The Epidemiology and Prevention of Pertussis in Australia

This thesis is submitted for the degree of Doctor of Philosophy, University of Sydney

Siranda Torvaldsen (BAppSci, GradDipEpi&Biostats, MAppEpid)

June 2001

Department of Paediatrics and Child Health
Abstract

Background

Pertussis (whooping cough) remains an important public health problem in Australia. Although mortality and morbidity from pertussis declined dramatically following the introduction of mass vaccination programs in 1953, the level of morbidity remains unacceptably high for a vaccine-preventable disease.

Aims and methods

The primary aims of this thesis were (i) to ascertain the epidemiology of pertussis in Australia between 1993 and 2000 by analysing and interpreting sources of routinely collected data on pertussis; and (ii) to examine the effectiveness of vaccination against pertussis in a number of ways. Data from three primary national sources (notifications of disease, hospitalisations for pertussis and death certificates) were used to examine the burden from pertussis in Australia over these eight years. Analyses included the age distribution of cases, temporal and geographic trends, comparisons of notification and hospitalisation data, and the impact of differences in the method of diagnosis of notified cases between years and age groups. In addition to analyses at the national level using data from the national databases, further detailed analyses were undertaken at the State level for New South Wales (NSW), the most populous Australian State.

Pertussis vaccine coverage was estimated using data from the recently established Australian Childhood Immunisation Register (ACIR); these data were also used to track the transition from whole-cell to acellular pertussis vaccines.

The different types of studies used to evaluate vaccine effectiveness were reviewed, and a method suitable for ongoing estimation of vaccine effectiveness in Australia was developed. This was then applied to the NSW data, to determine the effectiveness of pertussis vaccination in this State.
Main findings

The annual notification rate for pertussis in Australia ranged from 23–59 per 100,000 population over the eight years. Infants had the highest notification and hospitalisation rates in Australia — they accounted for 5% of notifications, 61% of hospitalisations and 100% of deaths. Age-specific notification and hospitalisation rates in children aged less than two years strongly suggested a protective effect of vaccination, with the greatest reduction in rate coinciding with eligibility to receive a second dose of pertussis vaccine at four months of age. Notification rates among 5–9 year olds progressively decreased in successive age cohorts, consistent with an effect of the introduction in 1994 of a pertussis vaccine booster for preschool-aged children. Although adults (persons aged 15 years or more) accounted for half the notifications, they had the lowest notification rate.

The highest numbers of pertussis notifications were in 1997, when most jurisdictions experienced an epidemic. Notification and hospitalisation rates varied across the States and Territories and also across smaller geographic regions in NSW. Areas and years with high notification rates tended to also have high hospitalisation rates, suggesting that trends in notifications reflected trends in incidence. The number of infant hospitalisations in NSW between July 1993 and June 1999 exceeded the number of notifications by 32%, highlighting the extent of under-notification.

Overall, and particularly amongst those aged more than 12 months, the majority of cases notified in NSW were based on the results of serological tests. The proportion diagnosed by culture of the organism was greatest in infants; the proportion diagnosed by serological tests increased with age. There was no evidence that the use of serology had increased since 1994 in NSW, hence changes in notification rates after this time are unlikely to be attributable to increased use of serological diagnosis.

ACIR records indicated that in December 2000, 92% of one-year-old children had received three doses of diphtheria-tetanus-pertussis (DTP) vaccine and 90% of two-year-olds had received four doses. Vaccine coverage varied by jurisdiction. Since 1997, there was an increased use of DTP vaccines containing acellular pertussis components with a corresponding decrease in the use of vaccines containing whole-
cell components. In 2000, almost all DTP vaccines administered contained acellular pertussis components.

The results of the vaccine effectiveness study showed that pertussis vaccination was highly effective at preventing pertussis in NSW children, as measured by notified cases. Vaccine effectiveness was highest (91%) in the youngest age group (8–23 months) and lowest (78%) in the oldest age group (9–13 years). The screening method has not previously been used to estimate pertussis vaccine effectiveness in Australia.

