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A STUDY OF INTRAFAMILIAL TRANSMISSION OF SMALLPOX[a]

by

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An epidemiologic study was conducted among the 464 family contacts of the first cases in 47 smallpox outbreaks in rural West Pakistan during the period 1968-70. Secondary attack rates were 70.3 per cent. in unvaccinated and 4.8 per cent. in previously vaccinated contacts, with an overall rate of 19.6 per cent. Variations in attack rates were significantly associated with differences in pre-exposure vaccination status of the contact, in exposure patterns and in age, vaccination status, and severity of illness of the index case. Previously vaccinated secondary cases experienced reduced mortality and morbidity. Results indicate that under the conditions of intimate exposure of a village compound, the majority of contacts becomes infected, and that the development of overt disease in previously vaccinated contacts depends both on the level of immunity of the contact and on the intensity of the virus challenge.

Keywords: communicable diseases; epidemiology; immunity; smallpox; vaccination; virus diseases.

The immune status of an individual is undoubtedly the major determinant of his susceptibility to smallpox. However, in every large outbreak, some exposed unvaccinated subjects escape infection, while some vaccinated persons develop disease. Obviously the protection afforded by vaccination is variable. Furthermore, such factors as intensity of exposure and severity of illness of the source case also appear to influence transmission, although the relative importance of these factors is unclear.

It is well known that intimate exposure is required for the effective propagation of smallpox, a natural consequence of the fact that infection occurs principally by person-to-person droplet spread. Thus studies of familial contacts of smallpox cases provide the most appropriate means of investigating specific factors of transmission, since such contacts constitute a well-defined denominator population of which all members are truly at risk.

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Studies of intrafamilial transmission of smallpox have recently been conducted in India,[1] East Pakistan,[2] West Pakistan[3] and Brazil.[4] This paper reports a similar study in rural West Pakistan over a two-year period.

METHODS

The study was conducted in villages of six rural districts in Punjab Province of West Pakistan in 1968-70. Study villages ranged in size from a few houses to populations of approximately 5000. Surveys conducted in 1967 in one of the six districts showed the overall vaccination rate to be 83 per cent., while 88 per cent. either had vaccination scars or a past history of smallpox. Approximately two-thirds of the unvaccinated susceptibles were infants or children of less than five years of age.[5]

The typical Punjabi village dwelling is a mud-brick house consisting of one or two small rooms without windows. Two or more such houses, usually occupied by relatives, may be grouped around a common walled courtyard to form a compound. When a case of smallpox occurs, no isolation measures are taken. During the most acute phase of illness, the case may be kept indoors, but after a few days his bed often is brought out into the courtyard in the daytime.

When an outbreak is reported to the authorities, a team of vaccinators is sent to the affected village for vaccination and revaccination of the inhabitants, with particular attention to household and compound contacts of cases. However, during the period of this study, it was unusual for countermeasures to have been initiated until after second-generation cases had appeared.

Plan of study

The present study was limited to the compounds of cases who were determined to have been the first cases in outbreaks, in order to ensure that contacts under investigation had been exposed to a single source of infection. Only those compounds were included in which the onset of illness of the index case had occurred not more than 100 days prior to the first visit of the investigators, this time limitation being imposed for the sake of historical accuracy.

On the initial visit to a village which had experienced an outbreak, the first case of the outbreak was identified. Each case was diagnosed by a physician on the basis of clinical and epidemiologic criteria, and when lesions were still present, the diagnosis was subsequently confirmed by isolation of virus on the chorioallantois of embryonated eggs. If the compound was determined to be eligible for inclusion in the study, all household and compound contacts of the index case were registered and examined for vaccination scars. At the same time, a questionnaire was completed which included demographic data, history of vaccination and of previous smallpox and a record of the contact's exposure to the index case. Subsequent visits were made to examine contacts who had been absent at the time of the initial visit, and a final visit was made not less than six weeks after the onset of illness of the index case, for the purpose of recording secondary cases.

Definitions

An index case was defined as the first case of smallpox in a compound.

