risk of MERS spreading to other countries is high due to travel in endemic areas and exposure to dromedaries, animal products, or humans. Moreover, the transmission mechanism from animals to humans is still unclear. Although dromedary camels are considered a major reservoir for MERS-CoV, the role of dromedary camels in MERS transmission is not fully understood. Limited, non-sustained human-to-human transmission of MERS has been reported, mainly in healthcare settings (37). Although MERS surveillance and case detection have been improved in the region, case management, compliance with infection control measures in hospitals, and contact follow-up remain major challenges (39).

## Other zoonotic diseases

Rabies has been controlled in most countries of the Americas and Western Europe; however, it is still a public health challenge in the EMR, where only three countries (i.e., Bahrain, Kuwait, and the

United Arab Emirates) are rabies-free (40). Rabies is endemic in at least 14 countries in the region, comprising Egypt, Iran, Iraq, Jordan, Lebanon, Morocco, Oman, Palestine, Pakistan, Tunisia, Syria, Saudi Arabia, Sudan, and Yemen (23, 40). During 2017 alone, there were 239,578 cases in humans caused by dog bites reported in 11 countries and 52 reported cases of human rabies in nine countries, although the actual case numbers are thought to be much larger, due to underreporting (41). Most cases of rabies in the region are dog-mediated (42); however, high positivity rates have been reported in foxes in Oman and wolves in Syria (43). The risk of rabies is reported to be higher in children, people with low socioeconomic backgrounds, and those living in rural areas (44). Very little information is available on the rabies situation in conflict-affected countries such as Palestine and Syria (40), although rabies cases have recently increased in some of their neighboring countries (45).

Brucellosis is also a major public health problem in the region, and *Brucella* spp. is widespread in many countries. Human cases have been reported in Saudi Arabia, Yemen, Iran, Egypt, and Jordan; however, accurate estimates of human cases of brucellosis are lacking, largely because of underreporting and misdiagnosis (46). Risk factors for human brucellosis in the region are the consumption of unpasteurized milk, direct contact with infected animals, and occupational exposure. Although Ebola is currently not circulating in the region and no cases have been reported during recent outbreaks, the risk of contracting it is very high. Ebola outbreaks occurred in Sudan in 1976, 1979, and 2004, resulting in 284, 34, and 17 cases, respectively (47, 48). Finally, outbreaks of RVF have been reported in Saudi Arabia, Yemen, and Sudan (49–51).

## Emerging and re-emerging vector-borne diseases

The region is home to several arthropod-borne viruses (arboviruses) and mosquito-borne diseases, which are particularly expanding their range and emerging in new areas. Dengue is one of the fastest-growing mosquito-borne viral diseases in the region and is endemic in at least eight countries in the region. Large outbreaks of dengue have been reported in Pakistan, Afghanistan, Egypt, Sudan, and Yemen (52, 53). The disease has also spread to some neighboring countries including Syria and Kuwait. Chikungunya outbreaks have been reported in Pakistan, Somalia, Yemen, and Sudan (14, 16). Similar to dengue, chikungunya is also spreading to new areas, and Sudan's first ever outbreak, resulting in more than 20,000 cases, was reported in 2018 (16). In the region, yellow fever outbreaks have been reported in Sudan only (54); however, serologic studies have also shown evidence of the circulation of yellow fever in Djibouti and Somalia (14, 55). According to a systematic review of 35 seroprevalence studies in the region, WNV-specific antibodies were detected in the human population of 11 countries, namely Djibouti, Egypt, Iran, Iraq, Jordan, Lebanon, Libya, Morocco, Pakistan, Sudan, and Tunisia. WNV RNA was also detected among patients in Iran, Pakistan, and Tunisia (56).

In addition to mosquitoes, diseases are also spread by other vectors in the region. The incidence of CCHF has increased in many countries in the region, with sporadic human cases and outbreaks of CCHF reported in 10 out of the region's 22 countries (57–59). CCHF is endemic in Afghanistan, Iran, Iraq, and Pakistan, and several outbreaks have occurred during the last few years, particularly in the border areas of these countries, owing to several factors including population movement and animal trade. Despite the regular reporting of CCHF cases and outbreaks, its true disease burden in the region is still unknown due to limited awareness and reporting of suspected cases and the different surveillance systems used for CCHF in EMR countries. Other major challenges include the delay in diagnosis and lack of awareness among healthcare providers. Leishmaniasis are also widespread in the region due to poor awareness and reporting, difficult case management, and a lack of effective control measures (60). Most cases of leishmaniasis are reported in disadvantaged communities in the region (61).

