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Economic evaluation of rotavirus vaccination

Rochanathimoke, Onwipa; Riewpaiboon, Arthorn; Praditsitthikorn, Naiyana; Tharmaphornpilas, Piyanit; Jiamsiri, Suchada; Thavorncharoensap, Montarat; Postma, Maarten J.

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Economic evaluation of rotavirus vaccination: an important step of the introduction to the national immunization program in Thailand

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ORIGINAL RESEARCH

Economic evaluation of rotavirus vaccination: an important step of the introduction to the national immunization program in Thailand

Onwipa Rochanathimoke^a, Arthorn Riewpaiboon^a, Naiyana Praditsitthikorn^b, Piyanit Tharmaphornpilas^b, Suchada Jiamsiri^b, Montarat Thavorncharoensap ^a and Maarten J. Postma ^{c,d,e,f}

^aDivision of Social and Administrative Pharmacy, Department of Pharmacy, Faculty of Pharmacy, Mahidol University, Bangkok, Thailand;

^bDepartment of Disease Control, Ministry of Public Health, Nonthaburi, Thailand; ^cUnit of Pharmacotherapy, -epidemiology & -economics, University of Groningen, Groningen Research Institute of Pharmacy (GRIP), Groningen, The Netherlands; ^dDepartment of Health Sciences, University of Groningen, University Medical Center Groningen, Groningen, The Netherlands; ^eDepartment of Economics, Econometrics & Finance, University of Groningen, Faculty of Economics & Business, Groningen, The Netherlands; ^fDepartment of Pharmacology and Therapy, Faculty of Medicine, Universitas Airlangga-Soetomo Hospital, Surabaya, Indonesia

ABSTRACT

Introduction: World Health Organization recommends rotavirus vaccine for all national immunization programs (NIPs). To provide country-specific evidence, we conducted economic evaluation of a monovalent rotavirus vaccination using specific data of the pilot phase in Thailand.

Method: A Markov model was adopted to compare the 2020 birth cohort once receiving rotavirus vaccination versus no vaccination from healthcare and societal perspective over five years. Data on disease burden, vaccine effectiveness, costs, and utilities were taken from a cohort study in two provinces of Thailand. Sensitivity analyses were performed to test the robustness of the results.

Results: Rotavirus vaccination would reduce rotavirus diarrhea and costs of illness by 48% and 71%, respectively, over the first five years of life. At USD 13 per dose, vaccine was cost-effective with the ICERs of USD 4,114 and USD 1,571 per QALY gained from healthcare and societal perspective, respectively. Results were sensitive to incidence and vaccine cost. The budget for vaccine purchasing was estimated at USD13 million per year.

Conclusion: Incorporating rotavirus vaccination into the NIP substantially reduced health and cost outcomes and was cost-effective for both perspectives. However, the government needs to negotiate vaccine price prior to program implementation to achieve favorable budget impact.

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Economic; rotavirus; vaccination; national immunization program; Thailand

1. Introduction

Rotavirus is a major cause of severe diarrhea leading to morbidity and mortality in children under the age of 5 years worldwide with 128,500 deaths in 2016 [1]. In Thailand, the burden of rotavirus infection represented 27–50% of children hospitalized attributable to diarrhea during 2000–2011 [2]. Although the mortality rate of rotavirus has been low, rotavirus remains an important cause of childhood morbidity and resource utilization and potentially has major impacts on families [2]. The estimated cost of illness for rotavirus diarrhea in children aged <5 years was USD 21 million in societal perspective [3]. Vaccination is considered the potentially most efficient intervention for preventing and reducing severity of rotavirus diarrhea. In 2007, the World Health Organization (WHO) has recommended the incorporation of rotavirus vaccine into all national immunization programs (NIP) [4]. In Thailand, rotavirus vaccine was first registered by the Food and Drug Administration in 2006. Then, two model-based economic evaluations on rotavirus vaccination in Thailand [3,5] demonstrated the potential favorable cost-effectiveness results including preliminary break-even analysis on the vaccine price. At the time of study, there are two rotavirus vaccines licensed for use in Thai market: two-dose

monovalent Rotarix® and three-dose pentavalent Rotateq®. They have been proven safe and efficacy; however, their impact varies between developed and developing countries [6]. The National Vaccine Committee considered to add rotavirus vaccine into the NIP. Addressing the importance of local evidence on effectiveness and cost-effectiveness of the monovalent rotavirus vaccine the Department of Disease Control conducted a pilot immunization project in Sukhothai province compare with non-rotavirus vaccination in Phetchabun province from between 2012 and 2014 [7].

