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The budget impact of controlling wastage with smaller vials: A data driven model of session sizes in Bangladesh, India (Uttar Pradesh), Mozambique, and Uganda

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ABSTRACT

Introduction: Open vial vaccine wastage in multi-dose vials is a major contributor to vaccine wastage. Although switching from 10-dose vials to 5-dose vials could reduce wastage, a higher total cost could be triggered because smaller vials cost more to purchase and store.
Methods: This study drew field data of daily session sizes in local vaccination facilities from Bangladesh, India (Uttar Pradesh), Mozambique, and Uganda, and used Akaike Information Criteria to determine the best fit statistical distribution across various clinic types. These distributions were input to estimate the vaccine wastage using Lee's (2010) model. Inactivated polio vaccine (IPV) immunization was simulated to compare the costs over ten years with 10-dose vials versus 5-dose vials.
Results: By switching from 10- to 5-dose vials, the observed open vial wastage rate due to vial size preference and session size for IPV was reduced from 0.25 to 0.11 in Bangladesh, 0.17 to 0.08 in India (Uttar Pradesh), 0.13 to 0.06 in Mozambique, and 0.09 to 0.04 in Uganda, respectively. The cost savings realized from lower IPV wastage did not offset the higher costs of procurement and storage costs associated with smaller dose presentation.
Conclusion: While our model showed that switching from 10-dose vials to 5-dose vials of IPV reduced open vial wastage, it was not cost-saving.

1. Introduction

One of the largest impediments to efficient immunization is the wastage of opened and unopened vaccine vials [1]. As developing countries introduce new and expensive vaccines, there is a need to understand factors that contribute to vaccine wastage so potential solutions can be assessed.

Vaccine wastage is defined by the World Health Organization (WHO) [2] as "loss by use, decay, erosion, or leakage or through wastefulness", and can be calculated as the proportion of vaccine administered against vaccine issued [1]. Vaccine wastage falls into two categories: wastage in unopened vials and wastage in opened vials. Wastage in unopened vials results from expiration, thermo-instability, breakage, missing inventory, and other incidental causes [3], and is generally a static rate [4].

Wastage in opened vials is much higher than in unopened vials [5], and varies from facility to facility. It is related to many factors including immersion of opened vials in water, uncertainty about the sterility of prior withdrawals, thermal handling, and poor vaccine administration practices [1]. With the use of a multi-dose vial (MDV), there is a risk of contamination every time a needle is inserted into the vial. Furthermore, when a health care worker (HCW) opens a MDV and is unable to use the remainder before it expires, excessive open vial wastage can occur at the clinic level [6].

To address open vial wastage, the WHO has a multi-dose vial policy (MDVP) that permits vials of certain vaccines to remain open for up to 4 weeks so long as certain criteria are met regarding handling, administration, and storage [7]. Some local health programs may feel that they are unable to meet these conditions (for instance, in rural vaccination clinics or outreach settings) and workers may discard open vials after each clinic day. With certain vaccines, the MDVP may not apply [4,8].

For countries and clinic settings that cannot comply with the WHO MDVP, there are two driving factors that influence open vial

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vaccine wastage: (1) the session size of a vaccination facility, and (2) the vaccine vial size [8,9]. The larger the session size (the more children who showed up for vaccination during one session), the fewer the overall remaining doses.

One strategy that has been examined to help reduce open vial wastage is to lower the number of doses per vaccine vial [2,3]. A 2012 study found that in primary care settings in urban India, vial size is statistically significantly related to vaccine wastage [10]. While switching to lower dose vials might reduce open vial vaccine wastage, it will incur higher purchasing, manufacturing, storage and vaccine delivery costs. Moreover, many new vaccines come at a higher price per dose than traditional vaccines, and thus wastage is more costly [11]. A 2009 study found that the optimal vial size depends on country-specific wastage rates, and concluded that these critical data are missing for most GAVI eligible countries [12].

In 2010, Lee et al. [6] applied a mathematical model to capture the vaccine wastage and associated economic impact of different vial size strategies. Due to the lack of facility data in real-life settings, the paper assumed that session size follows a Poisson distribution. The paper emphasized that in order to calculate the expected wastage rate, one needs to first define the distribution of session size. No studies have since collected data on vaccine session sizes and defined a statistical distribution to generate open vial vaccine wastage as an output.

In our study, we used session size data from four countries to develop a realistic statistical model of open vial wastage rates and their associated costs. We use the term "session size" in our study to refer to the number of children who arrive at a given vaccination session. There were two primary objectives to this study: first, to use session size data from four GAVI-eligible countries to understand country-level factors that influence wastage in open vials; second, to estimate the economic impact of switching to smaller dose vials.