## Progress toward control of zoonotic and vector-borne diseases in the EMR and lessons learned

Despite many challenges, countries in the EMR have made significant progress toward the control of zoonotic and vector-borne diseases in recent years. Prevention, preparedness, and response capacities to emerging and re-emerging zoonotic and vector-borne diseases have been improved. IHR (2005) core capacities have been strengthened and 17 countries in the region have completed joint external evaluations of IHR (2005) capacities (62, 63). Surveillance systems have been improved and 19 out of 22 countries have sentinel surveillance to collect and analyze data on severe acute respiratory infections (SARIs) and influenza-like illnesses (ILIs) (64). After the emergence of avian influenza virus A (H5N1) in Egypt, the Eastern Mediterranean Acute Respiratory Infection Surveillance (EMARIS) network was established in the region to improve SARI and ILI surveillance and to strengthen countries' capacities to detect seasonal and new influenza viruses (65, 66). Moreover, the Early Warning Alert and Response Network (EWARN) has been introduced in many countries facing humanitarian emergencies. The laboratory diagnosis capacity for emerging and re-emerging infectious diseases has been enhanced across the region, with more reference laboratories with adequate capacity being built. The Emerging and Dangerous Pathogen Laboratory Network (EDPLN) has also expanded (67). In January 2020, only four countries in the region had the laboratory capacity to test for COVID-19. By mid-February that same year, however, with the support of the WHO and partners, all 22 Member States had built laboratories with the capacity to conduct COVID-19 reverse transcription-polymerase chain reaction (RT-PCR) testing in 2021 (68). By late 2022, with the support of the WHO and partners, 21 Member States could carry out domestic COVID-19 genome sequencing.

Similarly, outbreak response capacity has been improved and most countries in the region have trained rapid response teams at the central level to investigate outbreaks due to emerging and re-emerging pathogens (64). Training has been provided on surveillance, field investigation, and diagnosis. Many new activities were initiated to control the *Aedes* mosquito in the region, which is the primary vector for many emerging and re-emerging VBDs. The WHO EMRO has also developed a framework for a One Health approach, although the coordination mechanism between human and animal health sectors is still weak in most countries in the region (69). Various activities are ongoing in the region to prevent outbreaks during events with mass gatherings, such as risk assessments, strengthened surveillance and case detection/reporting, case management training, laboratory capacity scale-up, vaccination against common infection, increased awareness, and rapid response. The WHO EMRO has also developed a strategic framework for the prevention and control of emerging and epidemic-prone diseases in the region, with the goal of reducing the burden of emerging and epidemic-prone zoonotic and vector-borne infectious diseases in the WHO Eastern Mediterranean Region by 2024 (70). Countries in other WHO regions may also adopt some of these strategies in a local context to control zoonotic and vector-borne diseases.

Owing to these initiatives, a number of outbreaks of emerging infectious diseases have been successfully contained in the region. The lessons learned from these outbreaks were leveraged to manage the COVID-19 pandemic in several countries. For example, surveillance systems, laboratories, infection prevention and control measures, and clinical care networks for endemic diseases were rapidly utilized during the early phase of the COVID-19 pandemic. Guidelines, policy documents, training modules, standard operating procedures, risk assessment tools, and checklists developed for MERS-CoV and other emerging and re-emerging diseases were used to inform initial technical guidance documents and information products for COVID-19. Similarly, standardized seroepidemiological protocols developed for other emerging and re-emerging infections were quickly adapted for COVID-19 and were implemented across many countries in the region to rapidly identify key epidemiologic parameters of SARS-CoV-2, and also to understand the nature of the infection, the extent of its spread, and risk factors. Reference laboratories in high-resource countries in the region were leveraged, particularly in the early stages of the pandemic, to provide laboratory support and confirmatory testing for affected countries.

## Challenges and the way forward

There are many challenges associated with the control of zoonotic and vector-borne diseases in the EMR, most of which are also common in other WHO regions, such as increased population movement, the unavailability of vaccines and specific treatments for many zoonotic and vector-borne diseases, and zoonotic spillover. The challenges specific to the EMR are highlighted in Table 2. Some important challenges, particularly in countries experiencing humanitarian emergencies, are weak

detection and response capacities, poor animal source/vector control measures, fragile health systems, the lack of resources, competing priorities, and the unavailability of drugs and vaccines (61). Countries need to address these challenges to control emerging and re-emerging zoonotic and vector-borne diseases and to prevent morbidity and mortality, particularly among vulnerable groups. Table 2 also contains some strategies to address these challenges in the EMR countries and countries in other regions in similar circumstances. These strategies are in line with the WHO strategy for the Eastern Mediterranean Region, 2020–2023 (68), and the strategic framework for the prevention and control of emerging and epidemic-prone infectious diseases in the Eastern Mediterranean Region (70).

