original research

Pertussis hospitalisations and mass vaccination in New Zealand 1948 - 1996

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ABSTRACT

Prior to mass vaccination which began in 1960 the period between epidemics was three years. Since 1967 epidemics have occurred at intervals of four, three, four, four, four, five, and five years, with an epidemic occurring in 1996. There has not been a reduction in the number of people hospitalised with whooping cough and, unexpectedly, the average number of children aged under one admitted annually with whooping cough has increased from 78 (1950-1961) to 112 (1979-1996) while the number of children born each year has not increased.

Mass vaccination of the very young against whooping cough has been associated with both a lengthening of the period between epidemics and a paradoxical increase in the number of very young children hospitalised as the result of infection with this parasite. It is known that vaccine induced immunity wanes more rapidly than that which follows natural infection. We suggest that this fact links the increased inter-epidemic period and the increased burden of disease in the very young. As a result of waning vaccine-induced immunity babies are now liable to be infected by parents, aunts, uncles and even grandparents as well as siblings. A solution may be to continue vaccination into and through adulthood and to encourage expectant parents and their relations to have a booster whether they are "due" for one or not. We note that increased prevalence in the very young is only possible because of a failure to reach vaccination targets using an adequate vaccine.

INTRODUCTION

Whooping cough vaccine has been available in New Zealand since 1945 although the first immunisation schedule was not put into place until 1960.[1] The objective of this mass immunisation programme, which aims to reach all infants, is to halve the number of children under one admitted to hospital as a result of whooping cough infection.[2] The ultimate goal is to eradicate the parasite from New Zealand.

In this paper, hospital discharge statistics for the period 1948-96 are presented. Our aim in collecting these data was to quantify the effect of more than 30 years of mass vaccination on the period between epidemics, and on hospitalisations of the very young. This is a fairly natural progression from the hospital discharge data presented in two recent reviews of pertussis in New Zealand[2,3] which considered the post-vaccination period 1970-1992 and did not stratify for age. The aim of those reviews was to establish where we are now in order to establish quantitative goals for the future. The aim of our work was to establish what impact mass immunisation has al-

Key points

- Mass vaccination has progressively increased the period between epidemics from three to five years
- Since mass vaccination, there has been a 41 per cent increase in the average number of one year olds discharged from hospital as the result of pertussis
- This increase reflects our failure to reach coverage targets using an adequate vaccine
- As vaccine-induced immunity wanes more quickly than that which arises from natural infection we speculate that the very young may be exposed to more infective contacts than previously (parents, aunts, siblings)
- One solution may be to offer prospective parents and their social contacts booster doses of vaccine

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Table 1 Patients discharged from or dying in New Zealand hospitals 1948-1996

Year	Total	Aged > 1	Aged ≥ 1
1996	549	414	135
1995	181	146	35
1994	44	31	13
1993	107	60	47
1992	131	80	51
1991	329	204	125
1990	131	87	44
1989	59	48	11
1988	11	10	1
1987	79	58	21
1986	339	201	138
1985	63	41	22
1984	17	7	10
1983	137	102	35
1982	570	386	184
1981	39	30	9
1980	41	27	14
1979	130	85	45
1978	254	175	79
1977	62	47	15
1976	47	34	13
1975	79	55	24
1974	221	147	74
1973	58	38	20
1972	107	80	27
1971	144	98	46
1970	42	28	14
1969	63	45	18
1968	89	64	25
1967	101	64	37
1966	58	34	24
1965	50	34	16
1964	192	129	63
1963	119	77	42
1962	40	21	19
1961	157	107	50
1960	99	63	36
1959	171	116	55
1958	117	83	34
1957	37	21	16
1956	115	58	57
1955	149	79	70
1954	113	51	62
1953	195	100	95
1952	214	112	102
1951	173	60	113
1950	225	89	136
1949	308	na	na
1948	108	na	na

na = not available

ready had, with a view to estimating what further change can be achieved.

METHODS

The Health Information Service of the New Zealand Ministry of Health publishes an annual set of morbidity data (presently called "Hospital and Selected Morbidity Data").

One table in this publication lists by ICD code the number of patients discharged from or dying in public hospitals. These data were extracted for the 49 years 1948 -1996.

