Huge impact of assumptions on indirect effects on the cost-effectiveness of routine infant vaccination with 7-valent conjugate vaccine (Prevnar®)

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Several recently published European cost-effectiveness studies on the 7-valent pneumococcal conjugate vaccine (PCV-7; Prevnar®) have included net-indirect vaccine benefits for non-vaccine protected groups in their analyses (indirect effects)[1–4]. Net-indirect effects result from herd protection minus serotype replacement effects. In this study we analyze the impact of net-indirect effects in non-vaccine protected groups of 5 years of age and older with updated assumptions regarding epidemiologic data and health care unit costs. Without net-indirect benefits for non-vaccine protected groups included the cost-effectiveness ratio is estimated at €72,360 per QALY. In order to obtain cost-effectiveness ratios below the threshold of €50,000 per QALY – which is in the middle of the range that is often referred to in the Netherlands – the net-indirect protective effect should at least be 16% of which has been observed in the USA after the introduction of PCV-7.

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Vaccine efficacy for IPD was estimated at 97.4% for 7 serotypes included into the vaccine IPD, 11.1% for hospitalized CAP, 6% for CAP treated by the GP and 7% against AOM, based on the Kaiser trial [11–13]. PCV-7 was assumed to be effective after two doses of vaccination for the birth cohort analyzed (180,000 infants; corresponding to the size of the Dutch birth cohort). As the aim of this paper was to show the indirect effects in unvaccinated individuals due to routine vaccination of children we excluded serotype placement and herd protection effects for the followed cohort. The time horizon of our cohort analysis was 5 years, which justifies the use of a stable vaccine efficacy for IPD. For non-invasive disease it was conservatively assumed that children would be protected up to the second year of life [14].

Indirect effects for those outside the vaccine-protected cohort were implemented in a sub-module using straightforward proportional calculus on registered numbers of IPDs [10]. Three studies present data on the net-indirect effects (herd protection benefits minus serotype replacement) on IPD among non-vaccinated groups in the USA [5,15,16]. The most recent study was performed by Hsu et al., focussing solely on meningitis for all age groups [15]. In another study, detailed information was available on IPD for citizens aged 50 years and over [16]. Finally, a study performed by Whitney et al. describes the net-indirect effects on an aggregated level for all IPD together, but does present data from the age 20 and onwards [5]. The net-indirect effects assumed in our study for those outside the followed cohort (i.e., individuals aged 5 years and older) were based on Hsu et al. regarding meningitis, for all other IPD the findings of Whitney et al. were used for those aged 5–50 years (assuming that the effects in children aged 5–19 years are similar to those observed in individuals aged 20–40 years) and those by Lexau et al. [16] for the age groups of 50 years and over. Table 1 summarizes the assumptions on the net-indirect effects. In this table negative percentages indicate a relative decrease in the disease incidence and positive percentages indicate an increase (as compared to the pre-vaccination incidence; 2004–2006).

The main outcome measures were life years, quality-adjusted life years (QALYs) and costs. QALYs for IPD and non-invasive infections were taken from [22], sequelae related utilities were based on two specific studies [17,18]. The analysis was performed from a societal perspective including both direct medical and indirect non-medical costs of production losses (measured using the friction cost method), all updated to 2008 [9,19]. The costs of vaccination were assumed at €50 per dose including administration costs, which reflects the current price of PCV-7 in the Dutch vaccination program. Given 3+1 dose schedule applied in the Netherlands, pneumococcal vaccination would cost €200 per infant. According to the Dutch guidelines, effects and cost were discounted at 1.5% and 4%, respectively [19].

