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Impact of pneumococcal vaccine on hospital admission with lower respiratory infection in children resident in South Auckland, New Zealand

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Abstract

Aim To assess the change in admission rates for all Lower Respiratory Infection (LRI) including pneumonia for children resident in Counties Manukau District Health Board (CMDHB) with the introduction of the Pneumococcal Conjugate Vaccine 7 valent (PCV7) in June 2008.

Method National Minimum dataset ICD10 coded LRI admissions to any NZ hospital August 2001–July 2011 for children <2 year resident in CMDHB were analysed using Poisson regression, omitting 1 August 2008 to 31 July 2009, the first-year post vaccine introduction.

Results Pneumonia but not bronchiolitis admissions have been declining since 2001. Pneumonia admissions decreased significantly after PCV7 introduction (incidence risk ratio (IRR) (95% CI) 1.51 (1.08–1.77), additional to the gradual decline since 2001. There was significant decline for Pacific children post PCV7 introduction IRR 1.70(1.39, 2.07) but not for Māori children, IRR 1.05 (0.78–1.40). Māori and Pacific children are at increased risk of admission with LRI compared to European children (relative risk (RR) (95%CI) 4.6 (4.3–5.0) and 5.0(3.7–5.3) respectively) as are those living in Decile 9, 10 compared with those from other deciles, RR 1.43 (1.36–1.50).

Conclusion The introduction of PCV7 is associated with reduced admissions for pneumonia in young children yet there has been less impact for Māori in CMDHB.

New Zealand (NZ) children have very high rates of admission with lower respiratory tract infection (LRI) when compared with other developed countries.[1–7] Lower respiratory illness is the most common cause of admission in children 0–14 years in Counties Manukau District Health Board (CMDHB) after the neonatal period.[6]

CMDHB has a significantly higher burden of respiratory disease than the rest of New Zealand with rates of admission for bronchiolitis almost double those of other regions.[6] Pacific, Māori and disadvantaged children bear a disproportionate burden.[6] Furthermore, Grant et al have also shown that Pacific children admitted to hospital with pneumonia have a greater disease severity.[9]

Admission to hospital with pneumonia under 2 years of age is linked to the later development of chronic lung disease including bronchiectasis in indigenous populations in Australia, Alaska and New Zealand.[10–12]

The population of CMDHB, particularly Māori and Pacific children and young people, have very high rates of bronchiectasis.[6] Any reduction of pneumonia

admissions to hospital is likely to reduce later complications of chronic lung disease for our population.

Pneumococcal disease is a common cause of pneumonia in childhood but is also a leading cause of invasive disease, particularly in infancy. Studies using different techniques and child populations have demonstrated that bacterial infection with *Streptococcus pneumoniae* (*S. pneumoniae*), viral/bacterial co-infection and viral infection are common in children admitted to hospital with community-acquired pneumonia (CAP).[13–15]

Pneumococcal conjugate vaccines including 7 (PCV7), 9 (PCV9), 10 (PCV10) and 13 (PCV13) serotypes have been developed and subjected to randomised double-blind controlled trials.[16–19] Studies of the impact of PCV7/9 vaccines on CXR diagnosed pneumonia in young children shows an efficacy varying between 20 and 65% (per protocol analysis).[16–20]

A time series analysis based on the discharge diagnosis from the US Nationwide Inpatient sample compared admission rates before and after routine PCV7 immunisation in the US and reported a 39% [22–52] reduction in all cause admission rates for pneumonia in children under 2 years of age.[20]

A comprehensive summary of the impact of PCV7 worldwide has recently been published.[20] PCV7 was introduced as part of the routine immunisation schedule in NZ in June 2008, backdated to infants born on or after 1 January 2008.

This analysis was undertaken to provide background for a study of the viral aetiology of admissions to KidzFirst Hospital (CMDHB) in children under 2 years, in the 1 year prior to and the 2 years following PCV7 introduction.

The population in Counties Manukau is estimated to be 500,600 in 2011 (454,700 in 2006). In the birth cohort of 2010 29% of births were Māori, 32% were Pacific, 20% were European, and 17% Asian/Indian. It is estimated that in 2012 60% of children aged 0–3 years in CMDHB live in Decile 9 and 10 regions.[6]

The goal of this analysis was to assess the change in numbers of admissions of children under the age of 2 years hospitalised with pneumonia and other LRI over a 10-year period encompassing the introduction of PCV7 to the national immunisation schedule in June 2008.

