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Re-designing the Mozambique vaccine supply chain to improve access to vaccines

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ABSTRACT

Introduction: Populations and routine childhood vaccine regimens have changed substantially since supply chains were designed in the 1980s, and introducing new vaccines during the "Decade of Vaccine" may exacerbate existing bottlenecks, further inhibiting the flow of all vaccines.
Methods: Working with the Mozambique Ministry of Health, our team implemented a new process that integrated HERMES computational simulation modeling and on-the-ground implementers to evaluate and improve the Mozambique vaccine supply chain using a system-re-design that integrated new supply chain structures, information technology, equipment, personnel, and policies.
Results: The alternative system design raised vaccine availability (from 66% to 93% in Gaza; from 76% to 84% in Cabo Delgado) and reduced the logistics cost per dose administered (from $0.53 to $0.32 in Gaza; from $0.38 to $0.24 in Cabo Delgado) as compared to the multi-tiered system under the current EPI. The alternative system also produced higher availability at lower costs after new vaccine introductions. Since reviewing scenarios modeling deliveries every two months in the north of Gaza, the provincial directorate has decided to pilot this approach diverging from decades of policies dictating monthly deliveries.
Discussion: Re-design improved not only supply chain efficacy but also efficiency, important since resources to deliver vaccines are limited. The Mozambique experience and process can serve as a model for other countries during the Decade of Vaccines. For the Decade of Vaccines, getting vaccines at affordable prices to the market is not enough. Vaccines must reach the population to be successful.

1. Introduction

How can low- and middle-income countries (LMICs) handle the new vaccines arriving during the "Decade of Vaccines" when many LMIC vaccine supply chains are not even able to deliver current vaccine regimens to their populations? A country's vaccine supply chain is the complex system of locations, storage equipment, vehicles, transport routes, and personnel that bring vaccines from a central location to locations where children and expectant mothers receive immunizations. Since a majority of LMIC supply chains were designed in the 1970s and 1980s [1], populations and the standard childhood vaccine regimen have grown substantially. Vaccines in many LMICs stall in storage locations far from the people who need them, resulting in wasted resources, missed opportunities to provide immunization, and preventable disease burden. Sending new vaccines into outdated, inefficient, and ineffective systems could not only result in the new vaccines not reaching their destinations but also disrupt delivery of other vaccines.

Prior to this decade, consideration of LMIC vaccine supply chain design was more limited, as much of the focus was on developing and financing new vaccines. Project Optimize, including partners from PATH and the World Health Organization (WHO), began evaluating vaccine distribution in LMICs from 2007 to 2012. In 2009, the HERMES Logistics Team began developing the HERMES simulation software tailored for vaccine supply chain evaluation and

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planning and began working with WHO, the Bill & Melinda Gates Foundation (BMGF), UNICEF, PATH, Ministries of Health (MOHs), and other organizations in Niger, Thailand, Vietnam, and Senegal. The HERMES Logistics Team and Project Optimize joined a series of meetings BMGF convened in 2011 and 2012 to discuss the state of LMIC vaccine supply chains and how to improve them. Two major themes were (1) the need for a process to systematically evaluate and improve vaccine supply chains and (2) the question of whether vaccine supply chains could benefit from re-design. From these meetings emerged the idea for a process of evaluating and improving vaccine supply chains that was first refined and piloted in Benin [2] and later implemented to a greater extent in Mozambique. The meetings also catalyzed the formation of a WHO-UNICEF-Gavi hub to address vaccine supply chains and the initiation of the VillageReach and HERMES Logistics Team partnership to conduct the described work in Mozambique.

We explored the question of whether decades-old supply chain designs are in need of re-design in Mozambique, a low-income country in Southern Africa that has experienced challenges delivering vaccines to its population. Communications with the MOH and in-country non-governmental organizations (NGOs) identified supply chain bottlenecks, such as transport and human resource constraints, leading to an ad hoc adaptation of the vaccine delivery system in place, with health workers picking up vaccines by any means possible. Vaccine coverage rates have been well below 100% (e.g., in 2008, only 75% of one-year-old children were fully immunized with the third dose of diphtheria-tetanus-pertussis vaccine) [3]. Working closely with the MOH, UNICEF, and WHO, our team used a new combination of computational simulation modeling, information systems, stakeholder engagement, and training to help evaluate the Mozambique supply chain and develop, evaluate, and ultimately introduce a new supply chain design.