The Strategic Advisory Group of Experts on Immunization (SAGE) recommended inactivated polio vaccine (IPV) to be introduced to the routine immunization program by 2015 [13]. Because the MDVP will likely not apply to IPV, we focused our study on the case of IPV.

2. Methods

Bangladesh, India (Uttar Pradesh), Mozambique, and Uganda were chosen to reflect various population sizes and urbanicity among developing countries in Africa and Asia (see Table 1). Session size data were collected from representative facilities in the four countries. IPV wastage and associated costs were examined in this paper, though our model enables users to simulate different types of vaccines in various presentation and dose schedules. Our model uses a 1-dose schedule for IPV.

2.1. Data input

This study used data on session sizes to model populations from Bangladesh, India (Uttar Pradesh), Mozambique, and Uganda. The rural data from Bangladesh originated from four clinics in the Sunamganj district, consisting of one large outpatient clinic, two union health centers, and one subcenter. The urban data from Bangladesh came from three urban subcenters, two urban HC III clinics, and three large urban clinics ("HC" stands for "health center"). The number of pentavalent vaccine doses administered between January and December 2012 were counted at each session.

For India, we collected data on the number of DPT doses administered in two HC III clinics in the Basti district of Uttar Pradesh from January to February 2012. There were no data available from urban clinics in Uttar Pradesh.

The data from Mozambique came from 74 Centro Salud Rural (CSR) 1 sessions, 49 CSR2 sessions, as well as 45 outreach sessions from the Inhambane district of Mozambique in 2012. The number of children receiving a pentavalent vaccine each day was recorded. There were also no data available from urban clinics in Mozambique.

The Ugandan data originated from the Service Provision Assessment (SPA) Survey of 2007 that was collected by Macro International [14]. After weighting, the survey provided a national representative sample of all government health care facilities in Uganda. Data were collected by site inspections and health record review from 433 facilities providing immunization at HC-IIs, HC-IIIs, HC-IVs, rural hospital settings and urban settings. The SPA survey had sampling weights for each type of facility, so one can produce estimates of the national count of each type of facility. The counts of daily children arriving in facilities in the SPA data were based on all children, not just children requesting immunization.

The estimated number of facilities in each country relied on SPA data in Uganda [18], and Bangladesh [15]. Facility count estimates for Mozambique were extrapolated on a population basis from Inhambane province to all Mozambiquan provinces. Facility count estimates for India were confined to only rural Uttar Pradesh.

In each country or region, the daily session size data for each clinic type was determined by fitting the parameters of various distributions. A maximum likelihood algorithm to find parameters that minimized the root mean squared error between the data and each candidate distribution was implemented in Palisades @Risk Version 6.01. This algorithm provided three best-fitting distributions with their associated Akaike Information Criterion (AIC) scores and parameters. The distribution that had the lowest AIC score was chosen as the best-fit distribution at each type of clinic to express the pattern of session size observed. The AIC was preferable to a chi-squared goodness of fit test because it takes account of the degrees of freedom and it could be implemented for discrete data unlike the Kolmogorov–Smirnov test. (Please refer Table 2 for all model inputs.)

Table 1
Demographics of sample countries. We collected data from Bangladesh, India (Uttar Pradesh), Mozambique, and Uganda, 4 GAVI eligible countries, to reflect both small and large populations and combination of different immunization session sizes.

Region	Country	Population[a] (Million)	Birth cohort size (Million)[b]	Growth rate of birth cohort 2014–2024[c]	Current coverage rate[d]	Urbanicity[e]	Year of IPV introduction plan[f]
Asia	Bangladesh	157.6	Low (3)	−0.02	High (96%)	Rural (>70%)	2014
Asia	India	1260.5	High (27)	−0.003	Medium (72%)	Mixed (>65%)	2014
Africa	Mozambique	26.2	Low (1)	0.01	Medium (75%)	Mixed (>60%)	2014
Africa	Uganda	38.3	Low (2)	0.06	High (82%)	Rural (>85%)	2014

[a] GeoHive; population as of January 2014.
[b] GAVI alliance; birth cohort size.
[c] United Nations (2012). World population prospects: the 2012 revision.
[d] UNICEF; coverage rate using DTP3 as proxy: >80% high, 60–80% medium, <60% low; WHO/UNICEF estimates.
[e] World Bank estimates.
[f] GAVI; support plan for new vaccine introduction.