ABSTRACT. Objective. Vaccination does not cause sudden infant death syndrome (SIDS). However, SIDS peaks at 2 months of age, when vaccination encounters are frequent. There are no published estimates using population data on age of death and immunization coverage to indicate to practitioners how often coincident vaccination may occur by chance. This study aimed to determine the probability that an Australian infant who has died of SIDS was vaccinated in the days before death.

Methods. An analytical study of population death data and immunization coverage was conducted for Australian children who were born between April 1, 2002, and March 31, 2003. Also evaluated were Australian children who were registered as dying of SIDS between 1997 and 2001. The main outcomes measured were distribution of SIDS deaths by age and distribution of immunization coverage by age.

Results. The probability of recent vaccination and SIDS coinciding varied by age and day of the week of death. The overall estimated probability of vaccination within the last 24 hours for a child who has died of SIDS in Australia is estimated as 1.3%. In the last 48 hours, it is 2.6%. With the average number of SIDS deaths for the period 1997–2001 equal to 130 cases per year, we estimated that a case of SIDS will occur when vaccination was given in the last 24 hours in 1.7 cases per year and within 48 hours in 3.5 cases.

Conclusions. Although coincident vaccination and SIDS should not be a frequent problem, it can be expected to occur at least annually in Australia by chance alone. The probabilities of vaccination by age estimated in this study can also be applied to estimate the probability of a vaccination encounter for children who have experienced any unusual medical condition or death, when these occurrences are known to be unrelated to vaccination. Pediatrics 2005;115:e643–e646. URL: www.pediatrics.org/cgi/doi/10.1542/peds.2004-2185; sudden infant death, immunization, vaccination, probability, Australia.

From the *National Centre for Immunisation Research and Surveillance of Vaccine Preventable Diseases, Children’s Hospital at Westmead and the University of Sydney, Sydney, New South Wales, Australia; and ‡New South Wales Department of Health, North Sydney, New South Wales, Australia.

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Address correspondence to Julia Brotherton, BMed, MPH, GradDipAppEpi, National Centre for Immunisation Research and Surveillance of Vaccine Preventable Diseases, Locked Bag 4001, Westmead, NSW 2145, Australia. E-mail: julia2@chw.edu.au

ABBREVIATIONS. ACIR, Australian Childhood Immunisation Register; SIDS, sudden infant death syndrome.

A stute practitioners, who recognize unusual syndromes or associations in their patients, have been responsible for identifying many potential new or significant public health problems (eg, congenital rubella,1 HIV/AIDS,2–4 community-wide outbreaks of food-borne diseases such as hemolytic uremic syndrome5), but it is often difficult to gauge how many cases, when an apparently common exposure seems associated with an outcome, should be cause for alarm or rather should be treated with calm reassurance. In relation to vaccination, a low threshold approach is frequently taken whereby practitioners are advised to notify any suspected adverse event, and these reports are analyzed at a population level.6,7

In relation to such concerns, a novel use of population immunization registers, such as the Australian Childhood Immunization Register (ACIR), is to calculate the probability of having a vaccination encounter (when ≥1 vaccines are given) by age for cohorts of children in the country covered by the register. The register takes into account both coverage and timeliness of immunization by recording details of each encounter for each child. The nearly complete census of the ACIR makes it attractive for such analysis.8 We believe that this information could be useful to health care providers who encounter children who develop rare diseases during peak vaccination times (in Australia at 2, 4, 6, and 12 months of age9) to reassure themselves and affected families of the high probability that a child of that age would have been recently vaccinated by chance alone. Note that this technique does not calculate the probability of experiencing that event in a child who has been vaccinated but rather the conditional probability, given that the event has happened, that the child was vaccinated recently.

