

# Geographic Information Systems for Vaccine – Preventable Disease Management in Refugees

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## Research

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## Abstract

During conflicts, deaths from disease, often from vaccine-preventable diseases, outnumber deaths from violence. The current study was a quantitative, descriptive, case series investigating the burden of vaccine-preventable diseases in refugee populations using geographic information system (GIS) analysis. We focused on cholera, diphtheria, measles, and tuberculosis in the Dadaab complex (primarily Somali and Sudanese), Rohingya, Syrian, Venezuelan, and Yemeni refugee populations. We used retrospective data available to the public. Data were missing for many diseases. Cases of cholera ranged from 1.3 million (Yemen) to 1777 (Dadaab); fatalities ranged from 2500 (Yemen) to 14 (Dadaab). Cases of diphtheria ranged from 7340 (Rohingya) to 1249 (Venezuela); fatalities ranged from 214 (Yemen) to 45 (Rohingya). Cases of measles ranged from 6395 (Venezuela) to 104 (Syria); no fatalities were reported. The only data reported for tuberculosis was for Rohingya (880 cases). Our results suggested GIS analysis may be a beneficial resource to address refugee health.

## Introduction

During conflicts, people are often forced to flee their homes and fall into three categories: refugees, internally displaced persons (IDP), or asylum seekers. In 2019, there were 25.4 million refugees, 40 million IDP, 3.1 million asylum seekers, and 10 million stateless people, resulting in more than 68.5 million forcibly displaced persons (FDP) worldwide (Campbell, 2019). In 2017, the United Nations estimated there were 44,000 new FDP daily and that 52% of them were children (United Nations High Commissioner for Refugees, 2018). Because of the conditions that exist from conflicts and forced migration, deaths from disease in these populations outnumber deaths from violence, and many of those deaths are caused by vaccine-preventable diseases (Heudtlass et al., 2016). For instance, over 7 million people fled because of the Syrian conflict, resulting in the largest number of refugees since World War II (Ahmad et al., 2017). Further, although the Islamic State created a healthcare system to provide services to IDP, conditions made it difficult to provide vaccination and other health services (Akbarzada and Mackey, 2018).

Resultant of the civil war in Syria, the incidence of several diseases, such as diphtheria, cholera, measles, polio, and tuberculosis, has increased (Nimer, 2018). Some diseases—measles, meningitis, hepatitis A, poliomyelitis, and tuberculosis—have experienced a resurgence because vaccination coverage has declined from 91% before the war to 45% in 2014 (Akbarzada and Mackey, 2018). Because the international community has failed to find a political solution for Syria, healthcare workers in the region are forced to practice medicine in dangerous working conditions. For instance, 40% of all ambulances and 57% of all hospitals have been destroyed (Nimer, 2018). Thus, two problems associated with conflicts are interruption to vaccination programs and the flight of healthcare professionals (Crudo Blackburn and Lenze, 2017).

Another problem with conflicts and forced migration is overcrowding in refugee camps, which can lead to disease outbreaks despite the best efforts of healthcare professionals to prevent them. The measles outbreak in Tanzania during 2001 is an excellent example of this problem (Crudo Blackburn and Lenze,

2017). Polio, cholera, typhoid fever, rabies, and tuberculosis have all reemerged in Syria, and host countries accepting the more than 4 million Syrian refugees need health policies to address the needs of these FDP (Crudo Blackburn and Lenze, 2017). Although vaccine-preventable diseases were originally contained in Syria, the massive forced migration brought disease across borders with the refugees (Crudo Blackburn and Lenze, 2017).

Geographic information systems (GIS) were created in the 1960s as an improved method for gathering and analyzing spatial data (Waters, 2018). Since then, GIS has evolved to its current participatory (Waters, 2018), where voluntary data from individuals is used to provide a variety of information, such as weather updates, travel plans, traffic information, and emergency response efforts (Campbell, 2019). One example of how GIS was used to improve health outcomes is the Ebola outbreak in Sierra Leone in 2015 (Nic Lochlann et al., 2018). During the outbreak, residents were asked to use their smartphones to assist medical responders (Nic Lochlann et al., 2018). When applying GIS to medicine worldwide, physicians are able to compare health outcomes among populations, but traditionally these tools do not have real-time components (Musa et al., 2013).