Methods

A list of admissions to hospital for children younger than 2 years of age resident in CMDHB with an ICD-10 principal diagnosis code for acute bronchiolitis (J210, J218, J219), pneumonia (J100, 120-2, 129, 13-14, 150, 152, 154, 155, 159, 160, 180, 181, 189, 204, 209, 851, 852, 869), unspecified lower respiratory tract infection (J101,22), whooping cough (A370, 379) and bronchiectasis (J47) listed as the principal diagnosis on the discharge record was obtained from the National Minimum Data Set (NMDS) for the years 1 August 2001–31 July 2011.

The ICD10 coded diagnosis is made by trained medical information staff based on the discharge summary and clinical notes. NMDS includes all admissions of three hours and over. We analysed admissions with length of stay ≥1 day, i.e. excluding those who were admitted and discharged on the same day, but including readmissions and short stay patients if they stayed ≥1 day.

Admissions of CMDHB children to any hospital in NZ were included. A transfer between hospitals was counted as the same admission. Ethnic-specific hospitalisation rates were calculated using the Ministry of Health's level 1 prioritisation algorithm[21] and categorised into three groups: Māori, Pacific and Other.

Socioeconomic deprivation index for each child was estimated using the NZDep2006 index for their residential address at diagnosis.[22] The NZDep2006 combines 9 variables from the 2006 NZ Census. Individual area scores are then ranked and placed on an ordinal scale from 1 to 10, with Decile 10 representing the most deprived 10% of small areas.

In order to look at changes in admissions for LRI after the introduction of the pneumococcal vaccine, hospital admissions during the year immediately following the vaccine introduction (1 August 2008 to 31 July 2009) were omitted.

A Poisson regression was run with age (<1 year and 1–<2 years), ethnicity (Māori, Pacific, other), gender, decile [1–10], year, pre or post vaccine introduction, and diagnosis (pneumonia, bronchiolitis, other LRI) as explanatory variables and the number of admissions in the year as the outcome.

The log of number of births in CMDHB in the appropriate year, ethnicity, decile, and gender category was included as an offset with the births in the year the period began used for children under 1 year of age, and the previous year for the 1 year olds (e.g. for the year from 1 August 2001 to 31 July 2002 the 2001 births were used for under ones and 2000 births for 1 year olds).

Initially the 3 way interaction of diagnosis, year and pre/post was examined to see if there was a difference in the change of slope from pre to post vaccine introduction in the different diagnoses. When this difference could not be demonstrated the two-way interactions were examined.

Data from the National Immunisation Register (NIR) for the periods 1 July 2009 to 30 June 2010 and 1 July 2010 to 30 June 2011 for the CMDHB were accessed for those reaching 6 months of age and those reaching 12 months of age within the time period with analysis by total group, by ethnicity and by deprivation.[23]

Results

Ethnic and socioeconomic disparity—Over the period 1 Aug 2001–31 July 2011 Māori and Pacific children aged <2 years resident in CMDHB, were at increased risk compared with European children of admission with LRI to any NZ hospital, relative risk (RR) (95%CI) 4.6 (4.3–5.0) and 5.0(3.7,5.3) respectively. Also children living in Decile 9 or 10 regions were at increased risk of admission compared to other deciles, RR 1.43 (1.36–1.50).

Time trends—Figures 1 and 2 illustrate admission rates for pneumonia and bronchiolitis of children who are resident in CMDHB, and admitted to any NZ hospital, over the period 1 Aug 2001–31 July 2011.