**Conclusions**

This thesis demonstrates the value of integrating varied data sources in estimating the disease burden from pertussis. The data presented here show that the disease burden is substantial in all age groups, despite high levels of vaccine coverage in infants and children. This problem of disease control does not appear to be due to lack of vaccine effectiveness, but there is evidence of waning immunity over time.

The analyses presented here form a basis for the ongoing monitoring of trends in pertussis epidemiology following the replacement of whole-cell by acellular pertussis vaccines, and will assist consideration of the need for additional booster doses in adolescents and adults.
Acknowledgments

There are many people without whom this thesis would not have been possible. I am indebted to the National Centre for Immunisation Research and Surveillance of Vaccine Preventable Diseases (NCIRS), particularly Margaret Burgess, for allowing me to undertake a PhD at NCIRS and for providing me with a scholarship. I am extremely grateful to my supervisor, Peter McIntyre, for his enthusiastic encouragement, support and ideas, of which he has more per second than I could ever hope for in a lifetime. Thanks also to Ross Lazarus, my co-supervisor, and to all the NCIRS staff, past and present, many of whom have become valued friends as well as colleagues and have been a tremendous support over the past three years.

Judy Simpson’s statistical advice and encouragement regarding the vaccine effectiveness study is most appreciated. Many thanks to Brynley Hull, who so cheerfully provided me with the ACIR data, also to Janaki Amin and Heather Gidding, who helped me extract the national hospitalisation and notification data.

I could not have survived without Stephen Lambert’s encouragement, practical advice and good humour, not to mention his valuable comments on all aspects of this thesis. I am very grateful to Ross Andrews for his thoughts and comments on parts of this thesis and to Heather Gidding for her many sensible comments. Thanks also to Margaret Burgess and Jill Forrest who read and commented upon the thesis and to all my friends and family. I am especially grateful to Fiona Turnbull for many things including sharing much of the driving from the inner west to Westmead.

Without having had Christine Roberts as a supervisor during my masters degree I would never have had the confidence to complete this PhD. I am very grateful for Christine’s continued support and encouragement and for reading and commenting on this thesis.

Finally, I could not have managed without Kevin Varvell, who has endured the bad as well as the good parts of my candidature with endless patience and support. We look forward to a thesis-free life together!
### Abbreviations used in this thesis

<table>
<thead>
<tr>
<th>Abbreviation</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>ABS</td>
<td>Australian Bureau of Statistics</td>
</tr>
<tr>
<td>ACIR</td>
<td>Australian Childhood Immunisation Register</td>
</tr>
<tr>
<td>ACT</td>
<td>Australian Capital Territory</td>
</tr>
<tr>
<td>AIHW</td>
<td>Australian Institute of Health and Welfare</td>
</tr>
<tr>
<td>ARU</td>
<td>attack rate in unvaccinated (cases)</td>
</tr>
<tr>
<td>ARV</td>
<td>attack rate in vaccinated (cases)</td>
</tr>
<tr>
<td>CDT</td>
<td>combined diphtheria-tetanus (vaccine)</td>
</tr>
<tr>
<td>CI</td>
<td>confidence interval</td>
</tr>
<tr>
<td>CSL</td>
<td>Commonwealth Serum Laboratories</td>
</tr>
<tr>
<td>CV</td>
<td>cases vaccinated</td>
</tr>
<tr>
<td>df</td>
<td>degrees of freedom</td>
</tr>
<tr>
<td>DTP</td>
<td>diphtheria-tetanus-pertussis (vaccine)</td>
</tr>
<tr>
<td>DTPa</td>
<td>diphtheria-tetanus-acellular pertussis (vaccine)</td>
</tr>
<tr>
<td>dTpa</td>
<td>diphtheria-tetanus-acellular pertussis (vaccine — the lower case letters indicate a reduced dose for adults compared with child formulations)</td>
</tr>
<tr>
<td>DTPw</td>
<td>diphtheria-tetanus-whole-cell pertussis (vaccine)</td>
</tr>
<tr>
<td>ELISA</td>
<td>enzyme-linked immunosorbent assay</td>
</tr>
<tr>
<td>GPII</td>
<td>General Practitioners Immunisation Incentives</td>
</tr>
<tr>
<td>HOIST</td>
<td>Health Outcomes and Information Statistical Toolkit</td>
</tr>
<tr>
<td>ICD</td>
<td>International Classification of Disease</td>
</tr>
<tr>
<td>ISCOS</td>
<td>Inpatient Statistics Collection Online System</td>
</tr>
<tr>
<td>LOS</td>
<td>length of stay</td>
</tr>
<tr>
<td>NCIRS</td>
<td>National Centre for Immunisation Research and Surveillance of Vaccine Preventable Diseases</td>
</tr>
<tr>
<td>NDD</td>
<td>Notifiable Diseases Database (NSW)</td>
</tr>
<tr>
<td>NHMRC</td>
<td>National Health and Medical Research Council</td>
</tr>
<tr>
<td>NNDSS</td>
<td>National Notifiable Diseases Surveillance System</td>
</tr>
<tr>
<td>NSW</td>
<td>New South Wales</td>
</tr>
<tr>
<td>PCR</td>
<td>polymerase chain reaction</td>
</tr>
<tr>
<td>PCV</td>
<td>proportion of cases vaccinated</td>
</tr>
<tr>
<td>PD</td>
<td>principal diagnosis</td>
</tr>
<tr>
<td>PPV</td>
<td>proportion of the population vaccinated</td>
</tr>
<tr>
<td>VE</td>
<td>vaccine effectiveness</td>
</tr>
<tr>
<td>VIVAS</td>
<td>Vaccine Information and Vaccine Administration Service</td>
</tr>
<tr>
<td>WHO</td>
<td>World Health Organization</td>
</tr>
</tbody>
</table>
Author’s contribution