2. Methods

2.1. Overview

Our supply chain evaluation and re-design implementation process consists of the following steps: engage the Ministry of Health; conduct workshops to train decision makers and various stakeholders on using the HERMES (Highly Extensible Resource for Modeling Supply Chains) modeling software to develop a computational simulation model of the country's immunization supply chain, determine the supply chain's vulnerabilities and constraints, and gain practical experience in evaluating the impact of alternative supply chain designs; and begin discussions of how to move the computational modeling to real world implementation of chosen designs. Mozambique served as a pilot country for this process.

2.2. Engaging the MOH

With impending new vaccine introductions, the Mozambique MOH was interested in finding efficiencies in the vaccine supply chain through system optimization across all provinces. Thus, the MOH initiated a pilot modeling activity in two provinces where an alternative system was operating in order to generate evidence for analyzing different approaches to vaccine distribution. Using HERMES, we constructed models of the vaccine supply chains in the provinces of Gaza and Cabo Delgado and simulated scenarios of interest.

2.3. Conducting workshops

A significant part of this pilot was capacity building, i.e., building the skills of a local team of experts to use the models, interpret the results, and move decisions forward for system optimization. In September 2014, the Mozambique MOH, VillageReach, and the HERMES Logistics Team conducted a weeklong workshop in Mozambique. Participants included representatives from the Expanded Program on Immunization (EPI), Provincial Directorates of Health (DPS) from three provinces (including Gaza and Cabo Delgado), UNICEF, WHO, local University of Eduardo Mondlane, and VillageReach.

The workshop provided an introduction to simulation modeling and its applications to vaccine supply chains. After reviewing and discussing preliminary modeling results, participants provided information to refine the models and generated ideas for additional scenarios of interest. Participants then received hands-on training in creating and modifying a vaccine supply chain model, implementing and running scenarios, and analyzing simulation results within the HERMES user interface.

2.4. Developing the models

2.4.1. Original Mozambique vaccine supply chain design

Historically, the Mozambique routine vaccine supply chain has followed a multi-tiered system. Manufacturers ship vaccines to one national depot in the capital city of Maputo, which sends quarterly shipments of vaccines to most provincial stores by plane while nearby provinces pick up vaccines using 4×4 trucks. Each provincial store delivers monthly shipments to the district stores by truck. Health centers order vaccines from the districts on a monthly basis, and though national policy dictates that the district stores deliver vaccines to health centers by truck or motorbike, in reality many health centers must send health workers by public transportation to pick up vaccines due to unavailability of vehicles or lack of fuel funds at the districts. Health workers administer age-appropriate vaccinations at health centers and outreach sessions. The ad hoc nature of transport contributes to delays in getting vaccines to the health centers. This multi-tiered system continues to operate in 5 of the 10 provinces.

2.4.2. Alternative distribution system

In 2002, international NGO VillageReach, together with national NGO Foundation for Community Development, launched a five-year pilot project to streamline and improve the vaccine supply chain in Cabo Delgado province. In partnership with the MOH and the EPI, the project created an alternative distribution system. Instead of provinces delivering to the district level, each provincial store delivers monthly shipments directly to health centers using 4×4 trucks in transport loops (i.e., a truck visits multiple health centers in a single trip before returning to the provincial store). The pilot resulted in an increase in vaccine coverage, reduced stock-outs at the health center levels, and improved cost-efficiencies when compared to the original multi-tiered system [4,5]. These positive results encouraged VillageReach to expand the alternative system to three additional provinces, including Gaza, generating interest throughout the country.

2.4.3. HERMES simulation models of Gaza and Cabo Delgado supply chains

We constructed models of the routine vaccine supply chains for Gaza and Cabo Delgado provinces using the HERMES software platform. HERMES generates detailed discrete-event simulation models that include virtual representations of all vaccine vials, storage and immunization locations, storage and transport devices, ordering and shipping policies, and logistics costs associated with supply chain operations. A HERMES-generated model tracks each vial as it moves through the system to be shipped, stored, and ultimately used or wasted. Previous publications describe HERMES in detail [6–10].