Sudden infant death syndrome (SIDS) is defined as “the sudden unexpected death of an infant <1 year of age, with the onset of the fatal episode apparently occurring during sleep, that remains unexplained after a thorough investigation including performance of a complete autopsy and review of the circumstances of death and the clinical history.”10 In Australia, SIDS has been the major cause of death in the postnatal period over the last 3 decades. In 2000,
81 male and 48 female SIDS deaths were recorded, with rates of 63.2 and 39.5 per 100 000 live births, respectively. This represents a 62% decline in death rates since 1991, following the 1991 National SIDS Council of Australia public health education campaign “Reducing the Risks of Cot Death” that recommended placing infants on their back or side in such a way that they cannot roll onto their stomach to sleep.\textsuperscript{11} The possibility of a causal relationship between vaccination and SIDS was suggested by the peak of SIDS deaths at 2 months of age coinciding with the recommended age for vaccinations. Numerous studies have since concluded that there is no causal relationship between routine childhood vaccination (in particular with diphtheria-tetanus-pertussis vaccine) and the occurrence of SIDS.\textsuperscript{12–22} However, some infants who die of SIDS will have been recently vaccinated by chance alone. Roberts\textsuperscript{23} previously used basic probability calculations to attempt to determine the random expected coincidence of vaccination and SIDS in the United Kingdom. Whereas Roberts used wide age groupings (3–6 months) and approximate vaccination coverage estimates, the use of the ACIR and death records allows us to undertake probability estimates with greater accuracy.

We analyzed data from the ACIR to estimate the probability of a vaccination encounter by age (in weeks up to 17 weeks and by age in months up to 12 months) and used this information to establish the probability of an Australian child having been vaccinated within the last 24 or 48 hours by age group. The aim of this study was to calculate what the probability of vaccination is in Australian children by age group and to estimate how many of the children who die from SIDS in a year will have been recently vaccinated and thus how likely it is that a family with a SIDS death will face this situation in Australia each year.

**METHODS**

**Vaccination Encounters by Age**

We extracted data from the ACIR as at March 31, 2004, for the cohort of Australian children who were born between April 1, 2002, and March 31, 2003. This cohort consisted of 250 395 children. We calculated the percentage of children in the cohort who were vaccinated (ie, who had a vaccination encounter in which 1 or more vaccines were given) during each week of the first 17 weeks of life and during each month of life thereafter to the age of 12 months. We analyzed by week of age to 17 weeks to obtain more accurate probabilities at the peak incidence period for SIDS (2–3 months of age). The probability of vaccination for a child of that age on any given day in that week or month then was calculated by dividing the percentage by 100 to give the probability and then dividing this by either 7 or 30.44 to get the probability for 1 day. The probability of vaccination within 48 hours is the probability of vaccination on any given day multiplied by 2. These probabilities are also the probabilities that a child who died of SIDS at that age was vaccinated in the relevant time period, assuming that vaccination and SIDS are independent.

**Age Distribution of SIDS Deaths**

We obtained death data from the National Mortality Database for all children who were resident in Australia and registered with an underlying death as a result of SIDS (International Classification of Diseases, 10 Revision code R95) and with a date of death in 1997–2001 (n = 652). This time period was selected because it was the most recent period with sufficient cases and because the annual number of SIDS deaths had reached a relative plateau. We calculated the age at death from date of birth and date of death, or, when this was missing (19% of records, as Victoria and Tasmania did not report date of birth on most records), we used the age at death field in the National Mortality Database. We calculated the proportion of Australian SIDS deaths that occurred at each week of life up to 17 weeks and each month of life thereafter up to 12 months.

**Probability Calculations**

Using the law of total probability, we then estimated the probability of recent vaccination for all SIDS deaths in Australia. This can be expressed as $P(B) = P(A,B | A) + P(A)P(B | A) + \ldots + P(A_n)P(B | A_n)$, where $P(B)$ is the estimated probability of vaccination in a child who has died of SIDS in Australia, $P(A_n)$ is the probability of vaccination in Australian children of age $n$, and $P(B | A_n)$ is the probability that children who die of SIDS in Australia are age $n$. We then multiplied $P(B)$ by the number of SIDS deaths per year to estimate the annual number of SIDS deaths in Australia that will have recently been vaccinated.