I am solely responsible for the design, analysis and interpretation of all the studies presented in this thesis. The following information sources were used: ABS Causes of Death Collection, ACIR, AIHW, NNDSS, NDD and ISCOS. I had some assistance with data extraction: Heather Gidding extracted the national pertussis notifications from NNDSS, Janaki Amin extracted national pertussis hospitalisation data from the AIHW National Hospital Morbidity Database, Micheline Hanna extracted NSW hospitalisation data from ISCOS and Brynley Hull extracted the relevant vaccination data from the ACIR.
Table of Contents

ABSTRACT ......................................................................................................................................................... 1

ACKNOWLEDGMENTS ....................................................................................................................................... 4

ABBREVIATIONS USED IN THIS THESIS .................................................................................................... 5

AUTHOR’S CONTRIBUTION ............................................................................................................................. 6

TABLE OF CONTENTS ........................................................................................................................................ 7

LIST OF FIGURES .................................................................................................................................................. 9

LIST OF TABLES .................................................................................................................................................. 13

CHAPTER 1 INTRODUCTION ........................................................................................................................... 18

CHAPTER 2 PERTUSSIS IN AUSTRALIA: NOTIFICATIONS, HOSPITALISATIONS AND DEATHS ........................................................................................................................................ 32

CHAPTER 3 PERTUSSIS NOTIFICATIONS AND HOSPITALISATIONS IN NEW SOUTH WALES ........................................................................................................................................ 60

CHAPTER 4 THE AUSTRALIAN CHILDHOOD IMMUNISATION REGISTER AND PERTUSSIS VACCINATION ........................................................................................................................................ 92

IMMUNISATION REGISTERS AND DEVELOPMENT OF THE AUSTRALIAN CHILDHOOD IMMUNISATION REGISTER (ACIR) .................................................................................................................. 93

USING DATA FROM THE ACIR: PERTUSSIS VACCINATION IN AUSTRALIA ........................................... 99

USING DATA FROM THE ACIR: PERTUSSIS VACCINATION IN NEW SOUTH WALES ............................. 105

CHAPTER 5 OBSERVATIONAL METHODS IN EPIDEMIOLOGIC ASSESSMENT OF VACCINE EFFECTIVENESS ........................................................................................................................................ 119