In summary, the incidence of many zoonotic and vector-borne diseases is expected to increase in the future due to climate change, globalization, urbanization, and other factors (74). Therefore, countries should focus on strengthening their capacities to prevent, detect, and respond to outbreaks due to these diseases. Surveillance systems should be strengthened, incorporating an early-warning component for rapid detection and response to outbreaks due to zoonotic and vector-borne diseases. The IHR (2005) should be the key driver for rapid epidemic intelligence and global health security. There is a need to improve laboratory capacities for the timely and accurate detection of emerging pathogens, including point-of-care testing, with implications for regional and global health security.

The majority of zoonotic and vector-borne diseases spread due to close contact with animal hosts or vectors; therefore, countries should foster effective collaboration between the animal, human, and environmental health sectors to prevent the emergence and spread of these diseases. Intersectoral collaboration and coordination are important for the timely sharing of epidemiological and laboratory surveillance data and for exercising integrated responses. To achieve this, the One Health approach should be adopted and a system should be in place to oversee all One Health activities, including governance, policy and legislative frameworks, advocacy and communication, collaboration among various sectors, training and capacity building, data sharing, integrated surveillance and response systems, research, and monitoring and evaluation (75, 76). Countries in the EMR are at different stage of implementing the One Health framework. Countries without One Health initiatives in place should develop a national strategy and operational plan in consultation with relevant stakeholders, endorsed by relevant ministries. Countries with existing One Health plans should enhance their key activities, such as risk assessment, prioritization of zoonotic diseases, preparedness and response activities, assessment of existing capacities, identification of research priorities, and coordination with partners (75). Many countries in the region may lack the capacity to implement the One Health approach, thus international organizations, non-governmental organizations, academic institutes, and private sectors can be engaged (76).

Response capacity should also be strengthened to contain outbreaks of zoonotic and vector-borne diseases early; otherwise, they may cause significant morbidity and mortality. Tailored strategies should be developed for countries experiencing

**TABLE 2** Important challenges in the control of emerging and re-emerging zoonotic and vector-borne diseases in the Eastern Mediterranean Region and proposed strategies to address these challenges (10, 68–73).

Challenges	Proposed strategies to address these challenges
Surveillance systems in most of the countries in the Eastern Mediterranean Region remain fragmented and paper-based, and abilities to detect any aberration or impending health threat in real time remain variable and limited.	<ul style="list-style-type: none"> <li>* Periodical evaluation of existing surveillance systems along with any other systems that exist for specific disease control and intervention programs with a view to identifying gaps and improving system performance and/or efficiency.</li> <li>* Strengthen and monitor IHR (2005) core capacities.</li> <li>* Incorporate an early warning component in existing surveillance systems for rapid detection and response to outbreaks due to zoonotic and vector-borne diseases.</li> </ul>
Although the influenza surveillance system has been strengthened in 19 countries of the region, most countries do not collect data throughout the year.	<ul style="list-style-type: none"> <li>* Ensure that data on severe acute respiratory infections (SARIs) and influenza-like illnesses (ILIs) from all countries are collected and analyzed on a regular basis.</li> <li>* Develop a system to analyze data regularly to identify any aberrant patterns.</li> </ul>
The civil registration and vital statistics system of 15 countries in EMR is either weak or inadequate; consequently, these governments lack evidence-based data for health policy planning.	<ul style="list-style-type: none"> <li>* Improve civil registration and vital statistics in all countries using electronic records and other evolving information technology tools to improve the timeliness of reporting in accordance with national guidelines.</li> <li>* As many deaths occur outside of health facilities, verbal autopsy mechanisms should be scaled up to determine the most probable cause of these deaths.</li> </ul>
There are still countries without adequate laboratory capacities to detect or diagnose emerging or new pathogens or identify a novel influenza virus, which is a key component in the IHR core capacities.	<ul style="list-style-type: none"> <li>* Improve capacities and systems in countries to detect outbreaks early and undertake timely risk assessments to respond to those outbreaks.</li> <li>* Ensure that a functional nationwide laboratory system is in place with diagnostic and testing capabilities for emerging and re-emerging zoonotic and vector-borne pathogens, surge capacity for outbreak response throughout the country, and links to regional and international reference laboratories.</li> </ul>
Most countries in the region have biosafety level 2 facilities, some have biosafety level 3 facilities, and none has biosafety level 4 laboratories. A national system for biosafety and biosecurity does not exist in most of the countries of the region.	<ul style="list-style-type: none"> <li>* Promote sustainable national laboratory systems and networks at national and subnational levels, especially for quality diagnostic testing of high-threat pathogens, adhering to biosafety and biosecurity standards.</li> <li>* Ensure the availability of policies, guidelines, and standard operating procedures for specimen collection, storage, testing, transportation, data sharing, and quality control.</li> </ul>
The lack of effective collaboration, integrated surveillance, and data sharing between the animal and human health sectors under the concept of a “One Health” approach is a challenge in controlling zoonotic and vector-borne diseases in the region.	<ul style="list-style-type: none"> <li>* Countries should build effective collaboration between the animal, human, and environmental health sectors to prevent the emergence and spread of zoonotic and vector-borne diseases.</li> <li>* Ensure the timely sharing of epidemiological and laboratory surveillance data and exercising of an integrated response.</li> <li>* Countries without a One Health initiative in place should develop a national strategy and operational plan in consultation with relevant stakeholders, endorsed by relevant ministries.</li> <li>* Countries with existing One Health plans should enhance their key activities, such as risk assessment, prioritization of zoonotic diseases, preparedness and response activities, assessment of existing capacities, identification of research priorities, and coordination with partners.</li> </ul>
Although outbreak response capacity has improved at the national level, it is still suboptimal in rural and remote, geographically dispersed areas, where most of the zoonotic and vector-borne disease outbreaks occur.	<ul style="list-style-type: none"> <li>* Enhance capacities to respond to potential disease outbreaks caused by high-threat pathogens in rural and remote geographically dispersed areas.</li> <li>* Ensure the availability of fully resourced emergency operations centers (EOCs) at national and subnational levels, with adequate logistics support/supply chain and resource mobilization.</li> <li>* Train rapid response teams at national and sub-national levels to investigate outbreaks due to emerging and re-emerging zoonotic/vector-borne pathogens.</li> <li>* Test rapid response team operations using simulation exercises.</li> </ul>
Early detection of disease outbreaks is limited by the lack of field investigation capacities and inadequate resources to implement appropriate public health measures to control disease outbreaks and to monitor the progress of these measures in hard-to-reach populations.	<ul style="list-style-type: none"> <li>* Enhance capacity to rapidly deploy mobile laboratories and/or laboratory services for the detection of zoonotic and vector-borne diseases in hard-to-reach populations.</li> <li>* Strengthen the Early Warning Alert and Response Network (EWARN) in countries facing humanitarian emergencies.</li> <li>* Use innovative technologies and tools to detect and monitor zoonotic and vector-borne diseases in hard-to-reach populations.</li> </ul>
Some countries in the region have included additional vaccines in their Expanded Program on Immunization (EPI); however, the effectiveness and impact of these vaccines have not been studied owing to the limited data on population coverage.	<ul style="list-style-type: none"> <li>* Integrate selected vaccines against zoonotic and vector-borne diseases into routine immunization schedules in endemic areas where they are shown to be cost-effective.</li> <li>* Achieve and maintain high levels of immunization coverage against vaccine-preventable zoonotic and vector-borne diseases, particularly in endemic areas.</li> </ul>