To support the policy decision-making regarding the inclusion of rotavirus vaccine into the NIP, economic study that employed country-specific data was clearly needed. This economic evaluation study was a part of the pilot project, aims to estimate the cost-effectiveness of rotavirus vaccination in Thailand. Country-specific data from the pilot project together with other secondary data were adopted in the study. The findings of this study were presented to the Advisory Committee on Immunization Practice under the Thai National Vaccine Committee to inform the introduction of rotavirus vaccine into the expanded program on immunization (EPI) in Thailand.

2. Methods

2.1. Study design and model

The study was conducted from the societal and healthcare provider perspectives. The observational data from the pilot study [7] were used as major inputs for the evaluation and applied to the annual birth cohort in 2020 within the context of a simulation model.

A Markov model was designed to follow the birth cohort until the age of five years with a cycle length of one month (Figure 1). Time horizon was set at five years because the severe rotavirus diarrhea occur under the age of five years. The birth cohort included in the model was confronted with two options in the model: children who received the rotavirus vaccine at 2 and 4 months of age versus no rotavirus vaccination program being implemented. The vaccines were assumed to be administered together with the diphtheria-tetanus-pertussis-hepatitis b (DTP-HB) vaccines and oral poliovirus vaccine (OPV), which already included in the EPI. Every child under 5 years of age could potentially attract more than once a rotavirus infection. The possible health states in the model consisted of susceptible, infected, partial immune, and death. When children are exposed to natural rotavirus infection or received rotavirus vaccination, they were assumed to develop

partial immunity to subsequent rotavirus diarrhea. Individual could be stable at the same state or move between health states with different probabilities. Children developed the first episode of rotavirus infection may require home-based care, ambulatory treatment, hospitalization, or result in death. Subsequent episodes would be less severe compared to previous infections. After the second episode, rotavirus infection would not lead to hospitalization or rotavirus-related death. All children entering the model could die from either the rotavirus infection or other causes. Children aged 0–2 months were assumed to not have severe diarrhea caused by rotavirus due to maternal immunity.

2.2. Model input

Input parameters (Table 1) included country-specific disease burden, vaccine characteristics, costs, and utilities are as following:

2.2.1. Disease burden

We obtained the age-specific incidence rates of rotavirus-associated – hospitalizations, ambulatory care visits, and self-treatments from 1,937 consecutive children in Phetchabun province (control site of the pilot study) [7]. The

Figure 1. Model structure for the natural history of rotavirus diarrhea.

Self = self-treatment, Ambu = ambulatory care and IPD = inpatient visit

Table 1. Model inputs included in the analysis.

