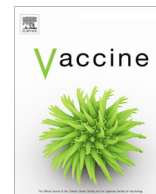




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Cost of a measles outbreak in a remote island economy: 2014 Federated States of Micronesia measles outbreak

Jamison Pike^{a,*}, Ashley Tippins^a, Mawuli Nyaku^b, Maribeth Eckert^a, Louisa Helgenberger^c, J. Michael Underwood^a

^a Centers for Disease Control and Prevention, National Center for Immunization and Respiratory Disease, Immunization Services Division, Atlanta, GA, United States

^b Centers for Disease Control and Prevention, Center for Global Health, Atlanta, GA, United States

^c Department of Health and Social Affairs, Government of the Federated States of Micronesia, Federated States of Micronesia

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ABSTRACT

After 20 years with no reported measles cases, on May 15, 2014 the Centers for Disease Control and Prevention (CDC) was notified of two cases testing positive for measles-specific immunoglobulin M (IgM) antibodies in the Federated States of Micronesia (FSM). Under the Compact of Free Association, FSM receives immunization funding and technical support from the United States (US) domestic vaccination program managed by the Centers for Disease Control and Prevention (CDC). In a collaborative effort, public health officials and volunteers from FSM and the US government worked to respond and contain the measles outbreak through an emergency mass vaccination campaign, contact tracing, and other outbreak investigation activities. Contributions were also made by United Nations Children's Emergency Fund (UNICEF) and World Health Organization (WHO). Total costs incurred as a result of the outbreak were nearly \$4,000,000; approximately \$10,000 per case. Direct medical costs (\approx \$141,000) were incurred in the treatment of those individuals infected, as well as lost productivity of the infected and informal caregivers (\approx \$250,000) and costs to contain the outbreak (\approx \$3.5 million). We assessed the economic burden of the 2014 measles outbreak to FSM, as well as the economic responsibilities of the US. Although the US paid the majority of total costs of the outbreak (\approx 67%), examining each country's costs relative to their respective economy illustrates a far greater burden to FSM. We demonstrate that while FSM was heavily assisted by the US in responding to the 2014 Measles Outbreak, the outbreak significantly impacted their economy. FSM's economic burden from the outbreak is approximately equivalent to their entire 2016 Fiscal Year budget dedicated to education.

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1. Introduction

Measles is a highly contagious rash illness that is transmitted from person to person by direct contact with respiratory droplets or airborne spread [1]. Once a common disease, tremendous progress has been made to reduce measles burden across the world, and cases have dramatically decreased with proliferation of two dose measles-containing vaccine coverage use [2]. According to the World Health Organization (WHO), from 2000 to 2014, measles mortality decreased by 79% from an estimated 546,800 in 2000 to 114,900 in 2014, and vaccination prevented an estimated 17.1 million deaths [3]. As a result, the WHO Global Vaccine Action Plan for

2012–2020 aims to eliminate measles in at least five WHO Regions by 2020 [2]. Despite the availability of a safe and effective vaccine, measles remains one of the leading causes of death among young children [3].

As a member country of the WHO Western Pacific Region, the Federated States of Micronesia (FSM) is committed to eliminating measles through achieving and maintaining regional goals of \geq 95% vaccination coverage with 2 doses of measles-containing vaccine (MCV) for each birth cohort of children (WHO website).¹ Under the Compact of Free Association, FSM receives immunization funding and technical support from the United States (US) domestic vaccination program managed by the Centers for Disease Control and Prevention (CDC). The international agreement establishes and

* Corresponding author at: Immunization Services Division, National Center for Immunization and Respiratory Disease, Centers for Disease Prevention and Control, 1600 Clifton Road NE, MS A-19, Atlanta, GA 30329-4027, United States.

E-mail address: jpik@cdc.gov (J. Pike).

¹ A single dose of MCV was introduced in FSM in 1963 and was replaced in 1982 with the MMR vaccine. A second dose of MMR was introduced was introduced in 1995.

governs the relationships of free association between the US and the three Pacific Island nations that formerly comprised the Trust Territory of the Pacific Islands: the Federated States of Micronesia, the Marshall Islands, and Palau [4]. Measles vaccination policy has evolved in FSM from one dose of monovalent measles vaccine at 9 months of age in 1963, to the current recommendation of two doses of measles, mumps, and rubella (MMR) vaccine, administered at 12 and ≥ 13 months [5,6]. Two doses of MMR are required for school entry [5,6], although enforcement is not stringent.

After 20 years with no reported measles cases, on May 15, 2014, CDC was notified of two cases testing positive for measles-specific immunoglobulin M (IgM) antibodies in FSM. Subsequently, 393 cases of measles were confirmed in FSM; 140 (36%) were laboratory confirmed, 244 (62%) were epidemiologically confirmed, and nine (2%) were clinically compatible [5,7].

In a collaborative effort, FSM public health officials, volunteers supplied by FSM, and staff from CDC worked to respond and contain the measles outbreak through an emergency mass vaccination campaign, contact tracing, and other outbreak investigation activities. Contributions were also made by United Nations Children's Emergency Fund (UNICEF) and WHO. Direct medical costs were incurred in the treatment of those individuals infected, as well as costs from lost productivity of the infected and time of the caregivers, and costs to contain the outbreak.

