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Distributional impact of rotavirus vaccination in 25 GAVI countries: Estimating disparities in benefits and cost-effectiveness

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ABSTRACT

Background: Other studies have demonstrated that the impact and cost effectiveness of rotavirus vaccination differs among countries, with greater mortality reduction benefits and lower cost-effectiveness ratios in low-income and high-mortality countries. This analysis combines the results of a country level model of rotavirus vaccination published elsewhere with data from Demographic and Health Surveys on within-country patterns of vaccine coverage and diarrhea mortality risk factors to estimate within-country distributional effects of rotavirus vaccination. The study examined 25 countries eligible for funding through the GAVI Alliance.

Methods: For each country we estimate the benefits and cost-effectiveness of vaccination for each wealth quintile assuming current vaccination patterns and for a scenario where vaccine coverage is equalized to the highest quintile's coverage. In the case of India, variations in coverage and risk proxies by state were modeled to estimate geographic distributional effects.

Results: In all countries, rates of vaccination were highest and risks of mortality were lowest in the top two wealth quintiles. However countries differ greatly in the relative inequities in these two underlying variables. Similarly, in all countries examined, the cost-effectiveness ratio for vaccination ($/Disability-Adjusted Life Year averted, DALY) is substantially greater in the higher quintiles (ranging from 2–10 times higher). In all countries, the greatest potential benefit of vaccination was in the poorest quintiles. However, due to reduced vaccination coverage, projected benefits for these quintiles were often lower. Equitable coverage was estimated to result in an 89% increase in mortality reduction for the poorest quintile and a 38% increase overall.

Conclusions: Rotavirus vaccination is most cost-effective in low-income groups and regions. However in many countries, simply adding new vaccines to existing systems targets investments to higher income children, due to disparities in vaccination coverage. Maximizing health benefits for the poorest children and value for money require increased attention to these distributional effects.

1. Introduction

Global and regional level analysis of rotavirus vaccination demonstrates that the impact and cost-effectiveness of vaccination is heterogeneous [1–4]. In general there are greater benefits and better cost-effectiveness ratios in low-income countries and regions, primarily due to higher estimated mortality. At the same time, lower vaccination coverage, along with reduced efficacy and great delays in timing mean that the percent reduction in rotavirus burden would be lowest in these countries [5].

However this global pattern of disparities is likely to be repeated within as well as between countries [6]. Poorer households and poorer regions within a particular country are likely to have high diarrhea mortality risk and lower levels of timely vaccination coverage. This suggests that distribution of the benefit, cost-effectiveness and residual (post-vaccination) rotavirus mortality are also likely to differ after vaccine introduction.

This paper estimates the geographic and socio-economic distributional effects of rotavirus vaccine introduction within a subset of countries eligible for funding by the GAVI Alliance. This includes the distribution of benefits, cost-effectiveness, and residual (post-vaccine introduction) mortality risk. The main research question is 'how do outcomes differ across geographic and socio-economic gradients at the regional, national, and sub-national scales?' Better understanding of distributional effects is essential in tackling the substantial remaining rotavirus mortality burden, even with

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vaccination. Distributional effects also have implications for decisions about where to invest first, even among and within GAVI-eligible countries.

Best practices for economic evaluations of health interventions typically require distributional analyses to assess who within a population is more or less likely to benefit. This is based on an understanding that cost-effectiveness is just one criterion in decision-making and other factors, such as who benefits, also need to be considered. While in practice, few vaccine cost-effectiveness studies directly explore these issues, there is evidence that vaccination can have both pro-poor and anti-poor distributional effects. Bishai et al. demonstrated that near universal measles vaccination in Bangladesh reduced disparities in under-5 mortality [7]. Michaelidis et al. found that efforts in reducing disparities in influenza vaccination among elderly minority groups in the US was moderate to highly cost-effective [8]. Human papillomavirus (HPV) vaccination provides a somewhat different scenario. While the burden of cervical cancer is disproportionately borne by poorer women with limited access to prevention and timely treatment, vaccination programs may similarly miss the target population [9,10].

Several approaches have been suggested for addressing distributional and equity concerns in cost-effectiveness. One approach is to explicitly weight outcomes among the poor as higher than those among better off sub-populations through an equity weight [11,12]. In some cases, weights are suggested based on socio-economic status and in other contexts based on the severity of individual conditions [13].

