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Combating infectious diseases in the Pacific Islands: sentinel surveillance, environmental health, and geospatial tools

Abstract: Infectious diseases are responsible for significant disease burden in the Pacific Islands. Environmental drivers of disease transmission and public health challenges vary between diseases, at times of emergence versus outbreaks, and also during the last stages of elimination where prevalence is low. In order to more effectively combat infectious diseases in the region, innovative approaches such as sentinel surveillance, environmental monitoring, the use of geospatial tools should be explored.

Keywords: environmental health; epidemiology; infectious diseases; Pacific Islands; public health; tropical medicine.

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Introduction

Infectious diseases are responsible for significant morbidity and mortality in the Pacific Islands (1). The region is vulnerable to outbreaks because of many reasons, including the tropical climate that provides a favourable environment for pathogens; relatively poor sanitation, hygiene, and vector control; increasing frequency of extreme weather like cyclones and floods associated with climate change; and limited human and financial resources to mitigate and respond to outbreaks (2). Such outbreaks not only cause significant disease burden but could also place enormous stress on health systems and result in huge socioeconomic losses for already fragile economies. In addition, isolated human populations are vulnerable to severe epidemics when new pathogens attack immunologically naïve populations and cause ‘virgin soil epidemics’ (3). Furthermore, low biodiversity and delicate ecosystems on remote islands render them vulnerable to invasion by vectors (e.g., rodents) (4) and associated pathogens, leading to emergence of infectious diseases.

Elimination programs for diseases like lymphatic filariasis (5) have significantly reduced disease incidence in some Pacific Islands; however, there are continuing challenges to ensure that elimination is sustained, including surveillance and management of resurgence and/or reintroduction through movement of infected people between the islands (6). The environmental drivers of disease transmission and public health challenges vary between diseases, at times of emergence versus outbreaks, and also during the last stages of elimination where prevalence is low. This article discusses some of the challenges faced when combating a few of the important infectious diseases in the Pacific Islands, and discuss a few relatively novel approaches to providing an evidence base and improving knowledge about infectious disease epidemiology and transmission. Such knowledge would be valuable for directing public and environmental health interventions to reduce disease burden associated with disease emergence and outbreaks, and inform optimal endgame strategies for elimination.

Disease emergence and outbreaks

Small remote islands are vulnerable to invasion by new pathogens, and isolated communities are highly susceptible to severe epidemics when new infections are introduced to the immunologically naïve population (3). Transportation of new pathogens could occur through the frequent movement of people between the Pacific Islands, and also from other parts of the world through the increasing growth in international travel and trade. Many Pacific Islands lack laboratory capacity to identify novel pathogens or real-time surveillance systems to provide early warning, thus increasing the opportunity for outbreaks to ‘escape’ before effective public health interventions could be instituted. In addition, acute febrile illnesses are common in the Pacific Islands and often treated empirically based on clinical judgement, without the opportunity for laboratory confirmation of diagnosis. All the above factors combine to create an environment where
novel pathogens could rapidly result in disease emergence and large outbreaks.

Arboviral infections provide striking examples that ‘virgin soil outbreaks’ are not just a theoretical concept. The combination of tropical climate, high rainfall, efficient vectors, favourable mosquito-breeding habitats, and outdoor lifestyle all contribute to the high risk of transmission. With global climate change and predictions of increasing frequency and severity of cyclones and flooding, together with population growth, urbanisation, and rising international travel, the threat of arboviral outbreaks loom large. Dengue is endemic throughout the region (7) and probably under-diagnosed and under-reported owing to poor laboratory capacity and inadequate surveillance systems (8). A recent study in American Samoa found a dengue seroprevalence of >95%, signifying almost universal exposure and infection (9). Other important arboviral infections that receive less attention include Ross River Virus and Chikungunya – both pathogens cause overlapping clinical symptoms and signs with dengue, and could potentially be misdiagnosed clinically as dengue where laboratory confirmation is unavailable.