Table 1

<table>
<thead>
<tr>
<th>Age category</th>
<th>0–4</th>
<th>5–17</th>
<th>18–39</th>
<th>40–64</th>
<th>65+</th>
</tr>
</thead>
<tbody>
<tr>
<td>Meningitis</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>PCV-7 serotypes</td>
<td>−97%</td>
<td>−8%</td>
<td>−69%</td>
<td>−62%</td>
<td>−67%</td>
</tr>
<tr>
<td>PCV-7 related types &amp; Other types</td>
<td>N/A</td>
<td>0%</td>
<td>76%</td>
<td>68%</td>
<td>37%</td>
</tr>
<tr>
<td>Net-overall effect meningitis</td>
<td>−97%</td>
<td>−2%</td>
<td>−1%</td>
<td>6%</td>
<td>−53%</td>
</tr>
<tr>
<td>Invasive Pneumonia</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>PCV-7</td>
<td>−97%</td>
<td>−40%</td>
<td>−40%</td>
<td>−14%</td>
<td>−48%</td>
</tr>
<tr>
<td>PCV-7 related serotypes &amp; Other types</td>
<td>N/A</td>
<td>−22%</td>
<td>−22%</td>
<td>−4%</td>
<td>11%</td>
</tr>
<tr>
<td>Net-overall effect pneumonia</td>
<td>97%</td>
<td>−28%</td>
<td>−27%</td>
<td>−4%</td>
<td>−15%</td>
</tr>
<tr>
<td>Bacteraemia</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>PCV-7</td>
<td>−97%</td>
<td>−40%</td>
<td>−40%</td>
<td>−14%</td>
<td>−77%</td>
</tr>
<tr>
<td>PCV-7 related serotypes &amp; Other types</td>
<td>N/A</td>
<td>−22%</td>
<td>−22%</td>
<td>−4%</td>
<td>−36%</td>
</tr>
<tr>
<td>Net-overall effect bacteraemia</td>
<td>−97%</td>
<td>−29%</td>
<td>−27%</td>
<td>−4%</td>
<td>−54%</td>
</tr>
</tbody>
</table>

| Overall change after correction for Dutch serotype specific incidence data [10]. |
| Related serotypes for invasive pneumonia and bacteraemia for individuals aged less than 50 years based on Whitney et al. 6A, 9A, 9L, 9N,18B,18F,19A,19B,19C, 23A, and 23B [5]. |
| The 16 serotypes not included the PCV-7 but yet in the 23-valent pneumococcal polysaccharide vaccine (1, 2, 3, 5, 7F, 8, 9N, 10A, 11A, 12F, 15B, 17F, 19A, 20, 22F, and 33F) for those aged 50 years and older and all other types based on Lexau et al. [16]. |
| N/A: Not Applicable. |
3. Results

Without net-indirect effects being incorporated in the model, PCV-7 is estimated to prevent 5778 cases of non-invasive disease and 128 cases of invasive disease in the followed birth cohort over a period of 5 years, corresponding to a total gain of 292 life years or 422 QALYs. The totals cost of vaccination is estimated at €34.2 million. Subtracting the cost savings on medical and non-medical costs from these vaccination costs, resulted in a net total cost of €30.6 million. Dividing the net cost by the number of QALYs or life years saved resulted in CERs of approximately €72,360 per QALY or €104,790 per life-year gained.

Yet, if similar indirect effects as observed in the USA are included into the model, additionally 1113 LY or 1117 QALYs will be gained. The amount of QALYs and LY gained is almost equal as the vast majority of QALY gained is due to averted deaths and utility losses related to sequelae were excluded. The additional averted costs of €4.8 million lower the total net costs down to €25.8 million. Dividing the net cost by the health benefits resulted in vastly more favourable CERs of €16,750 and €18,360 for the cost per QALY and life-year gained, respectively. Fig. 1 illustrates our findings for the CER per QALY gained through varying the level of net-indirect effects on IPD for individuals aged 5 years and onwards who are not directly protected by the vaccine. Again, it can be seen that the impact of these net-indirect effects on the CERs are tremendous.

4. Discussion

We estimated that without the inclusion of net-indirect effects vaccination with a 4-dose schedule would approximately costs €72,360 per QALY gained or €104,790 life-year gained. Full inclusion of indirect effects would lower these cost-effectiveness ratios to €16,750 and €18,360 per QALY and life-year, respectively.

In the Netherlands, CERs above €80,000 certainly reflect unfavourable cost-effectiveness. Indeed 80,000 have been mentioned for the Dutch situation is unfavourable cost-effectiveness. Indeed 80,000 have been explic-

## References


mination with the 7-valent pneumococcal conjugate vaccine in the Netherlands. Vaccine 2007 May 4;25(18):3659–78.


[8] Health Protection Agency (HPA). Cumulative weekly number of reports of inva-


[9] Bos JM, Rumlie H, Welte R, Postma MJ. Epidemiologic impact and cost-


[20] Ref Type: Generic.


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dorp (The Netherlands). A-JvH his contribution to this study was financed by the Netherlands Vaccine Institute (Bilthoven, The Netherlands). MJP received travel grants from GlaxoSmithKline and Wyeth to attend expert meetings in 2008 in Reykjavik (Iceland) and Istanbul (Turkey).