In some contexts there is an equity-efficiency tradeoff where the most impactful or efficient is not the most equitable [14]. Walensky et al. modeled a variety of prevention and treatment approaches for HIV in South Africa, considering the cost-effectiveness and equity of different intervention combinations [15]. Their model included a calculation of the opportunity cost of equity, based on the health improvements that would be forgone in order to select the most equitable solutions. Jehu-Appiah et al. demonstrated the usefulness of a similar modeling approach to quantify the trade-offs between efficiency and equity in health investment priorities in Ghana [16].

One of the simplest approaches to assessing distributional effects is to explicitly estimate costs and impacts for distinct sub-populations. This may include stratifying by age, sex, socio-economic status and/or geographic regions. Coyle et al. provide a general framework for population stratified cost-effectiveness analysis [17] and Sculpher describes the application of the approach in contexts such as the UK's NICE evaluation process [18].

2. Methods

2.1. General model structure

We used an existing country-level rotavirus impact and cost-effectiveness model [1] that has been updated with newly available data [5]. Estimates here are for vaccinating a single birth cohort, including outcomes during their first five years of life. National rotavirus mortality estimates were based on recently published figures [19]. Estimates of inpatient and outpatient visits are also from previously published studies [20].

Vaccine efficacy estimates were based on region and mortality strata [21–23]. Estimates for high mortality countries were based on pooled estimates from recent trials [21] and are described in full detail in Atherly et al. [5]. Efficacy was adjusted for the expected age at which first and second dose would be received in each country, based on DPT1 and DPT2 coverage from DHS surveys [3,24]. This was done by modeling coverage of 1 and 2 doses of vaccine at 0–2, 3–5, 6–8 and 9–11 months. Reported DPT1 and DPT2 coverage among 12–23 month old children was used to estimate the fraction of those that would receive each vaccine at the different age ranges [5]. Vaccination effectiveness was based on the fraction of children at each age with 0, 1, or 2 doses and the expected protection of each, assuming 50% lower efficacy for a single dose in the 2-dose regime. For each age band, the effectiveness was applied to the proportion of rotavirus deaths that would occur during that period. Current SAGE recommendations suggest that children over 8 months or 32 weeks not receive a vaccine in order to avoid potential adverse effects. The model used in this study assumes that children receiving their second DPT dose between 8 and 12 months of age would still receive it [25].

Medical treatment costs were estimated for inpatient and outpatient visits, using cost-estimates from WHO-CHOICE for facility charges and extrapolations of medication and diagnostic costs from published studies, as described elsewhere [1,3]. Medical costs were in 2010 US Dollars and presented in more detail elsewhere [5]. All costs and DALY estimates were discounted at 3%. Cost-effectiveness estimates are based on a two-dose vaccine with a price of $2.50 per dose.

In the original model we adjusted for a potential differential coverage among children likely to suffer rotavirus mortality [1]. For the current model we eliminated that assumption since we are explicitly modeling the co-distribution of risks and access.

Table 1
Selected Demographic and Health Survey (DHS) country data for the distributional impacts of rotavirus vaccination.

Country by DHS region	Year
Latin America and Caribbean	
Haiti	2006
South and Southeast Asia	
Bangladesh	2007
Cambodia	2005
India	2006
Nepal	2006
Sub-Saharan Africa	
Burkina Faso	2003
Cameroon	2004
Chad	2004
Dem. Rep. of Congo	2007
Ethiopia	2005
Ghana	2008
Guinea	2005
Kenya	2009
Lesotho	2004
Liberia	2007
Malawi	2004
Mali	2006
Mozambique	2003
Niger	2006
Nigeria	2008
Senegal	2005
Sierra Leone	2008
Tanzania	2005
Uganda	2006
Zambia	2007

2.2. Socio-economic distribution of immunization benefits at the national level

The distributional impact of vaccination in a given country was modeled by incorporating data on the disparities in vaccine coverage by wealth quintile at the national level and by estimating the distribution of rotavirus mortality risk by wealth quintile. Both of these were estimated using available data (2003 or later) from the most recent Demographic and Health Surveys of the 25 GAVI-eligible countries [26]. Countries were selected based on the availability of data at the time of the analysis. Countries with earlier surveys were excluded given that disparities may change over time due to ongoing efforts to achieve universal coverage. Table 1 shows