Modern technology like GIS has a vital role in disease eradication because it can be used for monitoring programs, such as house-to-house polio vaccinations; survey collection and analysis of disease locations; and follow-up management for patients (Chabot-Couture et al., 2015). In the treatment of diseases, GIS has been used to control and manage malaria (Chabot-Couture et al., 2015) and to assist in the response to outbreaks (Nic Lochlann et al., 2018). Therefore, research investigating applications of technology in the management of vaccine-preventable diseases in refugees may improve quality of life and help health officials monitor strategies for improving healthcare outcomes. Such information would be especially useful since refugees are rarely vaccinated before being displaced (Freidl et al., 2018).

Given the health difficulties created by conflicts like that in Syria, any solution to the crisis of vaccine-preventable diseases for refugees needs to include security in addition to political components. If citizens are afraid to go outside, they will be less likely to seek medical care for themselves and their families (Sharara and Kanj, 2014). Therefore, the purpose of the current study was to determine the burden of vaccine-preventable diseases in refugee populations using GIS analysis.

## Methods

The current study was a quantitative, descriptive, case series. The study was designed to investigate the current burden of vaccine-preventable diseases in refugee populations using applied GIS analysis techniques. Our goal was to apply this technology and other resources to be able to make recommendations to reduce this burden. We used random sampling of existing publication databases to build our dataset. Specifically, the vaccine-preventable diseases we evaluated were cholera, diphtheria, measles, and tuberculosis in the Dadaab complex (primarily Somali and Sudanese), Rohingya, Syrian, Venezuelan, and Yemeni refugee populations. Data were evaluated for reliability and validity using content analysis and for reliability by comparison with other data of the same type and topic. The local

institutional review board exempted the study, and every effort was made to abide by ethical research guidelines, such as using secondary source, publicly available, retrospective data to minimize risks to the populations of focus.

Data were collected by downloading information from the following databases: ClinicalKey, EBSCOhost, Esri's Geodata, Global Health, Google Scholar, MEDLINE, ProQuest, PubMed, ScienceDirect, United Nations (UN) databases, and the World Health Organization (WHO) databases. The following keywords were used to search the databases: refugee health, communicable disease, GIS, GIS for refugee health, GIS in health care, GIS in Zaatri, GIS in Zaatri for WASH (water, sanitation, and hygiene), mobile technology and refugee health, open data refugee, open data refugee health, refugee organizations, GIS epidemiology, individual disease names (cholera, diphtheria, measles, and tuberculosis), and WASH (WASH, GIS). Collected data were stored in an SPSS Statistics version 26.0 (IBM, Armonk, NY) file for later analysis.

To be included in the study, data had to be from credible sources and published in English within the last 5 years (data older than 5 years with an appropriate historical context was considered for inclusion). The information had to provide a context for disease landscape or applications of GIS and other technology. The data had to be publicly available without a data use agreement and representative of the populations of interest (Dadaab complex [primarily Somali and Sudanese], Rohingya, Syrian, Venezuelan, and Yemeni refugee populations). Data had to be related to the four diseases of interest (cholera, diphtheria, measles, and tuberculosis) and if it focused on vaccine-preventable diseases or provide context for recommendations.

Once collected, the validity of the data was evaluated using a 4-level scale, and every effort was made to use level 1 or level 2 data. Level 1 data were from a verified and high-degree certainty source. For example, data from Esri's Geodata database was considered level 1 data because Esri created the geodata and verified it before making it available for public use. Level 2 data were also from a verified and high-degree certainty source, but the data was validated by the entity that made it available for use. For example, geodata found in the Esri story map gallery that was provided by an organization other than Esri (eg, UN story maps) was considered level 2 data. Level 3 data were from sources that have a high degree of certainty after evaluation but were not validated by an independent source. For example, geodata from a Group on Earth observation was considered level 3 data. Level 4 data are from an unverifiable source and may or may not be valid.