In 1979–1980, a Ross River virus outbreak in the Pacific Islands resulted in >500,000 cases and affected 90% of the population in Fiji, 69% in the Cook Islands, 44% in American Samoa, and 33% in New Caledonia (10–12). The newly introduced virus was thought to have arrived via a viraemic Australian traveller to Fiji, and is likely to still be circulating at low levels (13). Over 30 years have passed since the epidemic, and the number of non-immune young people who were not yet born in 1980 will continue to grow, thus increasing the risk of future epidemics. In 2005, a Chikungunya outbreak in the Indian Ocean islands caused >250,000 cases in La Réunion (14). Since then, the virus has spread ferociously across the Indian subcontinent and Southeast Asia, causing significant morbidity for many millions of people (15). Recent local transmission of Chikungunya was reported in New Caledonia in 2011 (16), thus far the only evidence of locally acquired infection in the Pacific Islands. The outbreak was fortunately interrupted by timely public health response; however, most Pacific Islands do not have laboratory capability to diagnose Chikungunya or the capacity to respond adequately. Chikungunya continues to pose the threat of an epidemic in the region, and it is possible that undetected incursion might already have occurred in places where laboratory diagnosis is unavailable.

Some infectious diseases are already well established in the region; however, outbreaks are occurring with increasing frequency as a result of environmental change, with drivers of transmission related to both the natural environment (e.g., climate, rainfall) and the anthropogenic environment (e.g., overcrowding, urbanisation). For example, leptospirosis is identified as one of the climate-sensitive infectious diseases in Fiji, and currently the focus of a World Health Organization-funded research project aimed at developing early warning systems for outbreaks (17). Leptospirosis is a zoonotic disease with complex transmission dynamics involving the interaction between humans, animal reservoirs, and the environment. Human behaviour plays an important role in determining exposure to infection (18); however, the transmission of leptospirosis is also strongly driven by environmental factors like climate change, flooding, urbanisation, overcrowding, and poor sanitation (2). The importance of environmental drivers of leptospirosis transmission in the Pacific Islands is evidenced by the ability to predict hotspots in American Samoa based purely on indicators related to the environment and animal populations (19). The diagnosis of leptospirosis in the Pacific also poses significant challenges for clinicians – infection results in a wide range of presentations ranging from non-specific febrile illnesses to multi-organ failure and death, and symptoms and signs overlap with arboviral infections as well as numerous other tropical diseases. Poor access to accurate laboratory diagnosis further increases the risk of misdiagnosis and incorrect management (20).

**Disease elimination**

Lymphatic filariasis (6) is one of the infections targeted for elimination in the Pacific. The Programme for the Elimination of Lymphatic Filariasis was formed in 1999 to facilitate mass drug administration (MDA) in 22 Pacific Island countries and territories (5). Variable success has been achieved on different islands but significant progress has been made in many areas. For example, antigen prevalence in American Samoa has dropped from 16.5% in 1999 to <1% in 2011 after seven rounds of MDA (21). However, the sustained success of elimination programs depends on careful monitoring for potential resurgence after stopping MDA. Local mosquito species, like Aedes polynesiensis in the Samoan Islands, are highly efficient vectors for lymphatic filariasis; thus, disease transmission could potentially resurge, particularly in residual foci of high infection rates where there are strong environmental drivers of transmission. Frequent movement of infected people between islands could also be a potential source of parasite reintroduction (6).
Elimination programs face many logistical challenges, including the improvement of community uptake of MDA to achieve high coverage rates, difficulties with reaching remote communities, the sensitivity of surveillance systems to detect new and ongoing infections, and the limitations of diagnostic tests (6). Screening and treating entire populations are not cost-effective when prevalence is very low, and improved surveillance strategies are required to optimise detection of any residual foci of infection and identify high-risk populations that could potentially be targeted for screening and treatment. Operational research is required to determine the most efficient and cost-effective endgame strategies for elimination programs and to reduce the risk of resurgence.