Parameters	Base case (SD)	Distribution	Reference
Birth cohort in 2020	587,368		[32]
Birth cohort used in the budget impact analysis			
2021	572,684	n/a	Estimated from [32]
2022	558,367	n/a	
2023	544,408	n/a	
2024	530,797	n/a	
2025	517,527	n/a	
Epidemiological parameters			
Age-specific incidence rate of primary rotavirus hospitalization (per 100 person per month)			
Age 0-6 month	0.017 (0.002)	Beta	[7]
Age 7-12 months	0.167 (0.027)		
Age 13-18 months	0.302 (0.036)		
Age 19-24 months	0.239 (0.032)		
Age 25-36 months	0.144 (0.020)		
Age 37-48 months	0.103 (0.014)		
Age 49-60 months	0.057 (0.008)		
Risk reduction after the first episode of hospitalization	0.998 (0.001)	Beta	[7]
Ratio of incidence rate			
Ambulatory care to hospitalizations	1.81	n/a	[7]
Self-treatment to hospitalizations	8.13	n/a	[7, 8]
Proportion of the treatment of n th infections (%)			
1 st infection			Calculation (Additional file)
Hospitalization	11.2	n/a	
Ambulatory care	17.0	n/a	
Self-treatment	71.8	n/a	
2 nd infection			Calculation (Additional file)
Hospitalization	0.1	n/a	
Ambulatory care	18.7	n/a	
Self-treatment	81.2	n/a	
3 rd infection			Calculation (Additional file)
Ambulatory care	9.4	n/a	
Self-treatment	90.6	n/a	
4 th infection			Calculation (Additional file)
Ambulatory care	18.7	n/a	
Self-treatment	81.3	n/a	
5 th infection			Calculation (Additional file)
Ambulatory care	10.3	n/a	
Self-treatment	89.7	n/a	
Probability of dying from rotavirus diarrhea (%)	1.3*10 ⁻⁵ (0.000005)	Beta	[11]
Vaccine characteristics			
Vaccine effectiveness (%)			
Hospitalization	88 (5)	Normal	[7]
Ambulatory care	70 (7)	Normal	[14-16]
Vaccine coverage (%)	96.5	Beta	[7]
Waning rate after two years (%)	10		[17], Expert opinion
Vaccination program			
Vaccine cost per dose (THB)	399		[7]
Marginal logistic cost (THB per dose)	3		[23]
Wastage rate (%)	1		[19], Expert opinion
Adverse events of rotavirus vaccine (THB per dose)	12	Beta	Study data
Direct medical cost (THB)			
Hospitalization	Government Society*		
Before admission	27 (53) 342 (867)	Gamma	[24]
During admission	7,450 (5,452) 0 (0)	Gamma	[24]
After discharge	92 (58) 303 (1,648)	Gamma	[24]
Ambulatory care	123 (37) 425 (447)	Gamma	Study data
Self-treatment	7 (32)	Gamma	Study data
Direct non-medication cost (THB)			
Transportation and other's care			
Due to hospitalization	1,420 (1,310)	Gamma	[24]
Due to ambulatory care	369 (828)	Gamma	Study data
Due to self-treatment	69 (288)	Gamma	Study data
Informal care (THB)			
Due to hospitalization	2,159 (1,571)	Gamma	[24]
Due to ambulatory care	229 (726)	Gamma	Study data
Due to self-treatment	48 (263)	Gamma	Study data
Utility			
Healthy child	1.00	Beta	[30]
Child with hospitalized diarrhea	0.595 (0.125)	Beta	[30]
Child with non-hospitalized diarrhea	0.685 (0.016)	Beta	[30]
Caregiver when child is healthy	0.964 (0.097)	Beta	[30]
Caregiver when child has diarrhea	0.620 (0.120)	Beta	[30]

n/a not available, SD standard deviation, THB Thai Baht, all costs were in values of 2020; *In the societal perspective, the direct medical costs included treatment costs paid by providers and patients. The payment by patients occurred when the patients received treatment from elsewhere before coming to the study hospitals and after discharge. All costs were in values of 2020.

hospitalization rate was validated with data from Jiraphongsa et al., which was derived from six-hospital rotavirus surveillance and one-district community surveillance in Thailand [8]. The age-specific incidence rate of ambulatory care visits was adjusted by applying the ratio between rotavirus-associated visits and hospitalizations (~2:1), according to a recent study on children aged 19–60 months [7]. Similarly, the incidence rate of self-care treatments was estimated using the same approach with a specific ratio of ~8:1 [8]. These ratios were consistent with previous studies [9,10]. The incidence rates were differentiated by the number of the previous infections (see additional file). The transitional probabilities were derived from the pilot study [7] and rotavirus surveillance in Thailand [8] and were based on the following assumption: 1) both vaccinated and unvaccinated children had risk of reinfection due to the imperfect immunity, but vaccinated children would lower risk under the same number of infection, and 2) the probability of subsequent infection would be lower and less severe than previous infection. The mortality rate due to the rotavirus infection was obtained from the study of Jiraphongsa et al. [11] and the probabilities of death from non-rotavirus causes were taken from a report on Ministry of Public Health in Thailand in 2016 [12].

