Vaccine 36 (2018) 1757–1765

Contents lists available at ScienceDirect

Vaccine

journal homepage: www.elsevier.com/locate/vaccine

Towards the introduction of pneumococcal conjugate vaccines in Bhutan: A cost-utility analysis to determine the optimal policy option

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ARTICLE INFO

Article history:
Received 17 October 2017
Received in revised form 9 February 2018
Accepted 12 February 2018
Available online 22 February 2018

Keywords:
Cost-utility analysis
Pneumococcal conjugate vaccines
PCV
Human resources for health
Bhutan

ABSTRACT

Background: Due to competing health priorities and limited resources, many low-income countries, even those with a high disease burden, are not able to introduce pneumococcal conjugate vaccines.
Objective: To determine the cost-utility of 10- and 13-valent pneumococcal conjugate vaccines (PCV10 and PCV13) compared to no vaccination in Bhutan.
Methods: A model-based cost-utility analysis was performed in the Bhutanese context using a government perspective. A Markov simulation model with one-year cycle length was used to estimate the costs and outcomes of three options: PCV10, PCV13 and no PCV programmes for a lifetime horizon. A discount rate of 3% per annum was applied. Results are presented using an incremental cost-effectiveness ratio (ICER) in United State Dollar per quality-adjusted life year (QALY) gained (USD 1 = Ngultrum 65). A one-way sensitivity analysis and a probabilistic sensitivity analysis were conducted to assess uncertainty.
Results: Compared to no vaccination, PCV10 and PCV13 gained 0.0006 and 0.0007 QALYs with additional lifetime costs of USD 0.02 and USD 0.03 per person, respectively. PCV10 and PCV13 generated ICERs of USD 36 and USD 40 per QALY gained compared to no vaccination. In addition, PCV13 produced an ICER of USD 92 compared with PCV10. When including PCV into the Expanded Programme on Immunization, the total 5-year budgetary requirement is anticipated to increase to USD. 3.77 million for PCV10 and USD 3.75 million for PCV13. Moreover, the full-time equivalent (FTE) of one health assistant would increase by 2.0 per year while the FTE of other health workers can be reduced each year, particularly of specialist (0.6–1.1 FTE) and nurse (1–1.6 FTE).
Conclusion: At the suggested threshold of 1xGDP per capita equivalent to USD 2708, both PCVs are cost-effective in Bhutan and we recommend that they be included in the routine immunization programme.

1. Introduction

Pneumococcal disease is an infection caused by the *Streptococcus pneumoniae (S. pneumoniae)* bacteria [1]. This infection can result in meningitis, bacteraemia, pneumonia, and acute otitis media (AOM). Pneumonia has been a leading cause of child morbidity and mortality globally, accounting for about 1.6 million deaths annually in children under five years of age [2]. Incidence and mortality rates are high in low-income countries with the majority of pneumococcal deaths occurring in Africa and Asia. To combat pneumococcal disease, various types of vaccines have been developed. Currently, 10-valent pneumococcal conjugate vaccine (PCV10) and 13-valent pneumococcal conjugate vaccine (PCV13) are available on the market, which have proven to be safe and efficacious against *S. Pneumoniae* [3]. The high burden of pneumococcal disease in developing countries has led to global efforts in expanding the access to vaccines in these regions.

Bhutan is a lower middle-income country located in South Asia where pneumococcal infections remain a major cause of morbidity and mortality among young children. In 2015, there were 349 cases of meningitis and 10,891 cases of pneumonia [4]. The case fatality rate of meningitis due to *S. pneumoniae* was 7%. The Bhutanese government spends a large amount of health budget on the

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https://doi.org/10.1016/j.vaccine.2018.02.048
0264-410X/

treatment of pneumococcal disease, which also have high societal costs. The National Committee for Immunization Practice, an independent technical advisory committee to advice and guide the Ministry of Health, Bhutan, recommended the introduction of pneumococcal conjugate vaccines in the country, that was needed to conduct an economic evaluation.

The Expanded Programme on Immunization was first launched in Bhutan in 1979. The programme maintains high coverage with a routine immunization package. Bhutan has graduated from Gavi, the Vaccine Alliance's support in 2016 as its economic classification status has changed from a low income to lower-middle income country. As such, considerations around value for money and financial sustainability of the routine vaccination programme are of critical importance to Bhutan because introducing new vaccines poses a direct and long-term financial burden to the government. Prior to the introduction of the vaccines, the World Health Organization's Strategic Advisory Group of Experts on Immunization recommends all member states to conduct a systematic decision making process based on review of evidence from cost-effectiveness analysis and budget impact analysis studies [5]. Subsequently, the High Level Committee, the highest decision making body in the Ministry of Health, Bhutan, directed to conduct a cost-utility analysis of PCVs to inform policy decision and vaccine implementation.