CHAPTER 6 EFFECTIVENESS OF PERTUSSIS VACCINATION IN NEW SOUTH WALES

PART A: EFFECTIVENESS OF PERTUSSIS VACCINATION IN NSW CHILDREN, 1993 TO 1998 .............. 138

PART B: EFFECTIVENESS OF PERTUSSIS VACCINATION IN NSW CHILDREN, 1996 TO 1998 ............. 171

APPENDICES (SENSITIVITY ANALYSES OF VE ESTIMATES)

APPENDIX 6.1 HIGHER VALUES OF PPV ..................................................................................................... 183

APPENDIX 6.2 FOUR DOSES OF VACCINE REQUIRED ............................................................................. 188

APPENDIX 6.3 PARTIALLY VACCINATED CLASSIFIED AS UNVACCINATED ........................................... 193

APPENDIX 6.4 CASES ARE REQUIRED TO BE LABORATORY CONFIRMED ............................................. 200
CHAPTER 7  SUMMARY AND RECOMMENDATIONS.................................205

APPENDIX 1  STUDY PROPOSAL FOR A SURVEY OF COUGH AND PERTUSSIS
IMMUNISATION STATUS IN CHILDREN .................................................210

APPENDIX 2  EFFECTIVENESS OF PERTUSSIS VACCINATION IN NEW SOUTH WALES,
1996 TO 1998 ..................................................................................242
List of Figures

CHAPTER 1

FIGURE 1.1. ANNUAL ADJUSTED PERTUSSIS NOTIFICATION RATE, AUSTRALIA, 1917–2000 .........................................................22

FIGURE 1.2. DEATHS DUE TO PERTUSSIS, AUSTRALIA, 1907–1997 .........................23

FIGURE 1.3. PERTUSSIS CRUDE DEATH RATE, 1893–1996, AND NOTIFICATION RATE, 1917–1996, SOUTH AUSTRALIA ...23

CHAPTER 2


FIGURE 2.2. PERTUSSIS NOTIFICATIONS BY MONTH OF ONSET AND AGE GROUP, AUSTRALIA, 1993–2000 ........................................................................37

FIGURE 2.3. PERTUSSIS NOTIFICATION RATES BY FIVE YEAR AGE GROUP, AUSTRALIA, 1993–2000 ..................................................................................39

FIGURE 2.4. PERTUSSIS AGE-SPECIFIC NOTIFICATION RATES BY YEAR OF ONSET, AUSTRALIA, 1993–2000 ........................................................................40

FIGURE 2.5. PERTUSSIS HOSPITALISATION RATES BY AGE GROUP (ALL AGES) AND NOTIFICATION RATES IN INFANTS AGED LESS THAN 1 YEAR BY FINANCIAL YEAR OF ADMISSION/ONSET, AUSTRALIA, JULY 1993–JUNE 1998 ..........................................................42

FIGURE 2.6. PERTUSSIS NOTIFICATION RATES IN 5–14 YEAR OLDS BY AGE GROUP AND YEAR OF ONSET, AUSTRALIA, 1993–2000 ........................................43

FIGURE 2.7. PERTUSSIS NOTIFICATION RATES IN 5–11 YEAR OLDS, BY YEAR OF AGE AND YEAR OF ONSET, AUSTRALIA, 1993–2000 .........................44

FIGURE 2.8A. NOTIFICATION RATES BY STATE/TERRITORY AND YEAR OF ONSET, AUSTRALIA, 1993–2000, AUSTRALIAN CAPITAL TERRITORY, NEW SOUTH WALES, NORTHERN TERRITORY AND WESTERN AUSTRALIA ....46

FIGURE 2.8B. NOTIFICATION RATES BY STATE/TERRITORY AND YEAR OF ONSET, AUSTRALIA, 1993–2000, QUEENSLAND, SOUTH AUSTRALIA, TASMANIA AND VICTORIA .........................46
CHAPTER 3

FIGURE 3.1. PERTUSSIS NOTIFICATIONS BY MONTH OF ONSET, NSW, 1993–1999..............64

FIGURE 3.2. PERTUSSIS NOTIFICATION RATES BY AGE GROUP AND YEAR OF ONSET, NSW, 1993–1999 ...............................................................................................................65