2.2.2. Vaccine effectiveness and coverage

Vaccine effectiveness of the monovalent rotavirus vaccine in preventing rotavirus associated hospitalizations was based directly on the result of the pilot study in Thailand [7].

Notably, the effectiveness of the vaccine in reducing hospitalization was estimated at 88% (95% CI: 76% – 94%). No country-specific data were available on the effectiveness of the ambulatory setting in Thailand. From a review, in Latin America, efficacy of rotavirus vaccine against severe rotavirus gastroenteritis and any severity of rotavirus gastroenteritis was estimated to be 85% and 70%, respectively [13–15]. In Indonesia, the efficacies were estimated at 84% for preventing hospitalizations and 70% for preventing the outpatient visits [16]. Following the data from middle-income countries, we applied a vaccine efficacy against outpatient visit of 70% in the base-case analysis of the model. A 10% decrease in efficacies at 2-year post-vaccination was assumed in the model [17]. We assumed no impact on effectiveness from strain changes over time because the monovalent rotavirus vaccine has been reported to provide broad heterotypic protection [18]. The vaccine coverage was based on the pilot study at 96.5% [7]. From our cohort study, about 11% of all vaccinations were assumed to be associated with adverse events, with 3% experiencing diarrhea, 6% fever and the rest experienced vomiting, skin rash, and loss of appetite. No cases of intussusception were reported during follow-up and correspondingly not taken into account in the model.

2.2.3. Cost data

Costs of the vaccination program included vaccine price, number of doses given, incremental logistic cost of vaccine supply chain system, cost of adverse events, and the expected losses from wastage [19]. The incremental cost of children and parents or caregivers regarding receiving the vaccine was

assumed to be zero because the rotavirus vaccine was given at the same time as the current EPI vaccines. The vaccine price of USD 13 per dose was based on the negotiation for the research between the manufacturer and Department of Disease Control, Ministry of Public Health for the pilot study. Compared to other countries in the same region, previous studies reported the per-dose price at USD 5 in Vietnam [20], USD 6.5 in Malaysia [21], USD 7 in Indonesia [16], and less USD 9 in other upper-middle income countries [22]. The cost of adverse event was obtained from the pilot study [7]. Specifically significant increase in diarrhea was observed among rotavirus vaccine group compared with non-rotavirus vaccine group within the 14-day period after each vaccination. The average adverse event cost for diarrhea was calculated to 12 THB per dose. The marginal cost of adding a new vaccine for the supply chain system of the EPI was estimated from the published literature [23].

Direct medical and non-medical costs included costs of hospitalization, ambulatory care and self-care. The data were based on the pilot project [7] and were published elsewhere [24]. The treatment costs (e.g. medications, medical supplies, laboratory tests, OPD visit, bed-day, and medical services) were based on the medical records and interviews with the caregivers of children aged < 5 years with acute diarrhea. The costs included the whole episode covering the treatment both outside and inside the study hospitals and health centers; and before and after the treatment at the study health facilities. Direct non-medical costs consisted of cost of transportation, food, hotel, extra diaper, and costs consisted of those related to informal care of caregivers during children's illness. Non-medical costs were collected from face-to-face interviews. Costs of informal care were calculated based on the human capital approach and calculated from the daily wages as estimated from the gross national income (GNI) per capita per day of Thailand [25,26] and multiplied by the number of days caregivers spend on care their diarrheal children. The average time lost by caregivers to take care for a sick child was 6 days for an episode requiring hospitalization, 0.6 days for an episode requiring ambulatory care, and 0.13 days for an episode requiring self-treatment. All costs were adjusted to 2020 values using consumer price index (CPI) [27] and were converted to US dollars (USD) using exchange rate of 31.2937 Thai baht (THB) = USD 1 [28]. A discount rate for costs and outcomes of 3% per annum was applied [29].