A descriptive analysis of study data was performed using SPSS Statistics. The frequency of cases and number of deaths for the four vaccine-preventable diseases in the refugee populations of interest were reported. A web map using ArcGIS was also created.

## Results

Data were missing for many diseases (Table). Cases of cholera ranged from 1.3 million (Yemen) to 1777 (Dadaab); fatalities ranged from 2500 (Yemen) to 14 (Dadaab). Cases of diphtheria ranged from 7340

(Rohingya) to 1249 (Venezuela); fatalities ranged from 214 (Yemen) to 45 (Rohingya). Cases of measles ranged from 6395 (Venezuela) to 104 (Syria); no fatalities were reported. The only data reported for tuberculosis was for Rohingya (880 cases).

## Discussion

The purpose of the current study was to determine the burden of vaccine-preventable diseases in refugee populations using GIS analysis. Our findings indicated that GIS and other technology illustrated the frequency of cholera, diphtheria, measles, and tuberculosis in this population and that such information may better inform a worldwide response. Despite a thorough search in appropriate databases, data were unavailable for several outcomes. Further, we were unable to find previously published studies with similar aims in the literature, so we were unable to make comparisons. This study indicated that better quality data would likely result in a higher quality analysis and may highlight best practices for preventing epidemics by using technology to detect and track diseases earlier and provide more timely interventions. Although GIS and other technologies are helpful for visualizing data, they have limitations. So even though research is lacking on the burden of vaccine-preventable diseases in refugees, finding innovative applications of technology may mitigate these burdens for refugees, create new opportunities for public health, and improve quality of life for the most vulnerable.

One difficulty in responding to the needs of refugees is discrepancies in data between government and non-governmental organizations, which can be caused by contested sovereignty or poor access for non-governmental organizations in conflict zones (Kennedy and Michailidou, 2017). Further, government surveillance systems may be weakened by conflicts, limiting the available data (Ismail et al., 2016). However, more individuals currently own personal technology and have access to free and open source software. As such, data collection has shifted from governments to community-based individuals, but this also contributes to discrepancies in data quality (Curry et al., 2019). The use of GIS and similar technologies presents an opportunity for international collaboration, allowing people to share knowledge and build infrastructure (Fletcher-Lartey and Caprarelli, 2016). In addition to data about health, GIS may be used to track genocide and other human rights violations, which could contribute to better location of IDP and better documentation for war crime tribunals (Madden and Ross, 2009).

Technology like GIS has been increasingly used for public health because it provides epidemiologists with improved insight into disease patterns, risk zones, and optimal resource allocation (Tripathi, 2018). Further, GIS has been shown to improve the response to complex emergencies, such as disease outbreaks. When GIS is combined with other technologies, like smart phones or mobile health applications, it has reduced the burden of response teams. For instance, when combined with mobile health technology, GIS helped emergency response workers reach people stranded in difficult locations (Larocca et al., 2016). The WHO used GIS and other web-based applications as an early warning system in Bangladesh to aid its response to the Rohingya crisis (Karo et al., 2018). National health ministries have used GIS for non-refugee related healthcare, such as managing cholera (Pezeshki et al., 2012). Since the number of people in the developing world with cell phones has increased in recent years,

combining GIS with other technology may provide additional resources to refugee responders (Nic Lochlann et al., 2018). Despite these positive benefits, additional research is necessary on the use of telemedicine, mobile health technology, and other tools currently in development to determine the optimal response for the treatment and care of refugees.

Another benefit of GIS is that it can be used to assist with needs analysis, tracking movements, and understanding the push/pull factors affecting people fleeing their homes (REACH, 2019). It can also be used to determine locations for constructing refugee camps or the allocation of resources, (Altawee, 2016). For instance, Canada has used GIS to determine the best locations for resettlement of refugees (Vaz et al., 2018). Another application involves the refugees learning the technology to use these tools. In Jordan's Zaatari camp, the UN is part of a joint program called RefuGIS, which teaches refugees how to use GIS for urban planning (Tomaszewski et al., 2017). By population, Zaatari is one of the largest refugee camps in the world and requires the same GIS services as cities (Tomaszewski et al., 2017). RefuGIS provides residents of Zaatari with access to livelihoods by teaching them the skills to operate the technology (Tomaszewski et al., 2017). Therefore, expanding the use of GIS and other technologies to aid FDP can address public health concerns, such as the vaccine-preventable disease burden and access to medical care, and assist with a variety of other needs of refugees.

