

# Health Care Costs of Diarrheal Disease and Estimates of the Cost-Effectiveness of Rotavirus Vaccination in Vietnam

Thea K. Fischer,<sup>1,2,4</sup> Dang Duc Anh,<sup>5</sup> Lynn Antil,<sup>3</sup> N. D. L. Cat,<sup>6</sup> Paul E. Kilgore,<sup>8</sup> Vu D. Thiem,<sup>5</sup> Rick Rheingans,<sup>3</sup> Le H. Tho,<sup>7</sup> Roger I. Glass,<sup>1</sup> and Joseph S. Bresee<sup>1</sup>

<sup>1</sup>Division of Viral and Rickettsial Diseases and <sup>2</sup>Epidemiology Intelligence Service, Centers for Disease Control and Prevention, and <sup>3</sup>Department of Global Health, Rollins School of Public Health, Emory University, Atlanta, Georgia; <sup>4</sup>Department of Epidemiology Research, Statens Serum Institut, Copenhagen, Denmark; <sup>5</sup>National Institute of Hygiene and Epidemiology, Hanoi, and <sup>6</sup>Department of Pediatrics, Khanh Hoa General Hospital, and <sup>7</sup>Khanh Hoa Health Service, Khanh Hoa, Vietnam; <sup>8</sup>Division of Translational Research, International Vaccine Institute, Seoul, Korea

**Background.** Rotavirus disease causes a significant health and economic burden worldwide. Several rotavirus vaccines may soon be available for use. A country's decision to introduce these vaccines will depend on its rotavirus disease burden, on the cost of the vaccine, and on the results of an economic assessment of the cost and effectiveness of a rotavirus vaccination program.

**Methods.** Data on medical and nonmedical direct costs and indirect costs were established in Khanh Hoa Province, Vietnam, and extrapolated to national estimates on the basis of the birth cohort in 2004. The main outcome measures were economic burden and cost-effectiveness ratio (United States dollars per disability-adjusted life-year averted and dollars per life saved) of vaccination.

**Results.** The disease burden is equivalent to an economic burden of an estimated \$3.1 million in medical direct costs, \$685,000 in nonmedical direct costs, and \$1.5 million in indirect costs. From a societal perspective, treatment of rotavirus disease costs an estimated \$5.3 million per year. From the health care system perspective, universal vaccination of infants at a cost of  $\leq$ \$7.26/vaccine dose would be a cost-effective public health intervention, according to the World Bank cost-effectiveness standard for low-income countries (\$140/disability-adjusted life-year).

**Conclusions.** Vaccination can effectively reduce the disease burden and health care costs of rotavirus-specific diarrhea in Vietnam.

Rotavirus is one of the most common causes of acute dehydrating diarrhea in young children worldwide. Rotavirus vaccines will soon become available for childhood immunization. The decision to introduce these vaccines will require policy makers to assess the ex-

pected health and economic benefits of a vaccination program. In developing countries with scarce economic resources, assessment of the cost-effectiveness of a vaccination program can help guide decisions about introduction of vaccine versus other health interventions. Ongoing surveillance of rotavirus in Vietnam has demonstrated that rotavirus is responsible for an average of 56% (range, 43%–60%) of diarrhea-associated hospitalizations among children <5 years old [1].

We field-tested the World Health Organization (WHO) generic protocol on cost assessment [2] to determine the direct cost of health care services for rotavirus-specific diarrhea as well as the indirect costs to the individual patient in Vietnam. We then used the data to assess vaccine cost-effectiveness in Vietnam. This study was the first pilot test of the WHO generic protocol, assessing the national rotavirus disease burden in cost-associated terms on the basis of actual data.

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Reprints or correspondence: Dr. Thea K. Fischer, Viral Gastroenteritis Section (Mailstop A-34), Centers for Disease Control and Prevention, 1600 Clifton Rd., Atlanta, GA 30333 (tfischer@dadlnet.dk); or Dr. Dang Duc Anh, National Institute of Hygiene and Epidemiology, 1 Yersin St., Hanoi 10,000, Vietnam (ducanhnie@hn.vnn.vn).