Some innovative strategies for combating infectious diseases

Surveillance by proxy

To detect and manage novel pathogens in a timely and effective manner, it is necessary to improve the availability of laboratory diagnosis as well as surveillance systems in the region. If limited resources preclude the availability of laboratory tests and sophisticated surveillance systems (e.g., in remote islands), ‘surveillance by proxy’ could be a useful strategy, where diagnoses in returned travellers are used to provide sentinel warning of outbreaks in the countries of disease acquisition. For example, dengue surveillance data in New Zealand show that the patterns of reported incidence of dengue acquired from the Pacific Islands closely reflect the reported incidences in those islands where retrospective data were compared (8). The real-time surveillance system in New Zealand could therefore potentially provide early warning of dengue outbreaks in the Pacific Islands and facilitate more timely public health response.

Environmental monitoring

Many infectious disease outbreaks are precipitated by changes in environmental conditions, e.g., flooding and other natural disasters. If it was possible to accurately predict disease incidence and prevalence based on environmental indicators, disease surveillance could be complemented by environmental hazard monitoring, which is usually cheaper and logistically simpler, thus providing a more cost-effective surveillance strategy (22). For example, recent studies have shown that leptospirosis hotspots and outbreaks could potentially be predicted using environmental and climate data in the Pacific Islands (17, 19). The ability to accurately predict hotspots for arboviral infections based on mosquito populations would also be very valuable, and allow the use of vector monitoring to help predict outbreaks and identify potential residual hotspots during elimination.

Geographic information systems

In recent years, geographic information systems are being increasingly used for the investigation of the environmental drivers for infectious disease transmission, including micro-spatial analysis of household-level environmental risk factors when high-resolution data are available (19, 23, 24). Geospatial databases are also potentially valuable for incorporating multiple sources of information on human health and demographics, animal and vector populations, and environmental and climate data. Geospatial analysis is useful for determining hotspots for disease transmission, and developing innovative tools like predictive risk charts and maps to inform public health resource allocation (19, 24). Spatial decision support systems are also playing an increasingly important role in elimination programs (25).

Integrated environmental health impact assessment

For pathogens that have complex transmission cycles (e.g., zoonotic and arthropod-borne diseases), a multidisciplinary approach is crucial for understanding the eco-epidemiology of disease transmission. An example of such an approach is an integrated environmental health impact assessment (IEHIA) that enhances the ability to quantify associations between a pathogen and its health impact by taking into account the environmental drivers of transmission, human behaviour, socioeconomic factors, and the multiple pathways through which exposure and infection could occur. An IEHIA approach is useful for improving the understanding of complex environmental health problems that involve multiple layers of hazards, exposure pathways, and data sources; and combine elements of epidemiology, risk analysis, and impact assessment (26, 27).
Conceptual frameworks are used to define the scope of the study; identify hazards; determine exposure pathways and interactions between different elements of the transmission cycle (e.g., humans, animals, mosquitoes, environment); select indicators of risk; and link potential sources of data, including geospatial data. Statistical modelling could be used to quantify the current health impact of each disease and provide a baseline or reference scenario, and future health impact could be predicted based on possible alternative scenarios like changes in environment and demographics, or implementation of interventions (26, 27). Predictive modelling could also be used to estimate current disease burden, and predict future burden based on changes in population demographics and distribution. An IEHIA approach also stimulates interdisciplinary collaboration, which is crucial for investigating and managing complex environmental health problems.

Conclusion

Combating infectious diseases in the Pacific Islands poses many challenges. Improved diagnostics and surveillance systems are required to improve the accuracy of clinical diagnosis and epidemiologic information. Intimate links between the environment and infectious disease transmission necessitates that environmental health is not forgotten when managing disease emergence, outbreaks, as well as elimination. Innovative methods and strategies are required to more effectively monitor, investigate, and predict infectious disease transmission, and provide an evidence base to direct public health and environmental health interventions aimed at reducing disease burden.

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References