In response to policy makers in Bhutan, this study aimed to determine the costs, outcomes and cost-effectiveness of the introduction of PCV10 and PCV13 compared to a no vaccination policy. In addition, the study also determined the feasibility of the vaccination policy by assessing human resource on health impact and 5-year budget impact for introduction of pneumococcal conjugate vaccines.

2. Methods

A model-based cost-utility analysis (CUA) was performed and government perspective was considered for the study. A Markov model was constructed to estimate the costs and health outcomes of infants using a lifetime horizon with a 3% discount rate per annum. Each of the three policy options, namely no vaccination, PCV10, and PCV13 were evaluated. The vaccine schedule was two-dose primary series at 2 months and 4 months, and one booster at 12 months of age (2 + 1 schedule). Health outcomes measured included number of pneumococcal episodes averted, number of deaths prevented due to the vaccination programme and quality-adjusted life year (QALY). The incremental cost-effectiveness ratio (ICER) was presented as cost in United State Dollar (USD) per QALY gained (USD 1 = Bhutanese Ngultrum 65).

2.1. Model structure and assumptions

A Markov model with one-year length of cycle was adapted from a Thai study [6] to compare costs and health outcomes of PCVs with no PCV programme for each age-specified cohort as seen in Fig. 1. The model assumes that vaccinated and unvaccinated individuals can experience each three different health events: no infection, S. pneumoniae infection, and death from all other causes. *S. pneumoniae* infection leads to four main diseases including meningitis, bacteraemia, pneumonia and AOM. Moreover, meningitis is associated with sequelae such as epilepsy, hearing loss, and neurodevelopment impairment, as well as AOM causes hearing loss. A cost-utility of vaccination programme for a single hypothetical birth cohort born in 2016 was simulated for a lifetime horizon which means that all individuals in this group are followed until transition to the death state at a maximum of 100 years of age. For a budget impact analysis, vaccination on hypothetical cohorts of infants born during 2016–2020 were examined over a period of five years. Two vaccine scenarios i.e. with and without indirect effects were modeled.

2.2. Model input parameters

2.2.1. Epidemiological data

The disease incidence rates of meningitis, bacteraemia, pneumonia, and acute otitis media were derived from the Annual

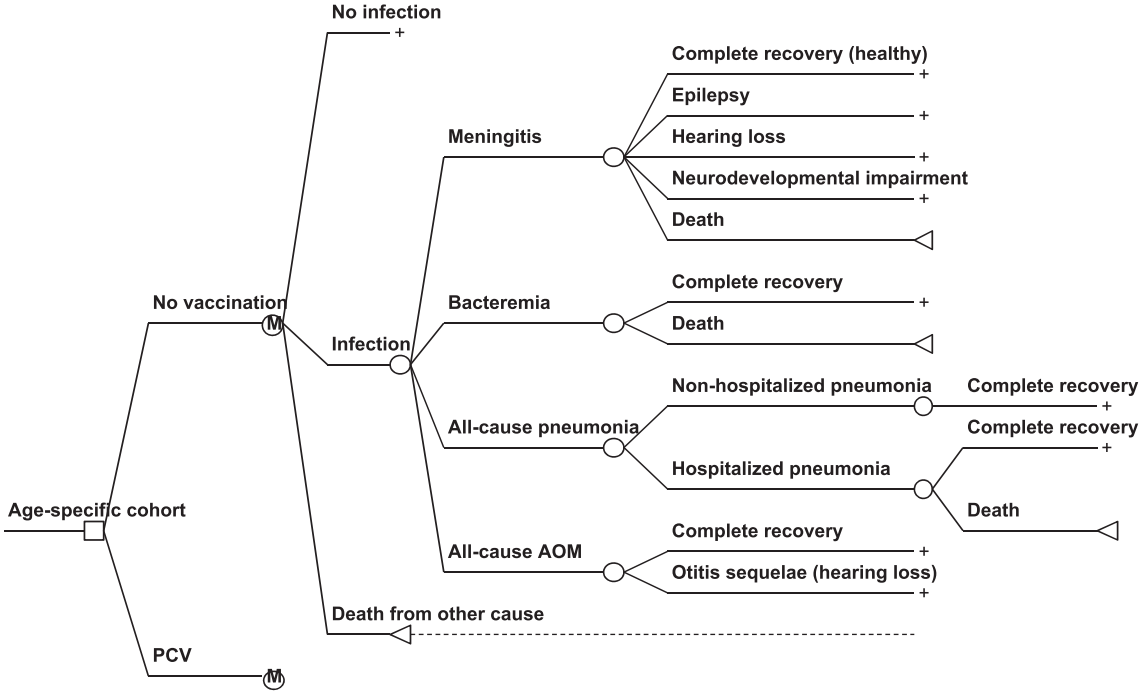

Fig. 1. Age-stratified economic model to represent associated health states for vaccinated and unvaccinated populations.