2.2.4. Utility data

A comprehensive study on utility values of the children and their family caregivers was previously conducted in the pilot study [7] using the EQ-5D-3 L questionnaires. The results were published elsewhere [30]. The values were categorized differently between the severities of illness using the Vesikari score [31]. Utility values of hospitalized and non-hospitalized children were categorized as severe (score >10) and mild (score <7) level, respectively. In the base-case analysis, only the QALYs related to the children were considered. The quality of life of caregivers potentially affected by the child's illness was considered in a sensitivity analyses.

2.3. Economic analysis and budget impact analysis

The cost-effectiveness results are presented as incremental cost-effectiveness ratios (ICERs) per QALY gained. For the budget impact analysis for the five years (2021–2025), the costing part of the cost-effective model was applied to estimate the financial consequences for implementation of a rotavirus vaccination program in the birth cohort from the healthcare system perspective. Total annual vaccine cost (c) was calculated as $c = v \times n$, where v is the vaccine price per dose and n is the number of doses requires. The number of dose required (n) was estimated as $n = p \times d \times i \times w$, where p is birth cohort, d is the number of doses per fully immunized child, i is the predicted vaccine coverage, and w is the predicted wastage factor. We estimated the birth cohort from the office of the official statistics registration systems [32]. Discounting was not applied in the budget impact analysis.

2.4. Sensitivity analysis

For cost-effective analysis, one-way sensitivity was performed to assess the uncertainty in all parameters including disease burden, vaccine effectiveness, costs related to rotavirus diarrhea, and utilities by varying each parameter at a time between its 95% confidence intervals. Vaccine cost was set at $\pm 10\%$, and discount rate was varied at 0% and 6%. The results are presented as a tornado diagram. Probabilistic sensitivity analysis (PSA) was conducted to assess overall parameter uncertainty by running 20,000 Monte-Carlo simulations. The results of the PSA were presented as the cost-effectiveness acceptability curve (CEAC). For budget impact analysis, a sensitivity analysis was conducted to assess the uncertainty of input data by applying a range of vaccine cost (-20% to -50%) and vaccine coverage (100% and 90%).

3. Results

3.1. Base-case analysis

For the cohort of 587,368 children, the model predicted that rotavirus vaccination program could reduce the treatment

episodes of rotavirus diarrhea by 48%. The ICER comparing vaccination program with no vaccination program was estimated at THB 128,756 (USD 4,114) per QALY gained from the healthcare perspective and THB 49,149 (USD 1,571) per QALY gained from the societal perspective. Both ICERs were highly cost-effective under the Thai ceiling threshold of THB 160,000 (USD 5,113) per QALY gained [33] (Table 2).

3.2. Sensitivity analysis

For one-way sensitivity analysis, the most sensitive parameter from both perspectives were incidence rate of hospitalization due to rotavirus diarrhea, vaccine cost, and vaccine effectiveness against hospitalization (Figure 2). For the results of the PSA, the ICER was THB 125,104 (USD 3,998; 95%CI: THB 98,875 to 140,136) per QALY gained from the healthcare perspective and THB 49,362 (USD 1,577; 95%CI: THB 46,846 to 50,658) per QALY gained from the societal perspective. The probabilities that the rotavirus vaccine would be cost-effective were 84.9% and 99.9% for healthcare and societal perspective (Figure 3). When QALY impacts for one caregiver were taken into account, the ICERs was reduced by 49%.

3.3. Budget impact analysis

In the first year (2021), the annual budget of purchasing vaccination was estimated at THB 441 million (USD 14 million) and later falling to THB 399 million (USD 13 million) in 2025 due to the reduction in the size of birth cohort (Table 3). The vaccination was projected to reduce the healthcare cost by an average of THB 260 million annually (USD 8.3 million). Next, the government needed to pay an extra annual budget of about THB 159 million (USD 5 million). As shown in Table 4, all scenarios show that inclusion of rotavirus vaccine into the NIP lead to a high budget impact on the government. However, in case of 100% vaccine coverage, the total budget impact was reduced to 45% if the cost of vaccination was reduced by 50%, illustrating potential benefits for negotiating on the vaccine price.