FIGURE 3.3. PERTUSSIS NOTIFICATION RATES FOR 5–14 YEAR OLDS BY AGE GROUP AND YEAR OF ONSET, NSW, 1993–1999 ......................................................................66

FIGURE 3.4. PERTUSSIS NOTIFICATION RATES IN CHILDREN AGED UNDER 2 YEARS, BY MONTH OF AGE, NSW, 1993–1999 ........................................................71

FIGURE 3.5. PERTUSSIS NOTIFICATION RATES IN CHILDREN AGED UNDER 2 YEARS, BY AGE GROUP, NSW, 1993–1999 .................................................................71

FIGURE 3.6. PERTUSSIS NOTIFICATION RATES IN CHILDREN AGED UNDER 2 YEARS, BY AGE GROUP AND NUMBER OF DOSES OF PERTUSSIS VACCINE RECEIVED, NSW, 1993–1999 ..........................................................72

FIGURE 3.7. PERTUSSIS NOTIFICATIONS BY METHOD OF DIAGNOSIS, FOR ALL AGES, BY MONTH OF ONSET, NSW, 1993–1999 .................................................................73

FIGURE 3.8. PROPORTION OF PERTUSSIS NOTIFICATIONS BASED ON POSITIVE SEROLOGY, BY MONTH OF ONSET, NSW, 1993–1999 ................................................73

FIGURE 3.9. METHOD OF PERTUSSIS DIAGNOSIS BY MONTH OF ONSET, 0–4 YEAR OLDS, NSW, 1993–1999 .........................................................................................74

FIGURE 3.10. METHOD OF PERTUSSIS DIAGNOSIS BY MONTH OF ONSET, 5+ YEAR OLDS, NSW, 1993–1999 .........................................................................................74

FIGURE 3.11. METHOD OF PERTUSSIS DIAGNOSIS BY AGE GROUP, NSW, 1993–1999 ....74

FIGURE 3.12. METHOD OF PERTUSSIS DIAGNOSIS BY AGE GROUP IN CHILDREN AGED LESS THAN 2 YEARS, NSW, 1993–1999 .........................................................75

FIGURE 3.13. PERTUSSIS HOSPITALISATION RATES BY AGE GROUP AND FINANCIAL YEAR OF DISCHARGE, NSW, JULY 1993–JUNE 2000 ..................................................79

FIGURE 3.14. AVERAGE ANNUAL HOSPITALISATION RATES FOR PERTUSSIS IN CHILDREN AGED UNDER 2 YEARS, BY MONTH OF AGE, NSW, JULY 1993–JUNE 2000 .................................................................80
FIGURE 3.15. AVERAGE ANNUAL HOSPITALISATION RATES FOR PERTUSSIS IN CHILDREN AGED UNDER 2 YEARS, NSW, BY AGE GROUP, JULY 1993–JUNE 2000 ........................................................................................................... 80