**Adjustment for Day of Death**

We assumed in our primary analysis that vaccination encounters occur with equal probability on all days of the week in Australia. To adjust for day of the week, one can weight the final probability (7 multiplied by the proportion vaccinated on the day of the week before death multiplied by the overall estimated probability of vaccination in the last 24 hours).

**Study Approval**

Ethics approval was not required for this study. Analysis of data was undertaken within the confidentiality agreements maintained between both the National Centre for Immunisation Research and the Australian Institute of Health and Welfare and between the National Centre for Immunisation Research and the Australian Childhood Immunisation Register.
RESULTS

Table 1 gives the percentage of Australian children who were vaccinated by age (up to 12 months). This table provides the probability that a child of a given age was recently vaccinated (within 24 hours), which can be applied to any child, either healthy or who experiences an event known to be unrelated to vaccination (eg, SIDS) at that age. For example, if a child experienced an illness at the age of 8 weeks, then there is a 7% chance (or probability of 0.07) that the child would have been vaccinated in the preceding 24 hours.

The distribution of SIDS deaths by gender and age in months is given in Fig 1. The overall estimated probability of vaccination within the last 24 hours for a child who has died of SIDS in Australia is estimated as 1.3%. In the last 48 hours, it is 2.6%. With the average number of SIDS deaths for the period 1997–2001 equal to 130 cases per year, we estimated that a case of SIDS will occur when vaccination was given in the last 24 hours in 1.7 cases per year and within 48 hours in 3.5 cases. If we assume that the most recent year (2001) is more indicative of the future incidence of SIDS in Australia, with 86 cases, then we expect 1.1 and 2.3 cases per year, respectively.

Examination of the date of vaccination in this cohort indicated that most vaccinations are given on a Tuesday (21.5%) followed by Wednesday (21.0%), Thursday (19.8%), Monday (17.0%), Friday (16.4%), Saturday (3.5%), and Sunday (0.7%). Thus, for children who died of SIDS on a Wednesday in Australia, the overall probability of vaccination in the last 24 hours is estimated as 2.0%. The other corresponding overall probabilities of vaccination in the last 24 hours by day of death are as follows: Thursday, 2.0%; Friday, 1.9%; Tuesday, 1.6%; Saturday, 1.5%; Sunday, 0.3%; and Monday, 0.1%. Any association between day of the week and the incidence of SIDS remains controversial.24–29 In the Australian SIDS deaths data examined here, most deaths occurred on Saturdays (17.7%) and Fridays (17.4%), followed by Sunday (14.1%), Thursday (13.8%), Monday (13.2%), Tuesday (12.9%), and Wednesday (10.9%).

CONCLUSIONS

This study has demonstrated another useful application of the information collected by the ACIR. The main strength of the study is the comprehensive population coverage of the register. The main limitation of this analysis is the widely recognized problem with the classification of SIDS deaths.30,31 We also assumed in our analysis that there is no association between SIDS and vaccination, consistent with international findings. If in fact, as some authors suggest, children who die of SIDS are less likely to be vaccinated than average14,16,20 (perhaps as a result of a different socioeconomic profile or because they have a minor illness), then we will have overestimated the probability of recent vaccination. This may be the case in Australia, where recommended practice is to defer vaccination in children with acute febrile illnesses (temperature ≥38.5°C).9 Nonetheless, we believe that the information provided from this study is of relevance to public health professionals, pediatricians, and other providers. It indicates that although coincident vaccination should not be a frequent problem, it can be expected to occur at least annually in Australia by chance alone. The methods applied in this study could be

![Figure 1](https://example.com/figure1.png)

**Fig 1.** Australian SIDS deaths 1997–2001 according to gender and age in months. Source: Australian Institute of Health and Welfare Mortality Database.
used to provide similar estimates for other populations. For example, similar estimates for the American population could be obtained by using the National Immunization Survey32 or the databases of Medicaid programs33 or managed care organizations34 to determine the distribution of age for vaccination encounters and US death data on the distribution of age at death for American SIDS deaths.35 The probabilities of vaccination estimated in this study can also be applied to estimate the probability of a vaccination encounter for children who have experienced any unusual medical condition or death, when these occurrences are known to be unrelated to vaccination.

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