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## SUBJECTS, MATERIALS, AND METHODS

**Study population.** Cost and disease burden data were assembled for Khanh Hoa, a province in southeastern Vietnam. The catchment area includes 16 of 26 communes in urban Nha Trang and 17 of 27 communes in rural Ninh Hoa. Direct cost data were collected in 14 different health care facilities. We used information on health care utilization practices for childhood diarrheal illness, recently collected by Kaljee et al. [3], to assess the fraction of visits at the various health care facilities.

**Disease burden.** Rotavirus-specific diarrhea events used in the model were derived from age-specific rates of diarrhea, which were defined through active surveillance [4] combined with the proportion of diarrheal episodes attributed to rotavirus, as determined on the basis of surveillance data [5] (table 1). National estimates of the number of rotavirus-specific diarrhea events were calculated by extrapolating the regional rates in Khanh Hoa Province on the basis of the 2003 Vietnamese birth cohort ( $n = 1,639,000$ ) [7], and they were expressed as age-specific rates for each event. Because no data on the percentage of rotavirus-specific diarrhea events among outpatients in Vietnam are available, we used 28%, a percentage that has been documented in a recent outpatient study in China, where the percentage of diarrhea events among inpatients was similar to that found in Khanh Hoa Province (i.e., 50%) [8]. Estimates of diarrhea- and rotavirus-specific mortality were derived from a recent study by Nguyen et al. [5], in which they report that, among children >5 years of age, 9600–12,400 deaths were attributable to diarrhea, and 5300–6800 deaths (mean, 6050 deaths) were attributable specifically to rotavirus [5]. The morbidity and mortality of disease was also expressed as disability-adjusted life-years (DALYs) [9], which measures health gaps as opposed to health expectancies and which allows for comparisons with other diseases and interventions. DALY estimates included age weights and a discount rate of 3%.

**Health care costs.** The economic burden of rotavirus-specific diarrhea to the health care system was estimated by combining the number of each type of event (i.e., hospitalization, death, and outpatient visit) with information on the costs as-

sociated with each event. Estimates of the per day and per visit costs were obtained through interviews with governmental health officials, such as regional hospital directors and pediatric department administrators, regional health planners and administrators, and clinic owners. For hospitalization and outpatient visits, costs were partitioned into the cost of the visit, including costs for facilities, personnel, and the resources used for treatment (i.e., specific tests and medication).

All patient cost information was obtained with predesigned standard questionnaires [2] to interview parents with children <5 years of age who had acute diarrhea (symptoms lasting for <8 days). Team workers conducted interviews in rooms separated from the waiting areas and hospital wards. Inpatients were interviewed on the day of discharge, and information on treatment and diagnostic testing was obtained through subsequent review of the child's medical file. The medical direct costs for hospitalized patients were calculated by combining patient information on resource use (including length of stay) and unit cost of a hospital bed day, diagnostic tests, and medications. In a similar manner, we calculated the costs of outpatient visits with the duration of stay excluded, because none of the outpatient facilities offered overnight stays. Parents were asked to estimate the time they lost from paid employment while taking care of their sick child (in days) and about the time (hours) or distance (in kilometers) and mode of transportation to and from the health care facility. This information was included in the model when calculating the indirect costs and the non-medical direct costs, respectively.

Medical direct costs for rotavirus-specific diarrhea in the first 5 years of life were estimated for the 2003 Vietnamese birth cohort. Similarly, the average medical direct costs per child in the birth cohort were estimated for the child's first 5 years of life. All costs are expressed in 2004 US dollars.

**Rotavirus vaccination effectiveness and costs.** The effectiveness of vaccination was calculated by combining the estimated vaccine coverage and efficacy information as variable functions depending on the age at vaccination. We used a sim-

**Table 1. Rotavirus disease burden in Vietnam: estimates with and without a vaccination program.**

Variable	Rotavirus-associated events				
	Occurring without vaccination	Occurring per 1000 children	Occurring with vaccination	Prevented by vaccination	Reduction in, %
Death	6050	3.7	1049	5001	83
Hospitalization	125,468	76.6	20,040	105,429	84
Outpatient visit	194,745	118.8	57,498	137,247	70
DALY	201,541	123.0	35,019	166,522	83

**NOTE.** Estimates are based on 90% efficacy of the Rotarix vaccine [6] and coverage by age 2 years [4] in a 1-year birth cohort ( $n = 1,639,000$ ) followed to age 5 years. DALY, disability-adjusted life-year.

ulation model that combines information on disease burden, coverage, and effectiveness in a temporally explicit fashion [2].

The age distribution of the key rotavirus disease outcomes (death and hospitalization) was based on observations from a hospital surveillance study conducted in 6 Vietnamese hospitals [5], and the age-specific rates for outpatient visits were considered to be the same as those for inpatient visits. The estimated total number of events for the annual birth cohort was then divided for analyses into 8 age groups by months: 0–2, 3–5, 6–8, 9–11, 12–23, 24–35, 36–47, and 48–59 months.

Next, the model considered the expected vaccination status of children in each age group. Data on routine vaccine coverage were obtained from the vaccine safety data link [4]. We assumed that the timing of vaccination would be the same as that of dose 1 and dose 2 of the diphtheria–tetanus toxoids–pertussis vaccine at age 6 and 10 weeks, respectively. According to the vaccine safety data link data, we would expect the rotavirus vaccine coverage to be 94% and 93% for dose 1 and dose 2, respectively, of the rotavirus vaccine.

We examined efficacy data for the GlaxoSmithKline vaccine currently licensed in Mexico, which were 93% for preventing hospitalizations, 86% for severe rotavirus-specific diarrhea, and 70% for any rotavirus-specific diarrhea [6]. We used the efficacy estimates of 93% for the prevention of rotavirus-associated hospitalizations and deaths and 78% for the prevention of outpatient visits. Vaccination costs include the cost of administration, the price of the vaccine, and the expected losses from waste (10%). Because studies have estimated the cost of vaccination with the current Expanded Programme on Immunization (EPI) vaccines [10, 11] but have not assessed the marginal cost of adding a new vaccine, we applied a hypothetical administration cost of \$0.50/vaccine course. Our analysis included a range of price estimates, from \$1.00 to \$20.00, for a 2-dose regimen.

**Model overview.** We used the design and mathematical modeling principles introduced in the WHO generic protocol to estimate the health care costs of rotavirus-specific diarrhea and the cost-effectiveness of vaccination [2]. The cost-effectiveness analyses were conducted from 2 perspectives: the health care system perspective, which includes only the medical direct costs, and the societal perspective, which includes the other costs borne by individuals (e.g., work days lost). The model was constructed with Microsoft 2000 Excel software and compares the cost of a health intervention (rotavirus vaccination) with the cost of no health intervention. The principal inputs to the model include epidemiological information on rates of disease requiring treatment in hospitals and outpatient clinics and their associated health care costs and the estimated effectiveness and cost of vaccination. The model also accounts for the timing of the health events and vaccination, because the vaccine would be ineffective

if introduced at a later age, after the first episode of rotavirus-specific diarrhea.

**Cost-effectiveness.** The primary measures of cost-effectiveness in this study are the incremental cost-effectiveness ratios (CERs) expressed as cost per DALY averted and cost per life saved. CERs compare the net cost of the health intervention with the benefit gained by providing it. For this analysis, the net cost is the costs of administering the rotavirus vaccine minus the medical costs averted by vaccination. The DALY measure includes 2 components: years of life lost due to premature mortality and years lived with disability. The DALY loss from mortality (years of life lost) was calculated on the basis of the standardized life expectancy for children <1 year old.