CHAPTER 4

FIGURE 4.1. FLOW OF INFORMATION TO AND FROM THE ACIR .................................................. 97
FIGURE 4.2. DTP COVERAGE (DOSE 3) AT 12 MONTHS OF AGE, BY BIRTH COHORT, AUSTRALIA, MARCH 1997–DECEMBER 2000 ................................................................... 100
FIGURE 4.3. DTP COVERAGE (DOSE 4) AT 24 MONTHS OF AGE, BY BIRTH COHORT, AUSTRALIA, MARCH 1998–DECEMBER 2000 ........................................................... 101
FIGURE 4.4. NUMBER OF DOSES OF DTPw AND DTPa(DOSES 1-3) ADMINISTERED EACH MONTH, AUSTRALIA, JANUARY 1996–AUGUST 2000 ......................... 102
FIGURE 4.5. NUMBER OF DOSES OF DTPw AND DTPa(DOSES 4-5) ADMINISTERED EACH MONTH, AUSTRALIA, JANUARY 1996–AUGUST 2000 ......................... 103
FIGURE 4.6. NUMBER OF DOSES OF DTPw, DTPa AND CDT (DOSES 1–5) ADMINISTERED BY MONTH, AUSTRALIA, JANUARY 1996–AUGUST 2000 ......................... 104
FIGURE 4.7. NUMBER OF DOSES OF CDT (DOSES 1–5) ADMINISTERED BY MONTH, AUSTRALIA, JANUARY 1996–AUGUST 2000 .................................................................... 104
FIGURE 4.8. NUMBER OF DOSES OF DTPw AND DTPa(DOSES 1–3) ADMINISTERED BY MONTH, NSW, JANUARY 1996–AUGUST 2000 ........................................... 105
FIGURE 4.9. NUMBER OF DOSES OF DTPw AND DTPa(DOSES 4–5) ADMINISTERED BY MONTH, NSW, JANUARY 1996–AUGUST 2000 ........................................... 106
FIGURE 4.10. NUMBER OF DOSES OF DTPw, DTPa AND CDT (DOSES 1–5) ADMINISTERED BY MONTH, NSW, JANUARY 1996–AUGUST 2000 ......................... 106
FIGURE 4.11. NUMBER OF DOSES OF CDT (DOSES 1–5) ADMINISTERED BY MONTH, NSW, JANUARY 1996–AUGUST 2000 ............................................................. 107
CHAPTER 5

FIGURE 5.1. RELATIONSHIP BETWEEN THE PROPORTION OF CASES VACCINATED (PCV) AND THE PROPORTION OF POPULATION VACCINATED (PPV) FOR EIGHT VALUES OF VACCINE EFFECTIVENESS (VE) ..................................131

CHAPTER 6

FIGURE 6.1. HEALTH AREAS OF NSW .....................................................................................................140

FIGURE 6.2. ESTIMATED VE FOR EACH YEAR OF AGE, WITH AGE AS THE ONLY EXPLANATORY VARIABLE, 1993–1998........................................................................146
List of Tables

CHAPTER 2


TABLE 2.2. PERTUSSIS NOTIFICATIONS AND AVERAGE ANNUAL NOTIFICATION RATES, BY AGE GROUP, AUSTRALIA, 1993–2000 .............................................. 39

TABLE 2.3. PERTUSSIS HOSPITALISATIONS BY STATE/TERRITORY OF RESIDENCE AND FINANCIAL YEAR OF ADMISSION, AUSTRALIA, JULY 1993–JUNE 1998 ......................................................... 41

TABLE 2.4. PERTUSSIS HOSPITALISATION RATES PER 100 000 POPULATION BY STATE/TERRITORY OF RESIDENCE AND FINANCIAL YEAR OF ADMISSION, AUSTRALIA, JULY 1993–JUNE 1998 ......................................................... 41

TABLE 2.5. PERTUSSIS NOTIFICATIONS BY STATE/TERRITORY AND YEAR OF ONSET, AUSTRALIA, 1993–2000 ................................................................. 47

TABLE 2.6. PERTUSSIS NOTIFICATION RATES PER 100 000 POPULATION BY STATE/TERRITORY AND YEAR OF ONSET, AUSTRALIA, 1993–2000 .................. 48

CHAPTER 3

TABLE 3.1. PERTUSSIS NOTIFICATIONS AND AVERAGE ANNUAL NOTIFICATION RATES, BY AGE GROUP, NSW, 1993–1999 ...................................................... 65

TABLE 3.2. RELATIVE RISK OF PERTUSSIS NOTIFICATION BY AGE GROUP IN CHILDREN AGED UNDER 2 YEARS, NSW, 1993–1999 ........................................ 68

TABLE 3.3. THE NDD PERTUSSIS IDENTIFICATION FIELDS, NSW, 1993–1999 ............... 69

TABLE 3.4. METHOD OF PERTUSSIS DIAGNOSIS AFTER RE-CATEGORISING, NSW, 1993–1999 ................................................................. 70

TABLE 3.5. NUMBER AND PROPORTION OF PERTUSSIS NOTIFICATIONS BASED ON POSITIVE SEROLOGY, BY YEAR OF ONSET, NSW, 1993–1999 .................. 71

