Hospital costs of *Bordetella pertussis* in New Zealand children

Anusha Ganeshalingham, Peter Reed, Cameron Grant, Brian Anderson, Emma Best, John Beca

*Abstract*

**AIM:** To estimate hospitalisation costs for children with pertussis in New Zealand.

**METHOD:** All children less than 16 years of age and hospitalised with pertussis between 01/01/2003 and 31/12/2013 were identified from the National Minimum Data Set and the National Paediatric Intensive Care Unit database. The cost of hospital care was estimated by multiplying the diagnosis-related group cost-weight by the national price and inflating to 2013/2014 values.

**RESULTS:** There were 1,456 children with pertussis admitted to hospital including 65 admissions to the paediatric intensive care unit. Infants (<1 year) accounted for 78% of hospital admissions, 98% of paediatric intensive care admissions and 87% of hospitalisation costs. The total inflation-adjusted cost of the 11-year cohort was estimated at $8.3 million and the mean cost of hospital ward and paediatric intensive care was $4,242 and $42,016 respectively, per child. The 2011–2013 epidemic accounted for 39% of all hospital admissions and the cost estimated at $4.2 million. Peak annual hospitalisation costs during epidemic years increased from under $800,000 in 2004 and 2009 to over $2 million in 2012.

**CONCLUSION:** Infants with pertussis are more likely than older children to be admitted to hospital and to the paediatric intensive care unit and generate the majority of hospitalisation costs. A revised focus on protecting vulnerable newborns and infants has the potential to both improve health outcomes for infants with pertussis and reduce medical costs.

Pertussis, caused by infection with the Gram-negative bacterium *Bordetella pertussis*, is a highly contagious respiratory illness. Pertussis, which can cause severe and sometimes fatal disease in infants has proved more difficult to control than other vaccine preventable diseases included in national childhood immunisation schedules. Circulation of *B. pertussis* remains endemic. Epidemics continue to be reported from many countries, including Australia, England and the US. Pertussis affects people of all ages but is more prevalent and severe in children. In New Zealand, in 2014, children comprised 31% of notified cases and 62% of hospitalised cases. Infants (less than one year of age) accounted for 8% of all cases (an incidence six times greater than adults) and 43% of hospitalised cases. Pertussis epidemics occur in New Zealand every three-to-five years and last two-to-three years. In recent times there have been epidemics in 1999–2000, 2004–2005, 2008–2009 and most recently 2011–2013.

The most recent epidemic resulted in the largest number of admissions (38 children) and deaths (two children) in the paediatric intensive care unit (PICU) at Starship Children’s Hospital in Auckland, since the national unit was established in 1991. While the health burden of pertussis in New Zealand has been described, the economic burden has not. Documentation of these costs will inform decision-making around new strategies aimed at reducing pertussis disease burden. Our aim was to quantify the medical costs associated with hospital ward and PICU admissions for children with pertussis in New Zealand.

**Methods**

We completed a retrospective review of all children less than 15 years of age and hospitalised with pertussis between 1st
January 2003 and 31st December 2013. The regional hospital ethics committee approved the study.

**Identification of cases**

Pertussis is a notifiable disease in New Zealand and all notified cases are referred to the communicable disease centre at the Institute of Environmental Science and Research (ESR) Limited. The dataset held by ESR was cross-referenced with the National Minimum Data Set (NMDS) held by the Ministry of Health to identify children with pertussis admitted to hospital. The dataset included patient demographics, prioritised ethnicity, district health board, length of hospital stay and cost-weight. All children with severe pertussis are referred to and managed by the national PICU at Starship Children's Hospital in Auckland. Children with pertussis that required paediatric intensive care were identified using the PICU database. The PICU dataset included patient demographics, transport to intensive care and length of intensive care stay.

**Hospitalisation costs**

Hospitalisation costs were defined as those costs generated by hospital resource utilisation. Diagnosis-related group (DRG) cost-weights for all pertussis hospital admissions were obtained from the NMDS using the Weighted Inlier Equivalent Separations (WIES) methodology. The cost of each admission was calculated by multiplying the WIES cost-weight by the national price for the corresponding financial year. The annual cost was then inflated to 2013/14 values using the Consumer Price Index.