(Continued)

TABLE 2 Continued

Challenges	Proposed strategies to address these challenges
	<ul style="list-style-type: none"> <li>* Improve vaccination coverage among healthcare workers and other groups at high risk.</li> </ul>
The capacity for vector surveillance and control is not adequate in many countries at risk from vector-borne diseases. More research is required to understand the risk factors for animal-to-human transmission in the region so that evidence-based prevention and control strategies can be implemented.	<ul style="list-style-type: none"> <li>* Strengthen national vector control programs to prevent the emergence of new, and the re-emergence of existing, vector-borne diseases.</li> <li>* Implement national VBD control programs through intersectoral collaboration and community participation.</li> <li>* Strengthen entomological surveillance and integrated vector management approaches to control various VBDs.</li> <li>* Promote and support multidisciplinary research to understand the factors contributing to the transmission of emerging and epidemic-prone pathogens, including human-to-human transmission and animal-to-human transmission.</li> </ul>
Routine health services have been disrupted in many countries experiencing humanitarian emergencies owing to the destruction of healthcare facilities, attacks on healthcare workers, and a shortage of equipment, medicines, vaccines, and other supplies in some areas.	<ul style="list-style-type: none"> <li>* Strengthen health system governance structures and financing arrangements to expedite progress toward universal healthcare in all countries.</li> <li>* Integrate various emergency programs in countries experiencing humanitarian emergencies, to enhance health system resilience.</li> <li>* Support these countries in health-system recovery in the aftermath of humanitarian emergencies by providing action-oriented guidance and capacity-building for national and local health systems.</li> </ul>

humanitarian emergencies, as in addition to poor surveillance and testing capacities, these countries do not have adequate healthcare infrastructure and basic healthcare services such as immunization against common diseases. Therefore, rapid detection of and response to epidemics should be a high priority among affected populations. Finally, as there is limited information on the burdens, trends, and risks of zoonotic and vector-borne diseases in the region, more research is needed.

## Data availability statement

Publicly available data sets were analyzed in this study. These data can be found here: <https://www.emro.who.int/entity/about-us/index.html>.

## Author contributions

AC prepared the first draft of the manuscript. CK, MT, and MP provided data from regional offices and reviewed the manuscript; RJ and AA reviewed the manuscript and gave critical input. All authors approved the final version.

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## Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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