Table 2. Health outcomes and results of economic analysis of the base-case.

Parameters	No vaccination program	Vaccination program	Difference
Outcomes			
All rotavirus diarrhea (episodes)	479,142	405,186	- 73,956
Hospitalization (admissions)	39,296	8,281	- 31,015
Ambulatory care (visits)	64,756	23,646	-41,110
Self-treatment (episodes)	375,090	373,259	-1,831
Discounted QALYs	2,583,279	2,585,287	2,008
Healthcare perspective			
Total cost of illness (THB)	289,902,873	61,569,843	-228,333,030
Cost of vaccination program implementation (THB)	0	486,875,191	486,875,191
Total cost (THB)	289,902,873	548,445,034	258,542,161
Cost (THB) per QALY gained	n/a	128,756	
Societal perspective			
Total cost of illness (THB)	547,223,211	159,039,881	-388,183,330
Cost of vaccination program implementation (THB)	0	486,875,191	486,875,191
Total cost (THB)	547,223,211	645,915,072	98,691,861
Cost (THB) per QALY gained	n/a	49,149

Figure 2. One-way sensitivity analysis from the societal perspective.

Figure 3. Cost-effectiveness acceptability curves for each perspective and including/excluding carers quality of life (QOL).

4. Discussion

This study provided essential information to support policy decision-making regarding the inclusion of rotavirus vaccine into the Thai NIP. Our results indicated that rotavirus vaccination had a potential benefit to reduce the disease burden and cost of illness. Also, based on the threshold of Thailand, vaccination could be highly cost-effective from both perspectives. The results were in line with those of many other developing countries [34,35].

Our Markov model was similar to previous published studies in Vietnam [20] and India [36], which taken into account partial immunity and multiple rotavirus infection. As most previous studies, we used a static model, which did not incorporate herd immunity due to the lack of information on rotavirus epidemiology and transmission [34,35,37,38].

One of our strengths is that the epidemiological data used in our study was derived from the local study in Thailand [7]. These input data represented information of children under the age of five in the country. It was challenging to obtain the

actual incidence of rotavirus diarrhea, as rotavirus testing was not a part of routine clinical practice in all cases of diarrhea and nosocomial infections and asymptomatic data were not considered in this study. This may have led to underestimation of our findings. Due to the absence of reports on rotavirus-related deaths, we assumed mortality rate from previous study in Thailand [11], which might subject to some degree of biases. As rotavirus mortality rate has decreased more than half during the past decade both in developed and developing countries [1], our estimates, thus, were more likely to be overestimating the cost-effectiveness of the vaccine.

Vaccine effectiveness has significant impact on the cost-effectiveness results especially effectiveness against hospital admission. Specific effectiveness-estimated for hospitalization in our study was higher as compared to some Asian and African countries [39–41]. This can be related to the strain-specific effectiveness. In particular, in Thailand, diversity of rotavirus strains has been observed last decade [2]. The common predominant genotypes were G1, followed by G2, G9,

Table 4. Sensitivity analysis of the budget impact analyses in the five-year period.

Scenario	Costs (million THB)		Difference (million THB)
	No vaccination	With vaccination	
Vaccination cost (THB/dose)			
399 (base case)	1,540	2,336	796
319 (−20%)	1,540	1,915	375
279 (−30%)	1,540	1,704	164
239 (−40%)	1,540	1,494	−46
200 (−50%)	1,540	1,327	−213
Vaccination coverage			
100%	1,540	2,411	871
90%	1,540	2,194	654

THB Thai Baht

Table 3. Budget impact analysis of rotavirus vaccination over 5 years (2021–2025).