Figure 1. Pneumonia admissions for CMDHB resident children aged <2 years with stay ≥1 day to any NZ hospital facility
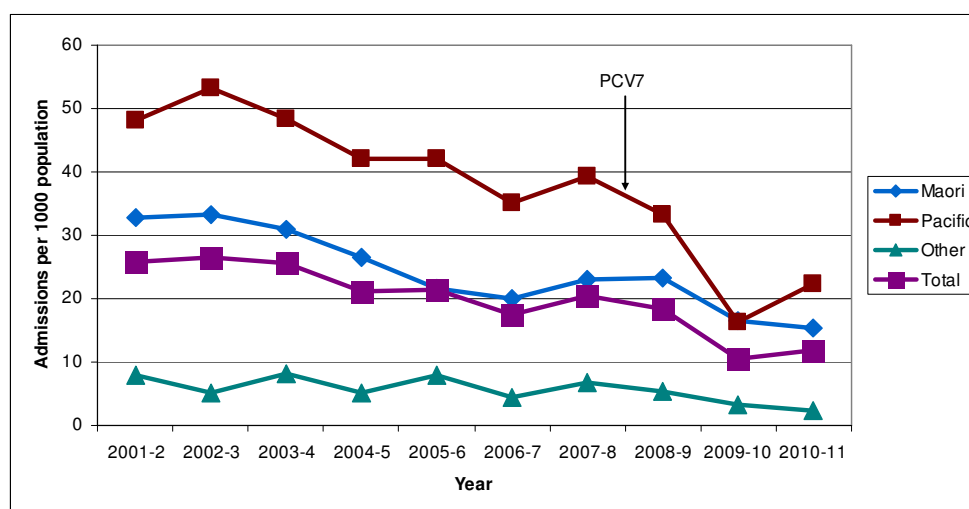
Figure 2. Bronchiolitis admissions for CMDHB resident children aged <2 years with stay ≥1 day to any NZ hospital facility
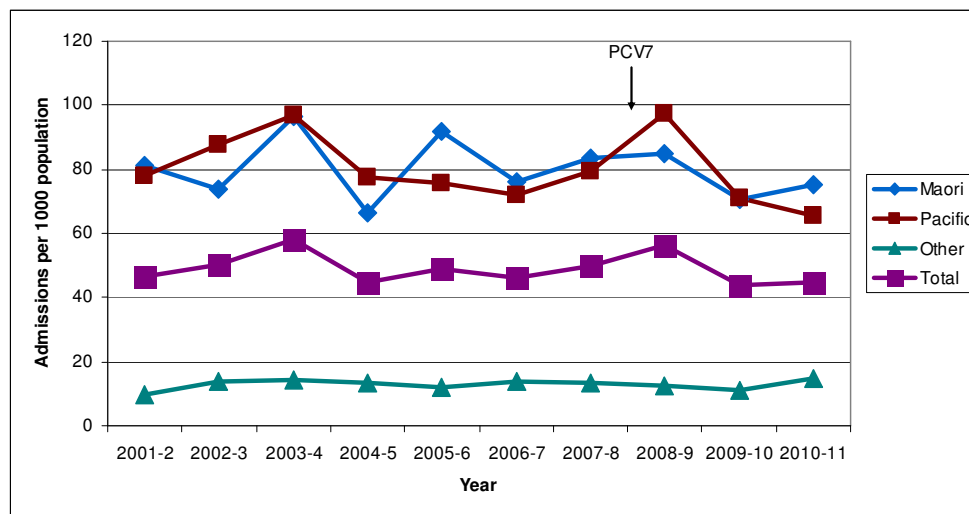
Poisson regression analysis—Initially the rate of change over time in admissions was modelled to be able to differ pre and post the vaccine introduction and for different diagnoses. However differences in these rates of change over time could not be shown so a constant rate of change pre and post vaccine introduction was assumed within diagnosis category.

In contrast there was strong evidence that the change in rate in admissions over time differed by diagnosis for the three diagnoses (p<0.0001). The size of their step in rates after vaccine introduction was also significantly different (p=0.003). Therefore the three diagnoses (pneumonia, bronchiolitis and other LRI) were examined separately.

There was strong evidence of a general decrease over time in rates of pneumonia admissions (incidence risk ratio (IRR) (95% CI) for a change of 1 year 0.96 (0.94–0.98), p<0.0001) and of an additional step down in rates of pneumonia admissions after vaccine introduction (IRR pre to post 1.51(1.08–1.77) p<0.0001) (Figure 1, Table 1).