The annual sets of morbidity data were not published for the years 1975,1976 and 1977 due to the conversion from punch-card records to a computerised database.

However the figures were extracted by Health Information Services advisors.

Figures for the annual number of births in New Zealand were obtained from volumes of the *Official New Zealand Yearbook* published by the Department of Statistics. The 1996 figure is not available at the time of writing and has been assumed to be equal to the 1995 figure (57791)

RESULTS

Figure 1 depicts the hospital discharge data for whooping cough for the 49 years from 1948 to 1996. Between 1949 and 1967 (triple vaccine was incorporated in the first immunisation schedule which was introduced in 1960) epidemics occurred in a three-yearly cycle.

The years since have been characterised by a lengthening of the period between epidemics. Since 1967 epidemics have occurred at intervals of four, three, four, four, four, five, and five years, with an epidemic in 1996. The troughs seem to have become lower and perhaps the peaks have risen.

This is consistent with US data, where from 1977 the number of reported cases has increased in each epidemic year.[4]

However, there has not been any reduction in the number of patients hospitalised with whooping cough.

Table 1 lists the annual number discharged from hospital aged under and over one year. Inspection of this table suggests that there has been an increase in the proportion of hospitalised patients aged under one year since mass immunisation was introduced.

This suspicion is examined in Table 2 which compares a summation of the figures for the three epidemic cycles that occurred in the period 1950 -1961 to a summation for the four epidemic cycles from 1979- 1996. There has been an increase in the proportion of hospital discharges occurring in those aged under one (chi-squared test, $p < 0.005$) The average annual number of hospital discharges has increased from 147 pre-vaccination to 164 in the post-vaccination period.

The combined effect has been that the absolute number of children aged under one admitted annually with whooping cough increased from an average of 78 in the years 1950-1961 to 112 in the years 1979-1996

One possible explanation for this 43 per cent increase is that more babies were being born in the latter period. This is not supported by an inspection of the numbers of babies born annually (*Official New Zealand Yearbook* figures). Figure 2 plots the discharge rates for under one year olds for the period 1950 -1996. In shape, this figure mimics Figure 1.

DISCUSSION

In New Zealand, mass vaccination has increased the period between epidemics of whooping cough from three years to five years.

There have been increases in both the total number of hospitalisations due to whooping cough and the proportion of admissions occurring in those aged under one year. The overall effect has been that the absolute number of children aged under one admitted annually with whooping cough has increased.

These results seem contradictory. The period between epidemics is the time it takes for the number of susceptibles in the population to increase from the post-epidemic trough to the pre-epidemic peak.

A longer period between epidemics

implies a slower restocking of the pool of susceptibles. With mass vaccination a proportion of newborns are vaccinated before they come into infective contact with the wild parasite. As a consequence, with say 50000 births each year and an effective 60 per cent vaccination rate only 20,000 susceptibles are "born" into the population annually compared to 50,000 prior to the onset of mass vaccination. Lengthening of the inter-epidemic period is evidence that it is taking longer for the susceptibles to build up again in the population and suggests that mass vaccination is having a positive effect.

On the other hand the incidence of disease in at least one age group (the under ones) seems to have increased since mass vaccination was introduced. Could this be an adverse effect of mass vaccination ?

An obvious alternative explanation for the increased number of under one year olds hospitalised is that discharge data in this age group have not consistently reflected community incidence. Hospital discharge data may well have been less reliable in the past and there may have been problems in diagnostic accuracy. Admission policies may have changed. In particular the poor and Maori/Polynesian (who are at greatest risk of requiring hospital care) may have become better able to access hospital care.

We accept the opinion formed by an authoritative review[2] "Hospital discharge data ...reflect the true incidence of pertussis influenced to some degree by changing criteria for hospital admissions" although one response to the data presented in this paper is to re-examine that proposition.–

Assuming then, that the incidence of pertussis in under one year olds has increased (and, indeed, as the number of under one year olds in the New Zealand population has been fairly constant over the last 50 years, prevalence has increased too), could this have come about as a result of mass vaccination?

The first point to make is that the increased prevalence of pertussis in under one year olds is only possible because of our failure to reach national coverage targets.