**Transportation costs**

Referral centres around New Zealand are invoiced directly by the transport providers for the cost of transporting critically ill children with pertussis to the PICU. Fixed wing or rotary wing aircraft are used to transport children from centres outside the Auckland region. An ambulance service is used for road transportation from hospitals within the Auckland region and from

**Figure 1:** Age of children hospitalised with pertussis (2003–2013).

**Figure 2:** Ethnicity of children hospitalised with pertussis (2003–2013).
Auckland airport for fixed wing transports, at a set cost per journey. The transport costs incurred by children with severe pertussis during the study period were made available by the transport providers.

Statistics
Data were analysed using JMP version 11.1 (SAS Inc., Wellington, NZ). The proportion of patients requiring intensive care was compared across patient demographics using odds ratios (OR) provided with 95% confidence intervals (95% CI).

Results
There were 9,812 pertussis notifications in children made between 1st January 2003 and 31st December 2013. During this time there were 1,456 (15%) admissions to hospital including 65 children admitted to the PICU (4.5%).

Demographics of children hospitalised with pertussis
There were 1,456 children hospitalised with pertussis and 747 (51%) were female. The majority (78%) were less than 12 months of age at presentation (Figure 1). Of children who were admitted to the PICU, 98% (64/65) were infants. In comparison with older children hospitalised with pertussis, the odds of an infant hospitalised with pertussis requiring admission to PICU were increased (OR=18.9, 95% CI 2.6–136.7, p<0.001).

Of children hospitalised with pertussis, 567 (39%) were European, 566 (39%) Māori, 254 (17%) Pacific Island and 41 (3%) Asian (Figure 2). Pacific children hospitalised with pertussis had increased odds of PICU admission compared to European (OR=4.2, 95% CI 1.9–9.4, p<0.001) or Māori children (OR=2.0, 95% CI 1.0–3.7, p=0.03).

Children with pertussis were hospitalised in all 21 New Zealand district health boards (DHB) (Figure 3). The greatest number of admissions was at the three Auckland DHBs and Canterbury DHB, which provide care for New Zealand’s largest and second largest metropolitan areas, respectively: Counties-Manukau, 254 (17%) children; Canterbury, 145 (10%) children; Waitemata, 130 (9%) children and Auckland, 112 (8%) children. New Zealand’s least populated area, serviced by the West Coast DHB had the least number of admissions (four children, 0.3%). Counties-Manukau had the largest proportion of hospital admissions requiring PICU admission (14%, 95% CI 10–20%).

Length of hospital and PICU stay
The mean length of hospital stay for all children was 5.2 days. The mean length of hospital ward stay for the 1,391 children whose illness did not require intensive care was 4.4 days (range, one to 98 days). The mean length of hospital stay for the 65 infants whose illness required intensive care was 22.6 days (range two to 81 days), with an average 12.9 days in the PICU.

Figure 3: Admitting district health board of children hospitalised with pertussis (2003–2013).
Transportation costs
There were 17 children who were admitted to the PICU directly from the paediatric ward (eight children) or the Children's Emergency Department (nine children) at Starship Children's Hospital and therefore incurred no transport costs. Table 1 details the mode of transport and the costs associated with transporting the remaining 48 children to the PICU. The mean transportation cost was $6,879 (Table 1).

Hospitalisation costs
The total inflation-adjusted cost of the entire 11-year cohort was $8,631,542 (Table 2). The total inflation-adjusted cost of children admitted to a hospital ward but not requiring PICU care was $5,900,530 and the mean cost per child was $4,242 (Table 2). The total cost of children admitted to PICU (including hospital ward stay before and after intensive care admission) was $2,400,826 and the mean cost per child was $36,936 (Table 2). The total intensive care cost including transportation was $2,731,012 and the mean cost per child was $42,016 (Table 2).

Costs by age group
Infants accounted for 87% of the hospitalisation costs at a mean cost of $6,571 per infant (Figure 5). For children aged one to four years (12% of admissions) and five to 10 years (7% of admissions), the mean hospitalisation costs were $2,693 and $3,582 per child respectively. For children greater than 10 years of age, the mean costs per child were greater ($8,219) but they accounted for only 3% of pertussis admissions.