There was no evidence of the step in pneumonia admissions after vaccine introduction differing by age (p=0.34), or decile (p=0.53). However there was some evidence of a difference according to ethnicity (p=0.05). For Māori, although there was strong evidence of a general decline over the 10-year period in admissions for pneumonia (p<0.0001), no step from pre to post vaccination could be demonstrated (p=0.76). However a drop from pre to post vaccination could be demonstrated for Pacific (p<0.0001) and other ethnicities (p=0.003) (see Table 1).

We also investigated whether there was a difference in the change in pneumonia rates from pre to post vaccine introduction in different age groups with age in four 6-month categories, in case the effect was different in those <6 months. However an age difference in the effect could still not be shown, (p=0.11).

There was still a significant reduction from pre to post vaccine introduction even in the youngest group, with an effect size very similar to the other age groups (IRR 1.48, 1.53, 1.49 and 1.64, for 0–6 months, 6 months–1 year, 1 year–18 months, 18 to 24 months respectively).

Table 1. Comparison of LRI admissions for CMDHB resident children aged <2 years with stay ≥ 1 day Pre vs Post PCV7 vaccine introduction

Variables	IRR*	95%CI	P
Pneumonia	1.51	1.08–1.77	<0.0001
Pacific	1.70	1.39–2.07	<0.0001
Māori	1.05	0.78–1.40	0.76
Other	1.93	1.26–2.98	0.003
Bronchiolitis	1.07	0.98–1.17	0.15
Other LRI	1.28	0.97–1.77	0.08

A general change over time could not be demonstrated for bronchiolitis (p=0.12, IRR for a change of 1 year 0.99) nor could a change from pre to post vaccine introduction (p=0.15 (Figure 2, Table 1).

For other LRI there was also no evidence of a general decrease over time (p=0.72, IRR 0.99) and only possible weak evidence of a change from pre to post vaccine introduction (p=0.08).

The National Immunisation Register (NIR) has data on immunisation coverage at 6 months and 12 months of age by DHB which is relevant to the age group in this study (see Table 2). By age 6 or 12 months, 3 doses of PCV7 would have been received if all doses given on time. At least 2 doses are needed for effectiveness.[24]

Māori rates are the lowest of all ethnic groups, being about 20% less than those of other ethnicities at 6 months and still at least 10% less at 12 months.

Table 2. Immunisation coverage (%) by age for CMDHB resident children

Variables	July 2009–June 2010		July 2010–June 2011	
Age group	6 months	12 months	6 months	12 months
Total	67	86	66	88
NZ European	75	91	73	90
Māori	53	77	51	79
Pacific	66	89	66	90
Asian	86	94	88	96
Other	75	86	73	89

Discussion

The analysis of hospital admissions for the 10-year period 2001–2011 for CMDHB-resident children has clearly demonstrated a gradual reduction in pneumonia admissions from 2001–2011 with no significant change in admissions for

bronchiolitis. A further step-down in admissions for pneumonia occurred in the 2 years after the introduction of PCV7 to the immunisation schedule in addition to the gradual reduction over the whole decade. This step-down was seen for children of Pacific and other ethnicities, but has not been seen for Māori children. There was no significant step-down effect for bronchiolitis admissions. The magnitude of this reduction in pneumonia is very comparable to international studies.[20]

The gradual reduction in pneumonia admissions in CMDHB, one of the most disadvantaged urban areas in New Zealand with very high Māori and Pacific numbers of children, contrasts with the rise in admissions to hospital for infectious diseases overall as described by Baker up to 2008.[25] However it is consistent with their observed decline in admission rate for the under 5-year group.

Their data for the periods 1999–2003 and 2004–2008 demonstrates a reduction in rate of hospitalisation for infectious diseases (ID) under 5-years of age for European (4608/100,000 to 3856/100,000) and Pacific (8857/100,000 to 8147/100,000). Māori children did not show a change in the rate of ID admission for the same time period and age group, (7971/100,000 to 7918/100,000).

In addition a social gradient was reported in hospitalisations for children age 0–14 years from 2000-2011, including admissions for bronchiolitis and pneumonia, by the Child and Youth Epidemiology service of the Paediatric Society of New Zealand, in the New Zealand Children's Social Health monitor.[26] There was an overall reduction in these admissions for CMDHB from a peak in 2001 contrasting with no change in these admission rates for the rest of New Zealand. Rates for CMDHB Māori and CMDHB Pacific were higher than the non CMDHB Māori and Pacific populations.