In an unvaccinated population an endemically persisting parasite such as pertussis would, according to standard theory[10], be expected to infect about 10 per cent of under one year olds. The prevalence of disease in that age group cannot increase post-vaccination if a 90 per cent vaccination rate at birth is achieved with a vaccine that always confers protection against infection for at least one year. This is because if 90 per cent are vaccinated only 10 per cent are available for infection. Further, the incidence of disease in that age group must fall by at least one half if a 95 per cent vaccination rate at birth is achieved (as the disease can affect, at most, the remaining 5 per cent). So if New Zealand met its vaccination targets and used a vaccine adequate to the task, the public health aim of halving hospital admission rates would be met.

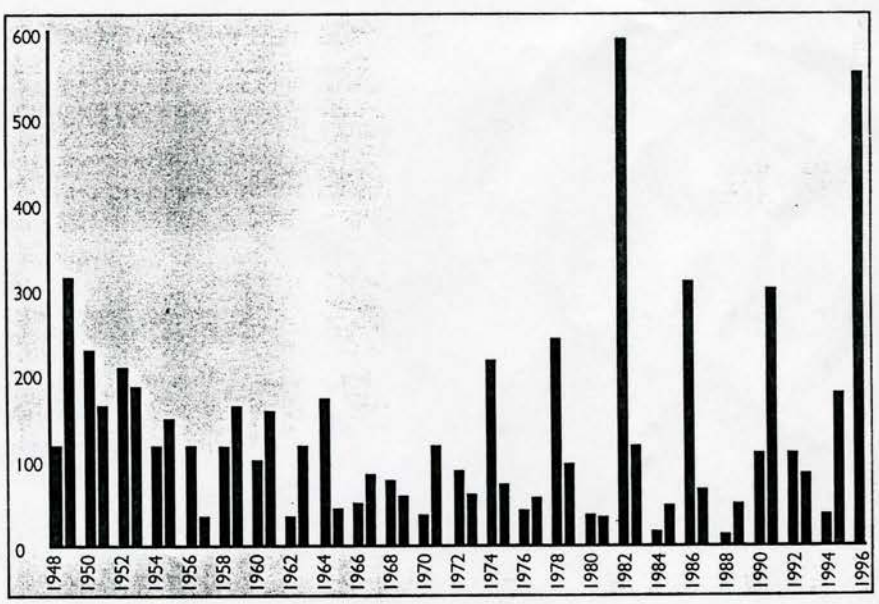
A possible reason for the observed increased prevalence of disease in those aged under one lies in the present vaccine, which confers limited and temporary immunity when compared to that provided by natural infection.[2,3,6] This allows mothers, uncles, aunts, siblings and other older social contacts to acquire sub-clinical or mild infection after the immunity conferred on them by childhood immunisation has waned. These people can then infect the newborn. Before vaccination, natural infection in childhood resulted in long lived (possibly lifelong) immunity and these older social contacts were not infective contacts.

There is an acceptance in countries which vaccinate against pertussis that the incidence of disease is increasing, especially in adolescents and adults.[7,8,9] The consensus seems to be that this reflects waning vaccine-induced immunity, although it is possible that at least part of the reported increase reflects a higher

Table 2 (%)patients discharged from or dying in hospital 1950-1961 and 1979-1996

Years from	Total Number	Patients aged < 1	Patients aged ≥ 1
1950-1961	1765	939 (53.2)	826 (46.8)
1979- 1996	2957	2017 (68.2)	940 (31.8)

Figure 1 Whooping cough: annual numbers of patients discharged from or dying in New Zealand public hospitals 1948-1996