Budget; million THB	2021	2022	2023	2024	2025
No vaccination					
Costs of rotavirus disease	324	316	308	300	292
Rotavirus vaccination (399 THB/dose)					
Vaccination costs	441	430	419	409	399
Costs of rotavirus disease	50	49	48	46	45
Total costs	491	479	467	455	444
Budget difference	167	163	159	155	152

THB Thai Baht

and G3, respectively. Our field effectiveness of monovalent rotavirus vaccine was seen against various homotypic (G1) and heterotypic (G2) strains, consistent with the previous findings [7,18,42]. If the distribution of new serotypes is likely to emerge in a different constellation, vaccine effectiveness may differ from the current evidence. Ongoing surveillance for strain-specific vaccine emergence and vaccine effectiveness should be continuously conducted. With very high vaccine coverage, herd protection for preventing rotavirus disease may play an increasing role in enhancing cost-effectiveness.

Our finding was similar to that of the previous studies in Thailand [3,5]. Nevertheless, some differences for input parameters were applied in our study: i) we used more realistic incidence data, ii) vaccine effectiveness and coverage in our study were based on cohort study recently conducted in Thailand and took into account the waning effect, iii) utility values used in our study were derived from Thai children and their caregivers, iv) we collected cost data from all types of health facilities (i.e. hospital, clinic, drugstore, etc.), and v) we used lower vaccine prices per dose. Thailand, an upper-middle income country, does not receive the financial support from the international nonprofit organizations (e.g. GAVI, UNICEF, or WHO). With limited budget, the government needs to negotiate the vaccine price with the manufacturer based on the results of break-even price analysis from the previous studies [3,5]. We used the actual price of this pilot study in our analysis. In practice, when the vaccine is fully expanded to the national immunization program, the purchasing price is negotiated again based on the availability of the budget.

Along with cost-effectiveness analysis, budget impact analysis is an essential part for policy-maker when making decision regarding the inclusion of vaccine into the NIP. The annual budget of a rotavirus vaccination program was relatively high, 32% as compared to total traditional EPI vaccine

costs. Notably, vaccination cost can be an important barrier in including the new vaccination into the NIP even if a vaccination program is cost-effective or even cost-saving.

This study has some limitations. First, this study collected data from public healthcare facilities in only two areas; therefore, generalization of the findings to the entire country should be made with caution together with considering of the results of the sensitivity analysis. Second, there are limited data on epidemiological data and vaccine effectiveness on non-severe rotavirus disease. As the result, we had to estimate such values from local previous studies and other countries. Third, due to the unavailability on the utility of non-hospitalized Thai children with diarrhea, we used the utility weight mostly collected from the non-severe hospitalized cases. Forth, this analysis used the static model that did not include the indirect effect for unvaccinated children. It should be noted that the inclusion of herd immunity would improve the cost-effectiveness of vaccine.

5. Conclusion

The rotavirus vaccine was estimated to provide good protection against disease burden and saving treatment costs associated with rotavirus diarrhea in Thailand. At USD 13 per vaccine dose, rotavirus vaccination was very cost-effective compared to no vaccination under the recommended threshold in Thailand. The incidence of hospitalization due to rotavirus infection was the most sensitive factor on the ICERs both two perspectives. Nevertheless, the cost of introducing rotavirus vaccine was relatively high compared to the total current EPI budget for children in the country. The cost of rotavirus vaccine should be negotiated before adopting into the national immunization program.

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Author contributions

OR, AR, PT, and SJ conceptualized and designed the study. OR, PT, and SJ collected data. OR, NP, and AR analyzed the data and drafted the manuscript. MT and MJP contributed to the study design, supervision, and the discussion. All authors revised and approved the final manuscript before submission.

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Declaration of interest

The authors have no other relevant affiliations or financial involvement with any organization or entity with a financial interest in or financial

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Data availability statement

In terms of all tables and figures we submitted, we confirm that all tables and figures are original. They have not been published elsewhere.

ORCID

Montarat Thavorncharoensap <http://orcid.org/0000-0002-8256-2167>
Maarten J. Postma <http://orcid.org/0000-0002-6306-3653>

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