Costs of the 2011–2013 pertussis epidemic
There were 572 children admitted to hospital during the most recent pertussis epidemic that began in August 2011 and ended in December 2013. Admissions during the epidemic accounted for 39% of all pertussis hospitalisations during the 11-year study period and 49% ($4.2 million) of the total costs.

There were 38 children (37 infants and one three year-old) who were admitted to the PICU during the epidemic, accounting for $176,000 in non-epidemic 2006 to over $2 million in 2012 at the height of the most recent epidemic (Figure 4). The other epidemics in this study period had peak annual costs of $784,000 (2004) and $759,000 (2009).

Table 1: Cost of transportation to the paediatric intensive care unit (2003–2013).

<table>
<thead>
<tr>
<th>Transport mode</th>
<th>Number of children</th>
<th>Total cost (NZD)</th>
<th>Mean cost per child</th>
</tr>
</thead>
<tbody>
<tr>
<td>Road</td>
<td>32</td>
<td>$4,640</td>
<td>$145</td>
</tr>
<tr>
<td>Helicopter</td>
<td>7</td>
<td>$65,055</td>
<td>$9,294</td>
</tr>
<tr>
<td>Fixed wing aircraft</td>
<td>9</td>
<td>$260,491</td>
<td>$28,943</td>
</tr>
<tr>
<td>Total</td>
<td>48</td>
<td>$330,186</td>
<td>$6,879</td>
</tr>
</tbody>
</table>

Legend: NZD, New Zealand Dollar in 2013/14 values.

Table 2: Hospital and paediatric intensive care unit length of stay costs for children with pertussis (2003–2013).

<table>
<thead>
<tr>
<th>Category</th>
<th>Number of children</th>
<th>Total cost (NZD)</th>
<th>Mean cost per child (NZD)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hospital ward</td>
<td>1391</td>
<td>$5,900,530</td>
<td>$4,242</td>
</tr>
<tr>
<td>Paediatric intensive care</td>
<td>65</td>
<td>$2,400,826</td>
<td>$36,936</td>
</tr>
<tr>
<td>Transportation costs</td>
<td>48</td>
<td>$330,186</td>
<td>$6,879</td>
</tr>
<tr>
<td>Total</td>
<td>1456</td>
<td>$8,631,542</td>
<td>$5,928</td>
</tr>
</tbody>
</table>

Legend: NZD, New Zealand Dollar in 2013/14 values.
58% of all PICU pertussis admissions during the 11-year study period. The mean length of stay was 15.9 days. The total hospitalisation cost for those PICU patients during the epidemic was $1.7 million, 20% of the total cost of all pertussis hospital admissions in the 11-year study period.

### Discussion

This study has a number of important findings related to estimating hospitalisation costs for children with pertussis in New Zealand. Firstly, total inflation-adjusted costs over the 11-year study period were estimated at $8.3 million and the mean cost of hospital ward and PICU care was $4,242 and $42,016 respectively per child. Secondly, infants accounted for 78% of hospital admissions, 98% of paediatric intensive care admissions and 87% of hospitalisation costs. Thirdly, the most recent epidemic lasting less than 2.5 years accounted for 39% of all hospital admissions and 49% of total costs. Finally, the peak annual hospitalisation costs during epidemic years increased from under $800,000 in 2004 and 2009 to over $2 million in 2012 (inflation-adjusted to 2013/14 values).

The medical costs of pertussis have not previously been reported at a national level for any country. A national estimate was possible for New Zealand because: (i) all pertussis notifications are reported to a single national institute for disease

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**Figure 4**: Annual hospitalisation costs of children with pertussis (2003–2013).

**Figure 5**: Hospitalisation costs of children with pertussis by age (2003–2013).
surveillance; (ii) one government agency collates and stores information on all patients hospitalised nationally; (iii) all hospital care is delivered by public hospitals funded by the New Zealand government and; (iv) all children with severe pertussis infection are referred to a single PICU.