We calculated the CER for a range of vaccine prices (\$1–\$20/vaccine course) and estimated the price at which vaccination would meet particular criteria for cost-effectiveness in terms of dollars per DALY. Criteria include cost neutrality (i.e., medical or total costs saved equal the cost of vaccination) and cost-effectiveness (i.e., cost per DALY averted would be less than or equal to a particular standard). The standard we chose was obtained from the World Bank's *World Development Report 1993: Investing in Health* [12], which suggests that interventions with a CER of <\$200/DALY are highly cost-effective in developing countries. Public health interventions that meet this level of cost-effectiveness include the EPI and many school-based health services, family planning services, nutrition programs, and AIDS prevention programs [12]. In addition, the World Bank assesses the costs and health gains of a cost-effective package of public health interventions and essential clinical services for low-income countries such as Vietnam. The cost per DALY averted for the package is ~\$140 in low-income countries [12]. This may be an appropriate standard for Vietnam, because, with a 2004 per capita gross domestic product of \$550, the country is classified as low income [13]. WHO suggests that an intervention is very cost-effective if the cost per DALY averted is less than a country's per capita gross domestic product [14].

**Sensitivity and uncertainty analyses.** To address the potential uncertainty created by the generalization approach of extrapolating regional incidence and cost data to a national level, sensitivity and uncertainty analyses were applied. A sensitivity analysis was conducted to assess the impact of rotavirus-specific diarrhea rate estimates, vaccine efficacy, per day and per visit cost estimates, and vaccine price on the incremental CER. An uncertainty analysis was conducted to evaluate the potential impact of this uncertainty on preliminary quantitative estimates and to assess the need for additional data collection.

A Monte Carlo model was developed on the basis of the model of rotavirus disease burden and cost-effectiveness of vaccination described above. For national disease burden variables, distributions were used to characterize the cumulative incidence of

rotavirus-associated outcomes (i.e., hospitalizations, outpatient visits, and deaths). The uncertainty range for the incidence of rotavirus-associated hospitalizations and outpatient visits was estimated to be  $\pm 20\%$ , and the uncertainty range (12%–14%) for the mortality estimate was determined on the basis of the range provided by Nguyen et al. [1]. For health care cost variables, uncertainty ranges of 25% were used. In addition, uncertainty ranges were used for the estimates of vaccine efficacy against death (54%–100%), hospitalization (54%–100%), and outpatient visit (46%–96%), as were reported in clinical trials conducted in Latin America [6].

**Ethical approval.** This study was approved by the human subjects research committees at the National Institute of Health and Epidemiology, Hanoi; the International Vaccine Institute, Seoul, South Korea; and the Centers for Disease Control and Prevention, Atlanta. Informed consent was obtained from all subjects enrolled in the study.

## RESULTS

We collected economic data from 177 families of children with acute diarrhea. In the urban setting of Nha Trang, we surveyed 60 inpatients, 42 hospital outpatients, 20 patients from private clinics, and 2 patients from a polyclinic. In the rural setting of Ninh Hoa, we surveyed 30 inpatients, 15 hospital outpatients, 3 patients from a polyclinic, and 5 patients from a community health care center.

**Cost burdens.** Our survey of patients from hospitals and outpatient units in rural and urban Khanh Hoa Province provided a full range of estimated medical costs (table 2). Total medical direct costs were  $\sim 1.5$  times higher at the urban than the rural hospital, but the total overall cost per outpatient visit was slightly higher at the rural than the urban facilities, except for visits to private clinics. Most ( $\sim 75\%$ ) of the medical expenditures were associated with hospitalizations. The weighted mean cost per hospitalization was \$12.22, and it was higher for children admitted to the urban (\$23.85) than to the rural (\$8.34) hospital, even though the duration of stay was slightly longer at the rural hospital (mean stay, 4.8 days vs. 4.3 days).

The weighted mean cost of an outpatient visit was \$0.37 (range, \$0.13 for a rural hospital outpatient clinic to \$0.66 for a private urban clinic). The lost income to parents due to a child's illness was highest among outpatients attending private urban facilities (\$4.27) compared with any other outpatient clinic (range, \$1.11 for urban hospital outpatients to \$2.75 for rural hospital outpatients).