As GIS use is increased, international organizations and governments need to coordinate collection, storage, and analysis of data for populations, such as refugees. These systems need to track symptoms and diseases to prevent epidemics and manage disease outbreaks more effectively. However, the data should be closely monitored, and recommendations should be implemented based on the data. Populations move, and diseases move, so there needs to be a better system to track immunization records, diseases, symptoms, and other critical data. Although technology is more advanced than ever before, healthcare continues to lag. Global health would benefit greatly from expanding the use of technology like GIS.

The current study had several limitations. Our data were limited by what was available from our secondary sources, which resulted in small dataset. Further, most of the available data did not clearly identify when patients were refugees, which meant much of the data on disease burden was excluded. Therefore, additional research is necessary to determine the best way to improve data coordination and access for outcomes that have better clarity and completeness. Another limitation is that government data are known to be unreliable in many parts of the world where refugees reside. Further, government data are not always released to the public. For example, the Syrian government's data is currently unavailable, even internally. In addition, non-governmental organizations do not always have or retain pertinent data, and sometimes international organizations do not have reliable data or data in a useful form. For example, the UN and WHO keep data on many things. The UN has an entire agency devoted to refugee affairs but has very little healthcare data, while the WHO collects little data on refugee populations.

Future research should focus on ways to provide better access to vaccine-preventable disease data for refugees, IDP, and asylum seekers and to establish practical applications of technology. Mitigation strategies should also be pursued to improve education, sanitation, and vaccination rates; such strategies may assist with eradicating disease and improving patient outcomes. Further, adding technology to the overall strategy, such as GIS, may lead to a more precise allocation of resources and may accelerate disease prevention goals. Finally, because many people already own smartphones and related technology, asking the public to use these tools to assist health officials may provide solutions that have yet to be discovered (Nic Lochlainn et al., 2018).

## Conclusion

Results of the current study suggested GIS analysis may be a beneficial resource to address refugee health and reduce the burden of vaccine-preventable diseases. In recent years, refugee crises have grown and show no signs of decline, so healthcare and policy communities need to create strategies that better address these on-going problems. Further, the international community, individual governments, non-governmental organizations, and citizens of the world all have a stake in improving communicable disease management, including tracking and prevention. Therefore, refugees, IDP, and stateless individuals provide an opportunity to conduct research on populations that do not have access to the safeguards of citizens. We live in a world where global travel is more common and technology is more advanced than ever, yet diseases from the past are resurging and emerging diseases are not given adequate attention. As such, everyone should be focused on creating better policies for data sharing, public health practices, and the use of GIS and other technologies to improve health outcomes and quality of life.

## Declarations

**Ethics approval and consent to participate:** The current study was granted an exemption by the A.T. Still University IRB.

**Consent for publication:** All authors consent to publication.

**Availability of data and material:** Every attempt will be made to make materials and data available to those seeking it. We include in this manuscript everything we could find to complete the study.

**Competing interests:** The authors have no conflicts of interest to declare.

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**Authors' contributions:** Dr. Fein was the lead author and Dr. Alexander provided supportive feedback on the study and writing of the manuscript.

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## Table

Table. Frequency of Cases and Number of Deaths for the Four Vaccine-Preventable Diseases in the Refugee Populations of the Current Study

Refugee Population	Frequency of Cases (Deaths)			
	Cholera	Diphtheria	Measles	Tuberculosis
Dadaab	1777 (14)	NA	NA	NA
Rohingya	3500 (NA)	7340 (45)	520 (NA)	880 (NA)
Syrian	NA	NA	NA	NA
Venezuelan	NA	1249 (NA)	6395 (NA)	NA
Yemeni	1,300,000 (2500)	3800 (214)	1728 (NA)	NA

Abbreviation: NA, not available.