We estimated the cost of children with pertussis that required hospital ward care to be $4,242 per child. Cost estimation studies have been published in Europe, South America and the US. The mean length of hospital stay upon which our estimates were based (5.2 days) is comparable to those used in an estimate of length of stay for pertussis in Germany in the 1990s (6.5 days). Our estimate of average direct medical costs per admission were comparable to those estimated in the US from 1996 to 1999 from approximately 1,000 hospitals in California, Florida, Maryland and Massachusetts (mean cost per child of $9,130 USD ($11,500 NZD)). In this study, mean length of stay was 6.0 days and 13% were admitted to a PICU. The inpatient hospital costs of pertussis in three hospitals in Argentina from 2010 to 2012 were estimated at $2,130 USD. The cost of providing paediatric intensive care services to infants with pertussis has not previously been reported. Our study estimated mean costs per infant of $42,016 NZD, including the cost of transportation to the PICU.

Direct comparisons of health care costs are difficult to make because of differences in the cost of health care between countries. However, with infant pertussis hospitalisation rates in New Zealand (2000s: 196/100,000) being three times higher than those in Australia (2001: 56/100,000) or the US (2003: 65/100,000), the direct medical costs of pertussis in New Zealand remain unacceptably high.

Our study confirms that infants account for the majority of hospital ward and paediatric intensive care admissions and the burden of cost. With the majority of direct medical costs for pertussis being generated by infants, New Zealand must continue to seek to improve the prevention of pertussis in this age group. Current immunisation coverage rates are at the highest that New Zealand has ever achieved. However, immunisation timeliness remains suboptimal. In the 12 months to September 2015, although 94% of infants in New Zealand had received the complete three-dose primary immunisation series (due at six weeks, three months and five months) by 12 months of age, only 80% had completed the series by age six months. Delay in receipt of any of the three infant doses of pertussis vaccine is associated with a five-fold increased risk of an infant being hospitalised with pertussis.

Because the majority of infants with severe and life-threatening pertussis are less than three months old, improving the timely delivery of the infant pertussis vaccine series will, on its own, be insufficient to prevent disease in those with the greatest risk of death and disability and for whom health care costs are highest. Better protection of those most likely to transmit pertussis to young infants is necessary. Mothers are a well-documented source of pertussis transmission to infants. Immunisation of pregnant women with acellular pertussis vaccine has been shown to be highly effective at preventing pertussis in infants less than three months old.

In response to the most recent epidemic in New Zealand, all pregnant women between 28–38 weeks gestation who had not received a booster dose of pertussis vaccine in the last 10 years were encouraged to undergo publicly funded immunisation. However the uptake of pertussis pregnancy vaccination is low. For this strategy to be effective, it will be necessary for pregnancy coverage rates to be as high as those now achieved with the infant immunisation series.

Our study has several important limitations. DRG-based cost-weights are used by the Ministry of Health to calculate revenue paid to each of the DHBs for providing health care services. These cost-weights are based on historical average expenditure per diagnostic group and do not necessarily reflect the true cost at the individual patient level. Cost-weights also exclude the cost of adjusters paid to DHBs in recognition of complexity of services, rural location, overseas visitors, Māori health and the Starship adjuster. In addition, it is likely that some infants with severe pertussis may have been managed in an adult intensive care unit at their referring DHB prior to transfer to the PICU. Our estimates of intensive care cost are therefore likely to be conservative.
Our study focused on costs associated with hospital resource provision to children, and therefore describes only a proportion of the total health care costs incurred by pertussis. Our cost estimates are an approximation and underestimate the full economic burden generated by general practitioner visits, public health involvement and the provision of antibiotics to close and household contacts. Direct non-medical costs such as travel expenses incurred for medical consultations and additional childcare provision were beyond the scope of this study as were indirect non-medical costs including lack of parental sleep and the effect on productivity, absenteeism from work and the effect on siblings and other family members.\textsuperscript{13,23}

The periodicity of pertussis epidemics in New Zealand is unlikely to change despite the recent improvements in infant immunisation coverage. Given the severity of the most recent epidemic there is an urgent need to better protect our infants from this severe and expensive disease. A clear focus on improved timeliness and high coverage of the infant immunisation series together with a pregnancy dose of pertussis vaccine are key components of this strategy. To be cost-effective, both of these immunisation strategies must make the prevention of pertussis in population groups at highest risk of disease a priority. In New Zealand these groups include children of Māori or Pacific ethnicity.\textsuperscript{24}

\textbf{Competing interests:}
Nil.

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