A contact was any person habitually sleeping in the same house or compound as the index case, but excluding persons with a history of previous smallpox. Exposure was classified as constant for persons sleeping in the same house or compound and remaining there during the day, and as daily for persons who left the house during the day.

The first day of rash of the index case, generally considered to mark the approximate onset of infectivity (six to eight), was regarded as the first day of exposure of a contact.

The exposure-illness interval was defined as the interval between first exposure and onset of fever in a secondary case. In many instances, infection probably did not occur on the first day of exposure. Thus this interval was presumably often longer than the incubation period, and may be considered to represent a maximum incubation period.

The usual incubation period of smallpox is 12 to 13 days, with a range from nine to 21 days.[6,7] Accordingly, any case in which onset of fever occurred less than nine days after onset of rash of the index case was regarded as a co-primary case. A case in which onset of fever occurred nine days or more after first exposure was considered a secondary case. A second-generation case was arbitrarily defined as one whose exposure-illness interval was between nine and 21 days, and a third-generation or later case as one whose exposure-illness interval was 22 to 42 days. Four persons were also considered to be secondary cases for whom the reported exposure-illness interval was shorter than nine days but for whom there was unequivocal epidemiologic evidence that the index case had been the only possible source of infection.

Contacts were classified as vaccinated or unvaccinated on the basis of presence or absence of vaccination scars. Fifteen secondary cases died before examination by the investigators, and the scar status of six other secondary cases could not be determined because of confluent smallpox lesions. Since previous studies have shown that fatalities in vaccinated individuals are extremely rare[6,9-11] and that the disease in vaccinated persons usually is characterized by relatively sparse and superficial lesions,[4,9,11,12] we have established for the analysis a single category of unvaccinated and probably unvaccinated. This category included all contacts without scars plus these 21 individuals of undetermined vaccination status. Although some erroneous classification is possible, this probably represents a much more accurate estimate of the number of unvaccinated contacts than does the count of persons without scars alone.

Smallpox cases were classified by the lesion density system of Mack and associates.[11] Class 1 comprises persons with confluence of at least 25 per cent. of lesions on face and arms; Class 2, confluence on face or arms; Class 3, no confluence but more than 100 lesions on the forearm; Class 4, fewer than 100 lesions but 10 or more lesions/100 cm^2 on the forearm; and Class 5, fewer than 10 lesions/100 cm^2 on the forearm.

Statistical analysis

The chi-square test was used in the determination of significance of differences in the composition of study subgroups and in attack rates of the various subgroups. However, whenever one of the expected frequencies was less than five, the Fischer exact probability test was employed. A p value of less than .05 was considered significant.

RESULTS

Compounds of the first cases of 47 outbreaks of smallpox were investigated, with a total of 464 contacts, of whom 258 were household contacts and 206 compound contacts of the index case. Among these contacts, there were 91 secondary cases of smallpox, representing an overall attack rate of 19.6 per cent. Seventy of these were by our definition second-generation cases, while 21 were of the third generation or later (Figure 1).

The 91 secondary cases occurred in 26 of the 47 compounds studied. Eight compounds had one secondary case each, nine had two cases and five had three cases. In the remaining four compounds there were six, 11, 14 and 19 secondary cases, respectively.

Contact factors

The effect of variations in the immune status of exposed contacts is demonstrated in Table 1. The secondary attack rate was 76.8 per cent. in unvaccinated or probably unvaccinated contacts, or 70.3 per cent. in known unvaccinated contacts, but only 4.8 per cent. in the previously vaccinated. Furthermore, the attack rate was significantly lower in contacts with a history of revaccination than in those who reported primary vaccination only ($p = .034$). If one considers only the 70 second-generation cases, i.e. those whose onset of illness occurred within 21 days of first exposure, attack rates were 57.9 per cent. (55/95) in unvaccinated or probably unvaccinated contacts, but only 4.2 per cent. (14/331) in contacts previously vaccinated.

A clear association of smallpox incidence with age was demonstrated, with high attack rates appearing in children under 10 years of age but declining rapidly thereafter (Table 2). However, it is apparent from Table 3 that this age variation is merely a function of immune status. