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Successful control of a school based measles outbreak by immunization

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SUMMARY

In an outbreak of measles in North Wales centred on a secondary school in 1991, 74 cases occurred over a period of 51 days. Before the outbreak started, 27% pupils did not have a history of measles or immunization and were considered susceptible. Active case finding and identification and vaccination of susceptible contacts commenced after the fourth generation of cases and further reduced the pool of susceptible schoolchildren from 17%, at the onset of the vaccination campaign, to 8%. A fifth generation of cases did not occur. Delays in diagnosis (mean 2·8 days) and notification (mean 6·1 days) hampered control. There was no evidence of primary vaccine failure (observed vaccine efficacy 97%). Sixty-nine (93%) cases were considered preventable. Reasons for the apparent success of the intervention are discussed.

INTRODUCTION

Localized outbreaks of measles in older children are an increasing problem [1–3] in the UK, and continue to pose problems in the USA despite high levels of vaccination coverage [4–7]. Since the introduction of measles vaccine in the UK in 1968 and measles, mumps, rubella (MMR) vaccination in 1988, the number of cases of measles reported annually has fallen from 80999 in 1986 [8] to 10264 in 1992 [1] but there has been a shift in the age distribution of notified cases. In 1992 15% of cases occurred in children aged 10–14 years compared with only 7% in 1986 [1, 8], a trend similar to that seen in the United States [9]. This has resulted in school outbreaks [1]. We report a large school-based outbreak of measles in North Wales in 1991 and the measures taken to control it.

The outbreak

In October 1991, 13 cases of measles were notified over a 10-day period by general practitioners (GPs) in a single valley in Gwynedd, North Wales, compared with 7 cases for the county in the first 9 months of the year. Twelve out of 13 cases occurred in children attending a single school (the index school). This school is the only secondary school in the valley and contained 723 pupils aged 10–16 years.

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There was also a primary school on the site, which along with 11 other primary schools in the valley act as feeder schools into the secondary school. Most pupils travel to school on school buses from outlying villages.

METHODS

A case was defined when one or both of the following requirements were met: (1) notification/diagnosis of measles by a doctor, (2) parental history of a generalized rash lasting 3 or more days with fever, and one of the following symptoms – cough, coryza or conjunctivitis.

Parental and general practitioner estimates of the date of onset of illness were compared for cases for which the date of onset was available from both sources. The date of onset from the general practitioner was obtained from notification forms and from parents by telephone. Parents were asked to recall the date their child became unwell and not the date the rash appeared. Children were deemed to be susceptible if there was no history of measles or of previous vaccination against measles.

The vaccination status of cases was checked against the partially computerized child health record system.

Case finding was undertaken by contacting local GPs and telephoning the parents of cases and asking about other cases in the family. The attendance register at the affected school was inspected and the parents of children absent for 3 or more days contacted. Cases of measles were reported subsequently in other schools in the valley and the exercise was extended to all 13 schools there.

School studies

A questionnaire was distributed to the parents of all children attending the 13 schools requesting information about a history of measles and vaccinations in their child. A random sample of 20 non-responders in the first school was subsequently contacted again to detemine whether there were any major differences between those who had returned the questionnaires and those who had not.

Case control study

A case control study was carried out in the index school to identify factors associated with measles transmission. This case control study was carried out to provide an estimate of vaccine efficacy and to find out if measles occurred more commonly in children who participated in group activities, or who used the school buses to get to and from school, or who had recently visited their general practitioner with a problem unrelated to measles.

Cases included all children from the index school meeting the case definition, and who had returned to school. Three controls per case were selected. Controls who had a previously parental reported history of measles were excluded from the analyses used to derive vaccine efficacy. Controls were seleced by taking every fourth child from the school register which was organized alphabetically by class. Information was collected on age, sex, school form, vaccination against measles or MMR, usual transport to school, and whether the child currently participated in

variety of group activities. Vaccination histories were compared with the child health records.

Vaccine efficacy

Vaccine efficacy was estimated using the parameters set by the World Health Organization for the field evaluation of vaccine efficacy [10]. In the cohort study of children attending the index school vaccine efficacy was calculated using the following formula: $VE = (1 - \text{relative risk}) \times 100$, where the relative risk is the ratio of attack rates in the vaccinated and unvaccinated groups.

In the case control study the odds ratio was substituted for the relative risk and separate analyses were carried out using all the controls, and only those with no previous history of measles.

Laboratory tests

Blood samples were taken from 19 notified and 11 non-notified cases of measles and sent to the PHLS Virus Reference Laboratory at Colindale for examination for measles specific IgM [11].

Data were analysed using Epi-Info [12]. The χ^2 and Mantel Haenszel stratified χ^2 tests were used to compare proportions, the Wilcoxon rank sum test for ranked data, and the Wilcoxon signed rank test for paired data when subtracting dates. Ninety-five percent confidence intervals were calculated for vaccine efficacy estimates using Confidence Interval Analysis [13].

Control measures

General practitioners were advised to offer normal human immunoglobulin to infant household contacts between the ages of 6 and 12 months, followed by MMR vaccine at the usual age. MMR vaccine was advised for all unvaccinated children over the age of 1 year. Special vaccination clinics were provided in the schools. Unvaccinated pre-school children were identified from the area child health records and vaccination was recommended by health visitors.

RESULTS

Seventy-four cases were identified, of which 48 (65%) were notified. The date of onset of cases was 15 September to 4 November (Fig. 1), a period of 51 days. As measles has an incubation period of 10–14 days, four generations of cases would have occurred during this period. The age distribution is shown in Figure 2. Of the 74 cases, 45 occurred in children attending the index school, 14 in 5 primary schools in the same valley. The remainder were pre-school age (4 cases), privately educated by a governess (2 cases), attending school outside the valley (4 cases), older siblings who had left school (5 cases). Of these 15 cases, 2 occurred in children too young to be vaccinated and 3 cases occurred in children with documented previous vaccination. Thus 69 (93%) cases were preventable.

Only 65% of cases were notified. The mean delay between disease onset as recalled by a parent and the arrival of a statutory notification at the Health Authority was 10·9 days (S.D. 4·7 days). The mean delay between the GP attending a case and notification was 6·1 days (S.D. 3·3). The parental estimate of the date

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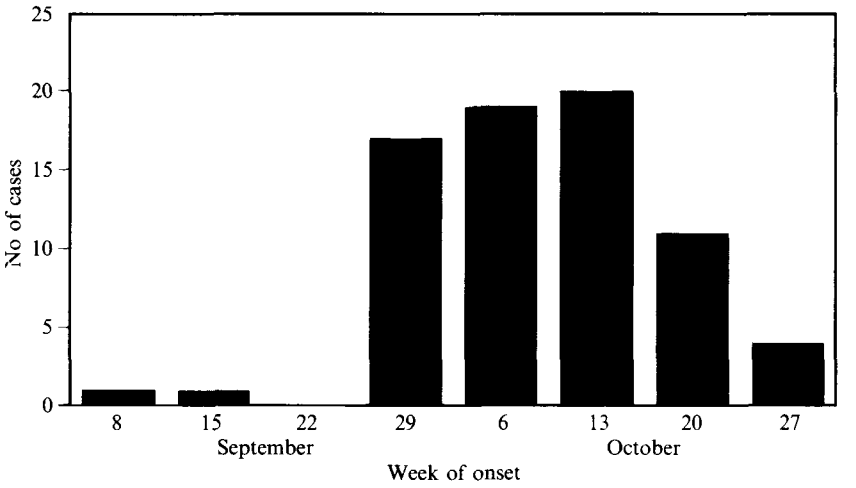

Fig. 1. North Wales measles outbreak: epidemic curve.

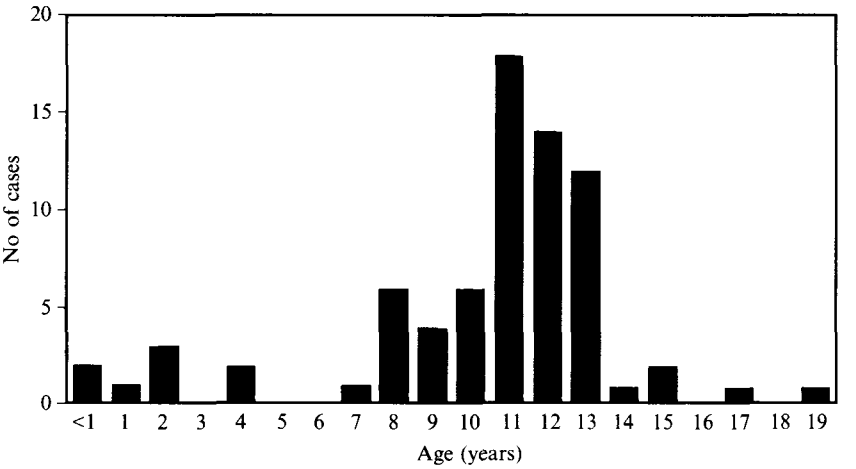

Fig. 2. North Wales measles outbreak: ages of cases.

of onset was, on average 2·8 days earlier than that of the general practitioner ($P < 0{\cdot}05$).

To determine whether immunity may be confounding these associations, the analysis was re-run to include only those controls with no history of measles or vaccination. None of the remaining controls played netball or used the school bus yielding odds ratios of infinity, although the smaller sample sizes meant the associations were no longer statistically significant ($P = 0{\cdot}15$).

School studies

Of 1408 questionnaires 1174 (83%) were returned (Table 1). Twenty-seven percent of respondents had a history of measles and 61% of previous vaccination. Allowing for the overlap between the two groups, 79% of children were considered not to be susceptible. Of the 296 (21%) schoolchildren in the neighbourhood who were considered to be susceptible 59 became cases before the onset of the

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Table 1. *Susceptibility to measles in affected and neighbouring North Wales schools at the time of outbreak in* 1991

School	No. pupils	No. (%) susceptible		
		Before outbreak	At onset of vaccination campaign	After outbreak and campaign
Index	723	195 (27)	150 (21)	60 (8·5)
Other (n = 13)	685	101 (15)	87 (13)	47 (7)
All	1408	296 (21)	237 (17)	107 (8)

Table 2. *Results of the case control study*

Exposure	Cases		Controls		Odds ratio	P value
	Exposed	Not exposed	Exposed	Not exposed		
Female sex	12	20	42	47	0·67	0·34
School bus	5	16	1	63	19·70	< 0·001
School musical	8	23	19	67	1·23	0·67
School choir	1	27	3	81	1·00	1·00
Rugby (males)	2	17	9	35	0·46	0·34
Soccer (males)	1	16	6	40	0·42	0·42
Netball (females)	3	8	2	38	7·13	0·03
GP attendance	4	23	5	72	2·50	0·18
Previous vaccination						
(History measles included)	1	31	43	46	0·03	< 0·001
(History measles excluded)	1	31	35	12	0·01	< 0·001

vaccination campaign, an attack rate of 20%. In the index school, 27% of children had neither a history of vaccination nor clinical measles and were considered susceptible. This latter rate compared with a rate of 30% in the random sample of 20 non-responders in the index school. The level of susceptibility was higher (31%) among pupils of the 6 schools where cases occurred than in the 8 schools without cases (8%) ($P < 0·05$).

Four generations of cases in the schoolchildren reduced the proportion susceptible to 17%. The vaccination campaign commenced 2 days after the onset of the last cases and 303 schoolchildren were vaccinated. This further reduced the proportion susceptible to 8% overall; an unknown number of vaccinations were also carried out by general practitioners.

Case control study

Thirty-two cases and 89 controls participated in the case control study. In this study (Table 2) children who travelled to school on the bus from one local village, and girls who played netball, had significantly elevated risk of developing measles. Consulting a GP with anything other than measles was not associated with subsequent development of measles. Child health records were available for 109 (90%) participants in the case control study. Histories and records matched in 101 cases, in 4 cases the history was unknown, and in a further 4 cases parents gave a history of vaccination which was not confirmed by the records. There were no cases with documented evidence of vaccination and a negative parental history.

Vaccine efficacy

In this study two estimates of vaccine efficacy were derived. In the study based on the cohort of 723 children in the index school, 338 children had no history of measles prior to this outbreak of whom 208 were vaccinated. Two cases of measles occurred among the vaccinated children compared with 43 cases among 130 unvaccinated children, yielding a vaccine efficacy estimate of 97·1% (95% CI: 90–100%). The corresponding estimate from the case-control study in the same school yielded a vaccine efficacy estimate of 99·3% (95% CI: 90–100%).

Laboratory tests

All serum samples from 11 non-notified cases and from 18 of 19 notified cases contained measles specific IgM.

DISCUSSION

Can school-based outbreaks of measles be controlled by immunizing susceptible contacts? On this occasion there was evidence of success. No further cases occurred after a vaccination campaign which reduced the pool of susceptibles to 8% (from 17% overall and 21% in the index school). This estimate of 8% is a maximum since it does not allow for an unknown number of vaccinations performed by GPs.

Thus it is not surprising that the outbreak stopped when the percentage of immune children exceeded 92% particularly since lower percentages of immune children may suffice when individuals do not mix at random but preferentially within their own age groups. Anderson and May have estimated that a 94–96% rate of immunity would eliminate measles [14]. It may be that in sparsely populated rural areas with fewer person-to-person contacts, measles transmission can be halted at slightly lower rates of immunity; vaccinations performed by general practitioners would also raise immunity levels closer to those predicted necessary by Anderson and May. Thus, although cases had occurred over a period of 8 weeks which must have spanned at least four generations of cases, the campaign probably prevented a fifth generation. Following the outbreak, over 800 presumed susceptible schoolchildren in the north-eastern part of Gwynedd were subsequently identified and vaccinated. No further cases of measles have occurred in this group, but a further school-based outbreak of 12 cases occurred in May and June 1992 in the western part of the county where the vaccination policy had not been applied.

It could be argued that a definition of susceptibility based on parental history is likely to be flawed due to poor recall and that the percentage of 'immunes' at the end of the outbreak may have been lower than 8%. However, comparison of vaccination history by parental recall with child health records revealed a high degree of correlation with no cases of documented vaccination occurring in those with a negative history of vaccination. The small number of positive vaccination histories unconfirmed by records may have been due to a failure in documentation. The fact that a previous history of measles was given for only 1 of 32 cases as compared with 43 of 86 controls also suggests that parental recall of measles is accurate.

If the control policy did work in this outbreak it is the only success out of three reported attempts in the United Kingdom. In 1985, in an outbreak of measles in a nursery and infants school in England, vaccination was commenced 7 weeks after the first case; however, only 4 children remained susceptible, of which only 1 accepted vaccination [15]. In 1988, in the Rhondda Valley in Wales, an unsuccessful attempt was made to halt an outbreak of measles by vaccination, with 676 cases occurring [16]. In Colchester, England, a vaccination campaign which took place 7 months after an outbreak has been claimed to have prevented subsequent outbreaks [17].

A crucial difference between this and previous attempts to halt outbreaks by vaccination in the UK is that the proportion of children receiving primary vaccination has increased from approximately 60% of 1-year-olds in 1979–83 to 93% by November 1990 [1]. This reduction in the proportion of susceptibles should result in the slowing of onward transmission of infection, and also make efforts to vaccinate a smaller percentage of non-immune individuals logistically possible, as in this outbreak.

However, it should be noted that school-associated outbreaks have occurred in the USA despite vaccine coverage in excess of 98% (4–7). In outbreaks occurring between 1985 and 1986, 60% of cases were due to vaccine failure, with vaccination prior to 12 or 15 months of age and vaccinations before 1979 (when the vaccine was less heat stable), being identified as risk factors [4, 7, 9]. There was, by contrast, no evidence of vaccine failure in our outbreak. Vaccine efficacy was estimated separately at 99·3% and 97·1%. It should be recalled however, that 27% of children had a history of measles in their lifetime, suggesting that vaccine induced immunity would have been considerably boosted by the circulation of wild virus. This may explain why control of the outbreak could be achieved by vaccinating only previously unvaccinated children rather than, as recommended by the US Immunization Practices Advisory Committee in 1989, also re-vaccinating those who either had been vaccinated before 1980 or who had received their primary vaccination at less than 15 months of age.

A greater segregation of different age groups may also have played a part in determining the course of this outbreak compared with other published outbreaks in which events encouraging mixing between age children are believed to have facilitated the spread of measles. Such extra-curricular events including school dances are referred to in an outbreak in Texas [4]. School buses were identified as a risk factor on the basis of the dates of onset of cases in an outbreak in upstate New York [18]. In this outbreak two factors which led to mixing between different age-group, membership of the netball team and using one of the school buses, were identified as risk factors. This suggests that curtailing activities during a measles outbreak which involve mixing of children of different ages may be worth evaluating as a control measure. If stopping activities is not practicable then susceptible children who take part in them may need to be considered as priorities for immunization.

Experience in this outbreak suggests that control of outbreaks by vaccinating previously unvaccinated children could become an important component of a comprehensive public health strategy to expedite the eradication of measles, notwithstanding the time and effort involved and the delays (6·1 days) and

shortfalls (35%) in notification which hampered control. Offering MMR to all first year secondary school children in place of rubella currently only offered to girls, as suggested by many, would help reduce, but not eliminate, outbreaks of measles [2, 3, 19]. Offering MMR at this age would not have prevented the 14 cases occurring in primary school children in this outbreak which supports the contention of those who believe that giving vaccine at age 11 years is too late to prevent disease in those who had not been vaccinated at age 1 year [20]. Finally, the time taken to institute immunization in response to outbreaks could be reduced if a convenient register of susceptibles were drawn up for each school in advance of any specific problem, using methods akin to those used in this outbreak. This would have the added benefit of allowing the true extent of the problem of susceptibility among schoolchildren.

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