TABLE 3.6. PERTUSSIS NOTIFICATION RATE PER 100 000 POPULATION BY HEALTH AREA AND YEAR OF ONSET, NSW, 1993–1999 ...................................................... 76
| Table 3.7. | Number of notifications and average annual rates per 100,000 population for infants aged less than 12 months by health area and financial year of onset, NSW, July 1993–June 1999 | 77 |
| Table 3.8. | Method of pertussis diagnosis by place of residence (rural versus metropolitan) and age group, NSW, 1993–1999 | 78 |
| Table 3.9. | Pertussis hospitalisations by age group, NSW, July 1993–June 2000 | 78 |
| Table 3.10. | Relative risk of pertussis hospitalisation by age group in children aged under 2 years, NSW, July 1993–June 2000 | 81 |
| Table 3.11. | Pertussis hospitalisations and average annual rates per 100,000 population in infants aged less than 12 months by health area and financial year of separation, NSW, July 1993–June 1999 | 82 |

CHAPTER 4

| Table 4.1. | Immunisation coverage by month of age for children aged 6–24 months, NSW, 1999 | 110 |
| Table 4.2. | Immunisation coverage (4 doses) by month of age for children aged 15–24 months of age, NSW, 1999 | 111 |
| Table 4.3. | Immunisation coverage (3 doses) by health area for children aged 12 months, NSW, 1999 | 112 |
| Table 4.4. | Immunisation coverage by health area for children aged 24 months, NSW, 1999 | 114 |

CHAPTER 5

| Table 5.1. | Observational studies evaluating VE in Australia and New Zealand | 127 |

CHAPTER 6

| Table 6.1. | Number of notifications and average annual notification rates by health area and vaccination status in children aged 8 months to 13 years, NSW, 1993–1998 | 143 |
TABLE 6.2. VACCINATION STATUS OF NOTIFIED CASES AND AVERAGE ANNUAL NOTIFICATION RATES BY AGE GROUP, NSW, 1993–1998...................................144

TABLE 6.3. VACCINATION COVERAGE BY HEALTH AREA FOR CHILDREN AGED 12 MONTHS, NSW, 1993–1998.................................145

TABLE 6.4. INCREASED VACCINATION COVERAGE USED IN SENSITIVITY ANALYSIS BY HEALTH AREA FOR CHILDREN AGED 12 MONTHS, NSW, 1993-1998 ....145

TABLE 6.5. SUMMARY OF MODELS, 1993–1998.................................................................147

TABLE 6.6. NUMBER OF VACCINATED CASES (CV), TOTAL NUMBER OF CASES (N) AND VE ESTIMATES FOR CHILDREN AGED 8–23 MONTHS BY NSW HEALTH AREA, 1993 –1998 ..................................................................................................................148

TABLE 6.7. NUMBER OF VACCINATED CASES (CV), TOTAL NUMBER OF CASES (N) AND VE ESTIMATES FOR CHILDREN AGED 2–4 YEARS BY NSW HEALTH AREA, 1993 –1998 ..................................................................................................................149

TABLE 6.8. NUMBER OF VACCINATED CASES (CV), TOTAL NUMBER OF CASES (N) AND VE ESTIMATES FOR CHILDREN AGED 5–8 YEARS BY NSW HEALTH AREA, 1993 –1998 .........................................................................................150

TABLE 6.9. NUMBER OF VACCINATED CASES (CV), TOTAL NUMBER OF CASES (N) AND VE ESTIMATES FOR CHILDREN AGED 9–13 YEARS BY NSW HEALTH AREA, 1993 –1998 .........................................................................................151

TABLE 6.10. VE ESTIMATES BY AGE GROUP, ADJUSTED FOR YEAR AND NSW HEALTH AREA, 1993 –1998 .........................................................................................152

TABLE 6.11. NUMBER OF VACCINATED CASES (CV), TOTAL NUMBER OF CASES (N) AND VE ESTIMATES BY AGE AND NSW HEALTH AREA, ADJUSTED FOR YEAR, 1993–1998 ..............................................................153

TABLE 6.12. NUMBER OF VACCINATED CASES (CV), TOTAL NUMBER OF CASES (N) AND VE ESTIMATES BY AGE AND YEAR, ADJUSTED FOR NSW HEALTH AREA, 1993–1998 ..............................................................155

TABLE 6.13. NUMBER OF VACCINATED CASES (CV), TOTAL NUMBER OF CASES (N) AND VE ESTIMATES FOR CHILDREN AGED 8–23 MONTHS IN NSW METROPOLITAN AND RURAL AREAS BY YEAR, 1993–1998.......................157

TABLE 6.15. NUMBER OF VACCINATED CASES (CV), TOTAL NUMBER OF CASES (N) AND VE ESTIMATES FOR CHILDREN AGED 5–8 YEARS IN NSW METROPOLITAN AND RURAL AREAS BY YEAR, 1993–1998 .........................158

TABLE 6.16. NUMBER OF VACCINATED CASES (CV), TOTAL NUMBER OF CASES (N) AND VE ESTIMATES FOR CHILDREN AGED 9–13 YEARS IN NSW METROPOLITAN AND RURAL AREAS BY YEAR, 1993–1998 .........................158

TABLE 6.17. NUMBER OF VACCINATED CASES (CV), TOTAL NUMBER OF CASES (N) AND VE ESTIMATES BY AGE GROUP IN NSW METROPOLITAN AND RURAL AREAS, ADJUSTED FOR YEAR, 1993–1998 .........................159

TABLE 6.18. VE ESTIMATES BY AGE GROUP, ADJUSTED FOR YEAR AND NSW HEALTH AREA (PARTIALLY VACCINATED CLASSIFIED AS UNVACCINATED), 1993–1998 ........................................................................................................160

TABLE 6.19. NUMBER OF VACCINATED CASES (CV), TOTAL NUMBER OF CASES (N) AND VE ESTIMATES BY AGE AND NSW HEALTH AREA, ADJUSTED FOR YEAR, 1993–1998 ..............................................................161

TABLE 6.20. NUMBER OF VACCINATED CASES (CV), TOTAL NUMBER OF CASES (N) AND VE ESTIMATES BY AGE AND YEAR, ADJUSTED FOR NSW HEALTH AREA, 1993–1998 ..............................................................162


TABLE 6.22. POTENTIAL SOURCES OF BIAS AND THE LIKELY EFFECT ON VE ESTIMATES ...............................................................................................................................167

TABLE 6.23. SUMMARY OF MODELS ..........................................................................................................................172

TABLE 6.24. NUMBER OF VACCINATED CASES (CV), TOTAL NUMBER OF CASES (N) AND VE ESTIMATES FOR CHILDREN AGED 8–23 MONTHS BY HEALTH AREA, 1996–1998 ..........................................................173

TABLE 6.25. NUMBER OF VACCINATED CASES (CV), TOTAL NUMBER OF CASES (N) AND VE ESTIMATES FOR CHILDREN AGED 2–4 YEARS BY HEALTH AREA, 1996–1998 ..........................................................174
List of Tables

TABLE 6.26. NUMBER OF VACCINATED CASES (CV), TOTAL NUMBER OF CASES (N) AND VE ESTIMATES FOR CHILDREN AGED 5–8 YEARS BY HEALTH AREA, 1996–1998 .............................................................. 175

TABLE 6.27. NUMBER OF VACCINATED CASES (CV), TOTAL NUMBER OF CASES (N) AND VE ESTIMATES FOR CHILDREN AGED 9–13 YEARS BY HEALTH AREA, 1996–1998 .............................................................. 176

TABLE 6.28. AGE GROUP: TEST STATISTICS, NUMBER OF VACCINATED CASES (CV), TOTAL NUMBER OF CASES (N) AND VE ESTIMATES ........................................... 177

TABLE 6.29. NUMBER OF VACCINATED CASES, TOTAL NUMBER OF CASES AND VE ESTIMATES BY HEALTH AREA AND AGE, ADJUSTED FOR YEAR, 1996–1998 .......................................................... 178