A number of factors may have influenced the findings in CMDHB. The Healthy Housing programme is a combined housing improvement, health and social intervention which has been implemented in nearly 6500 social housing (Housing New Zealand) homes in CMDHB between 2000 and 2011. Jackson et al[27] have reported on the outcomes for 3410 of these Healthy Housing interventions with a significant reduction in preventable childhood respiratory hospital admissions using a counterfactual design.

The majority of families served by Healthy Housing were living in areas of high deprivation and were of Pacific ethnicity (personal communication Jude Woolston, manager). Health care may also have improved with a number of DHB primary care strategies[28] aimed at reducing barriers to Primary Care access for children. Immunisation rates have improved and are now at 88% completion at 12 months of age.[23]

Since 1997 there has been an active programme of post discharge follow-up in the community using paediatric home care nurses and this has not changed over this time period.

Immunisation reports demonstrate that Māori have 10% lower completion rates than Pacific at 6 and 12 months.[23] We are unaware of reports specifically comparing barriers to primary care access for Māori compared with Pacific.[29] Delayed or incomplete immunisation would reduce the effectiveness of PCV7 because pneumonia presents from a young age.[6]

Pacific children live in more overcrowded circumstances and more live in Decile 10 areas than Māori[30] both of which increase the likelihood of nasopharyngeal carriage of *S.pneumoniae*[31] and also increase the likelihood of a high nasopharyngeal load which may then link to rates of pneumonia.[32] These hypotheses could also be a link to the increased vaccine effectiveness for Pacific infants.

Our observed reduction in pneumonia admissions for Pacific children brings their rates now to equivalent with Māori children. However both remain much higher than those for European and other ethnicities in New Zealand and populations overseas, although not as high as in aboriginal children.[1–5,9,33–35]

There are some limitations to this study. Hospital discharge data has to be interpreted with caution. Diagnostic shift from pneumonia to another diagnosis such as bronchiolitis or asthma could cause a gradual reduction as seen above however admissions for these entities over the same period have remained the same or reduced. Coding practice has been unchanged in this time period.

The admissions analysed were those with a recorded length of stay ≥1 day which is defined as greater than or equal to 3 hours and present at midnight. This will include all children admitted to the inpatient unit except rare cases admitted after midnight and then discharged before the end of the day. Patients who presented to ED just prior to midnight with a stay >3 hours but not admitted to a ward will have been included.

We have analysed admissions rather than patients as this represents workload for the health services and overall burden for the population. A number of children had multiple admissions. Our 'years' ran from 1 August through to 31 July of the following year. This does mean each year's worth of data includes two different winter seasons with different viral patterns in each winter.

We have used the birth cohort born to mothers resident in CMDHB from NMDS as the denominator population as it reflects the fast growing birth rate and changing demography of CMDHB over this period. Problems have been identified with the allocation of ethnicity in hospital data demonstrating that it under represents Māori ethnicity.[36,37]

The ethnicity data collection protocol was introduced in 2004 and there is evidence that Māori ethnicity was under reported in relation to other ethnicities in the late 90's and early 2000's. There is no assessment of the accuracy of the allocation of ethnicity at birth since the protocol was introduced in 2004. Ethnicity is self identified in the same way as for other admissions.

There was a significant decline in pneumonia hospitalisation in infants <24 months following the introduction of the Pneumoccocal Conjugate Vaccine 7 valent (PCV7) in CMDHB in addition to the gradual decline since 2001. This reduction post vaccination introduction appeared to be less in Māori children.

Ongoing effort to maximise on time vaccination for infants of all ethnicities is essential. Further study to understand the factors underlying both the decline in admission rates over the decade and the difference in the change in rates in Māori and Pacific since the introduction of PCV7 is important.

Despite the improvements since the introduction of PCV7 Māori and Pacific continue to bear an unequal burden of LRI including pneumonia. This requires urgent solutions particularly as pneumonia can lead to long term morbidity and early mortality.[38]

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