During a measles outbreak, the resources needed to identify and treat contacts can strain local public health resources [8]. In the case of FSM, a lower middle income country with a narrowly-based economy, this strain on resources was exacerbated by the unique logistical, economic, and geographical challenges in confirming diagnosis and containing the outbreak in a vast archipelago of islands with small and dispersed human populations. Although many aspects of this study are relevant to other countries, the idiosyncrasies of this event coupled with the Compact of Free Association with the US provide an opportunity to determine the economic implications of such an event to all parties. The objective of this report is to assess the economic burden of the 2014 measles outbreak to FSM in terms of containment costs, direct medical costs, and productivity losses, as well as the economic responsibilities of the US. Although the US paid the majority of total costs of the outbreak, examining each country's costs relative to their respective economy illustrates a far greater burden to FSM.

2. Methods

2.1. Setting

FSM is an independent nation comprising 607 islands located just north of the Equator in the Western Pacific Ocean. The islands are dispersed across 1 million square miles (2.6 million square kilometers) of ocean. FSM is made up of four groups of island states in geographic sequence from west to east: Yap, Chuuk, Pohnpei and Kosrae. According to the 2010 census, the population of 102,843 is distributed as follows: Chuuk (48,654 residents), Pohnpei (36,196), Yap (11,377), and Kosrae (6616) [5,7,9].

2.2. Outbreak

FSM was assisted by CDC in investigating suspected cases, identifying contacts, conducting analyses to guide outbreak vaccination response, and reviewing vaccine cold chain practices. Complementary funds to assist in the outbreak response were provided by CDC, WHO, and UNICEF. From February 16, 2014 through August 2014, three of FSM's four states reported measles cases: Kosrae (139 cases), Pohnpei (251), and Chuuk (3). In Kosrae and on the mainland of Pohnpei, cases were reported in all municipalities;

in Chuuk only one municipality (out of 40) reported cases. Although 16 suspected cases were investigated in Yap, these cases were ruled out following negative laboratory results. Cases were identified by febrile rash illness surveillance at the hospital, contact tracing, and a retrospective investigation of earlier fever and rash cases [7,10].

Median age of cases was 24 years, with 250 (64%) cases aged >19 years. Among adult cases aged ≥ 20 years, 49% had received ≥ 2 doses of measles-containing vaccine. Measles incidence was lower among children than adults, except infants <12 months who were too young for vaccination. Attack rates were highest for infants (22 cases per 1000 population), followed by adults aged 20–29 years (seven per 1000), and 30–39 years (six per 1000) [7].

2.3. Cost analysis

We defined the analysis period as May 1, 2014, two weeks prior to the first case of measles was reported to the CDC to encompass the incubation period, through December 10, 2014, when the vaccination campaign was completed [1,7,11]. This analysis uses standard cost analysis methods [12]. Costs of the 2014 outbreak were retrospectively collected and categorized into three main categories: (1) outbreak containment costs, (2) direct medical and non-medical costs, and (3) productivity losses (Fig. 1). Costs were collected from the FSM Department of Health, CDC, the FSM Office of Statistics, Budget and Economic Management, Overseas Development Assistance and Compact Management (SBOC), UNICEF, WHO, Feds Data Center, the International Monetary Fund (IMF), and the World Bank (Appendix 1, Table 1). [9,13–20] All expenses are in 2014 US dollars [21].

2.4. Containment

Containment activities were comprised of both an outbreak investigation and a mass vaccination campaign. Outbreak investigation efforts included contact tracing, conducting a retrospective review of prior fever and rash cases, conducting vaccination record checks, and assessing vaccine storage and handling practices. Further, samples had to be shipped and reshipped to different labs in either Guam, Hawaii, or Atlanta. This required significant person hours spent getting these samples to and from the airports and repackaging them for shipment.

To interrupt transmission and contain the outbreak, the mass vaccination campaign was launched successively in each FSM state pursuing children as young as age 6 months through adults up to age 57 years. In Kosrae, the campaign included vaccination record checks and only persons who did not have two documented doses of MCV were vaccinated. Campaigns in Pohnpei and Chuuk targeted all persons 6 months through 49 years of age, without checking vaccination status. In Yap, persons age 19–49 years were vaccinated without checking vaccination records, but those age 1–18 were vaccinated only if they did not have two documented doses of MCV [7]. The campaign targeted 82,472 individuals—80% of the national population. Because FSM includes 607 dispersed islands spanning 1700 miles, numerous boats were necessary as the primary mode of transportation for the outreach vaccination teams. When boats could not reach the shore during low tides, immunization staff had to carry the campaign supplies over the reef. Further, fixed and outreach vaccination posts were set up, as well as mobile vaccination units and door-to-door efforts, which were utilized to immunize hard-to-reach populations, such as isolated communities inhabiting mountainous terrain [10].

During the outbreak, eleven CDC employees were deployed to FSM, with one individual traveling twice to FSM. Non-deployed CDC staff worked over two-thousand hours, primarily conducting laboratory specimen testing. Approximately 32 individuals in

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