Extrapolating our estimates from Khanh Hoa Province to a national level, we found that the rotavirus-associated economic burden, from the health care system perspective, amounted to \$3.1 million/year (or \$1.91/child/year) in medical direct costs and \$685,000/year (or \$0.42/child/year) in nonmedical direct costs (table 3). Total direct costs (medical and nonmedical)

**Table 2. Weighted mean values of direct and indirect costs of rotavirus-specific diarrhea in urban and rural Vietnamese health care facilities.**

Aspect, type of cost, cost	Urban (Nha Trang) (n = 60)	Rural (Ninh Hoa) (n = 30)
<b>Hospitalization</b>		
Medical direct costs		
Bed cost per day	5.55	1.74
Bed cost per visit <sup>a</sup>	23.85	8.34
Diagnostics and medicine	3.25	9.25
Total	27.09	17.59
Nonmedical direct costs (transport)		
Indirect costs (lost wages)	4.33	9.04
Total	36.16	31.00
<b>Outpatient visit</b>		
Medical direct costs		
Cost per visit <sup>b</sup>		
Hospital outpatient	0.25	0.13
Polyclinic/CHC	0.20	0.17
Private clinic	0.66	0.53
Diagnostics and medicine <sup>c</sup>		
Hospital outpatient	3.76	3.98
Polyclinic/CHC	2.68	3.00
Private clinic	3.05	3.49
Total		
Hospital outpatient	4.01	4.11
Polyclinic/CHC	2.88	3.17
Private clinic	3.71	4.02
Nonmedical direct costs <sup>c</sup>		
Hospital outpatient	0.58	1.35
Polyclinic/CHC	0.40	0.92
Private clinic	0.47	1.13
Indirect costs (lost wages) <sup>c</sup>		
Hospital outpatient	1.11	2.75
Polyclinic/CHC	2.48	2.64
Private clinic	4.27	2.70
Total		
Hospital outpatient	5.70	8.21
Polyclinic/CHC	5.76	6.73
Private clinic	8.45	7.85

**NOTE.** Data are 2004 US dollars. CHC, community health care clinic.

<sup>a</sup> Calculated by multiplying the bed cost per day by the mean no. of days per stay (4.3 days for Nha Trang and 4.8 days for Ninh Hoa).

<sup>b</sup> Hospital outpatient (urban, n = 42; rural, n = 15), polyclinic/CHC (urban, n = 2; rural, n = 10), private clinic (urban, n = 20; rural, n = 0); cost estimates for visits to rural private clinics were extrapolated from costs for visits to urban private clinics by using 80% of the cost of a visit to a public clinic.

<sup>c</sup> Calculated as the average for rural hospital outpatient and polyclinic/CHC costs.

were  $\sim \$3.8$  million, which equates to  $\sim \$2.24$ /child. Of the direct medical and nonmedical costs, 74% and 77%, respectively, were associated with hospital expenses.

The approximate cost of administering the rotavirus vaccine in Vietnam is \$2.45 million (table 4), at a cost of \$1/vaccine course, and this cost will increase as the price of the vaccine increases. At \$5/vaccine course, there would be a net expenditure for vaccination (net medical costs) of \$6.65 million.

**Table 3. Economic burden of rotavirus-specific diarrhea in Vietnam.**

Cost	Cost, 1000s of 2004 US dollars			Total cost per child, 2004 US dollars
	Hospital	Outpatient	Total (95% CI)	
Medical direct	2460	680	3140 (2470–3565)	1.91
Nonmedical direct	550	135	685 (580–800)	0.42
Indirect	970	550	1515 (1270–1775)	0.92
Total	3980	1365	5340 (4480–5965)	3.25

**NOTE.** CI, confidence interval.

**Impact of vaccination.** Among a birth cohort of 1,639,000 in Vietnam, ~195,000 outpatient visits, 125,000 hospitalizations, and 6050 deaths are attributable to rotavirus disease. These events would result in a loss of 123 DALYs/1000 children. We estimated that introduction of a rotavirus vaccine in Vietnam could prevent ~137,247 (70%) of the 194,745 rotavirus-associated outpatient visits (including those to polyclinics, community health care centers, and hospital outpatient facilities), 105,393 (84%) of 125,468 rotavirus-associated hospitalizations, and 5001 (83%) of 6050 rotavirus-associated deaths (table 1).

**Cost-effectiveness.** The medical break-even price, the point at which the cost of vaccination would be offset by the medical costs averted, is ~\$1.04 for a 2-dose vaccine course. With the inclusion of indirect costs of rotavirus-specific diarrhea, the societal break-even price would be \$2.08/vaccine course.

**Sensitivity and uncertainty analyses.** The sensitivity analysis evaluated the impact of specific variables on the incremental CER. The cost-effectiveness is most affected by the rotavirus-associated mortality rate and the price of the vaccine (table 5). A 25% change in the mortality rate results in a 20%–33% change in the incremental CER. A change in the vaccine's efficacy against hospitalizations has only limited impact, whereas the price of the vaccine has a large impact on the incremental CER: a 50% difference in price results in a 54% change in the CER. Overall, an increase in the incidence of rotavirus disease and efficacy of the vaccine will result in a lower incremental CER, making a vaccination program more cost-effective.

We estimated uncertainty limits (5% and 95%) for total

health care and societal costs (table 3) and for our comparisons of cost-effectiveness (table 4). Another purpose of the uncertainty analysis was to identify variables that contribute most to uncertainty about the estimates of health care costs and cost-effectiveness. Uncertainty in the efficacy against death and the cumulative incidence of mortality due to rotavirus disease had the largest impact on the overall estimates associated with the incremental CER. Therefore, to minimize the uncertainty in the output parameters (health care cost and incremental CER), the input variables identified in the contribution of variance analysis represent a priority for collection of more precise data in the future.

## DISCUSSION

This study has extended our understanding of rotavirus disease burden in Vietnam to include an assessment of the cost of the disease and the cost-effectiveness of a program to introduce a rotavirus vaccine. In Vietnam, the rotavirus disease burden is considerable, with the disease causing ~125,000 hospitalizations, 195,000 outpatient visits, and 6050 deaths per year among children <5 years old [5]. In parallel, the health care costs are substantial: total direct costs, including medical direct costs and nonmedical direct costs (i.e., transportation), were ~\$3.8 million, which equates to ~\$2.34/child. This cost represents 0.5% of the gross national income of \$430 per capita. With the introduction of universal rotavirus vaccination, 82% of the total costs could be averted. At a price of \$10/vaccine course, the cost per DALY averted is \$91, and the cost per life

**Table 4. Expected costs and benefits of rotavirus vaccinations in Vietnam, by vaccine price.**

Variable	Price per vaccine course				
	1	5	10	15	20
Vaccination cost	2450	9195	17,623	26,050	34,480
Net medical cost	92	6650	15,079	23,510	31,935
Net societal cost	650	6090	14,521	22,950	31,380
Cost-effectiveness					
Cost per DALY averted (uncertainty range)	NA	40 (34–62)	91 (79–38)	141 (123–215)	192 (167–291)
Cost per life saved (uncertainty range)	NA	1330 (1136–2051)	3015 (2621–4600)	4701 (4092–7169)	6385 (5560–9708)

**NOTE.** All costs are in thousands of 2004 US dollars except for costs for vaccine courses, which are in 2004 US dollars. NA, not applicable (negative cost-effectiveness ratios cannot be calculated because a health system will not receive money for each disability-adjusted life-year [DALY] averted or life saved).

**Table 5. Sensitivity analysis of the effect of the incidence of rotavirus-specific diarrhea, efficacy of the vaccine, and cost estimates on the incremental cost-effectiveness ratio (CER) of vaccination.**

Parameter	Value (range)	Change, %	Incremental CER <sup>a</sup> (95% CI)	Change, %
5-year cumulative risk, no.				
Deaths	369 (277–461)	± 25	91 (72–121)	–20, 33
Hospitalizations	8000 (6000–9000)	± 25	91 (87–94)	–3, 3
Outpatient visits	11,900 (9000–15,000)	± 25	91 (90–91)	–1, 1
Vaccine efficacy, %				
Death	93 (80–100)	–14, 8	91 (84–105)	–7, 16
Hospitalization	93 (80–100)	–14, 8	91 (90–92)	–1, 2
Cost per day, \$				
Hospital	2.7 (2.02–3.39)	± 25	91 (89–92)	–2, 2
Outpatient visit	0.4 (0.28–0.46)	± 25	91 (90–91)	± 0
Vaccine price, 1 full course, \$	10.00 (5.00–15.00)	± 50	91 (40–141)	± 56

**NOTE.** Data are 2004 US dollars per disability-adjusted life-year, unless indicated otherwise. CI, confidence interval.

<sup>a</sup> Assumes a price of \$10.00/vaccine course.

saved is \$3015. Of note, hospitalizations contributed ~75% of the total medical costs, so it could well be argued that future economic burden studies in Vietnam should focus collection of data on this most costly outcome.

We found that the WHO generic protocol [2] was easy to understand and practical to apply in a field setting. The modeling approach facilitated extrapolation of results from disease surveillance and interventional trials to operational settings. The data could be processed to create realistic ranges, rather than simple point estimates, that incorporated the uncertainty surrounding the input parameters. In other words, modeling enabled us to draw robust conclusions from data obtained from various available sources and rates of disease created by extrapolation of estimates from the regional to the national level. Indeed, the standardized analysis provides an initial excellent basis to evaluate the cost-effectiveness of a vaccine within a country and to compare estimates of cost-effectiveness between countries.

This analysis shows that the rotavirus vaccine is cost-effective when thresholds established by the World Bank are used. Rotavirus vaccination will cost between \$40 and \$192/DALY averted, for a cost per vaccine course ranging from \$5.00 to \$20.00. If the cost-effectiveness standard for low-income countries (\$140/DALY averted) is used, the vaccine is cost-effective up to a price of \$7.26/vaccine dose or \$4.52/vaccine course. Some interventions that are cost-effective may also be cost-saving if the treatment costs averted are greater than the cost of introducing the health intervention. Although health interventions that result in improved health and money saved are excellent investments, few interventions achieve this outcome (even highly effective ones, such as EPI). The results from Vietnam indicate that a rotavirus vaccination program would be cost-neutral at a break-even price of \$0.94/vaccine course. Even though such a program may be considered cost-effective,

it might not be affordable by this country, with its limited resources and budget constraints. Vietnam's total expenditure on health care was ~\$21 per capita in 2001. Of this, the per capita government expenditure on health care was \$6. Given the competing demands for health care expenditures at both governmental and individual levels, it is likely that external resources would be needed to invest in the rotavirus vaccination program. In this situation, WHO suggests that outside resources should be made available for this investment [15], and the Global Alliance for Vaccines and Immunizations program was specifically designed to encourage such investments.

From a societal perspective, our results demonstrate that, in Vietnam, nonmedical direct costs and indirect costs, such as transportation and lost wages, constituted a considerable fraction of the overall costs in both urban (25%) and rural (43%) settings. These findings provide justification for the inclusion of these components in future economic studies and cost-effectiveness analyses.

This study did not include the costs of mild rotavirus disease, because data on the costs of mild illness in patients who do not reach health centers were not available. Adding the costs of mild illness would make the CERs more beneficial, so that the current model may well underestimate the cost-effectiveness of rotavirus vaccination in this population. Also, we want to underscore the potential limitations in our extrapolation of regional estimates from only 1 province to a national level to create national estimates of cost-effectiveness and DALYs averted, because the study population may not be representative of all other populations in Vietnam.

Rotavirus disease causes considerable morbidity and mortality among Vietnamese children and substantial costs to the Vietnamese health care system. Vaccination can effectively reduce this burden and health care costs. For a birth cohort of 1.6 million children, the net medical cost of rotavirus vacci-

nation is \$6.65 million, assuming a price of \$5/vaccine course, and vaccination would prevent >5000 deaths from rotavirus disease. At a price of \$5/vaccine course, the cost per DALY averted is \$40, and the cost per life saved is \$1330. In other words, our study suggests that universal vaccination with an effective and affordable vaccine could greatly reduce the health burden and costs associated with rotavirus-specific diarrhea.

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