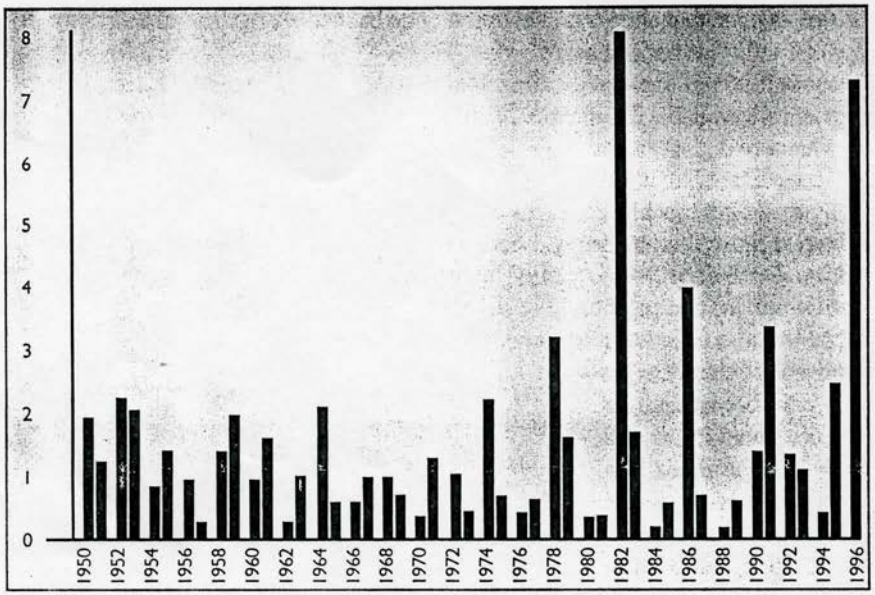


Figure 2 Annual hospital discharge rates - under one year olds, per 1000 births

index of suspicion. Certainly, at least part of the rise is due to the expected[10] shift in the average age of infection which follows mass vaccination.

If the incidence of disease is increasing because waning vaccine-induced immunity (secondary vaccine failure) means vaccinated individuals can catch pertussis more often during the course of their lifetimes than unvaccinated ones, then the period between epidemics would, intuitively, be expected to shorten as vaccine failure, as well as unvaccinated babies, adds to the number of susceptibles.

However, the inter-epidemic period has increased. This indicates that there are also age-related differences in transmission. For example, older people with pertussis may infect fewer others than younger ones do.

The development of this idea is beyond the scope of this article.

However, this explanation does suggest a second approach (the first is to increase on-time coverage in the first year of life) which should reduce morbidity in under one year olds. The current vaccination programme could be extended to include booster doses into and through adulthood, perhaps using an acellular vaccine combined with the tetanus-diphtheria product currently in use.

Many expectant parents would probably accept boosters for themselves and their older children as well as encouraging other relatives to do so if they understood that this would reduce the chances of their baby contracting a potentially nasty illness.

A third approach would be to attempt to prevent epidemics by mass vaccination of the whole population in the months before an epidemic was expected to develop. This approach has worked with measles in the UK[11]; however the vaccines have different efficacies.

References

1 Dow DA, Mansoor O. New Zealand immunisation schedule history. *NZ Med J* 1996; 109:209-12.

2 Reid S, Lennon D, Thomas M, et al. Pertussis control in New Zealand. *NZ Med J* 1994; 107:460-6 .

3 Lennon D, Reid S, Holdaway D, Thomas M. Control of whooping cough in New Zealand; slow progress. *NZ Med J* 1995; 108:495-7.

4 Centers for Disease Control and Prevention. Resurgence of pertussis - United States, 1993. *MMWR Morb Mortal Wkly Rep*. 1993; 42:952-3.

5 Cullen RM, Walker WJ. Measles epidemics 1949-1991: the impact of mass immunisation in New Zealand. *NZ Med J* 1996; 109:400-2.

6 Herwaldt LA. Pertussis and pertussis vaccines in adults. *JAMA* 1993; 269:93-4.

7 Nennig ME, Shinefield HR, Edwards KM, et al. Prevalence and incidence of adult pertussis in an urban population. *JAMA* 1996; 275:1672-4.

8 Mortimer EA. Pertussis and its prevention: a family affair. *J Infect Dis* 1990; 161:473-9.

9 Cromer BA, Goydos J, Hackell J, et al. Unrecognized pertussis infection in adolescents. *Am J Dis Child* 1993; 147:575-577 .

10 Anderson RM, May RM. Infectious diseases of humans - dynamics and control. Oxford University Press. Oxford. 1991; 757pp.

11 Department of Health. Measles, rubella (MR) immunisation campaign 1994: one year on. *CMO's Update* 1995; 8:1.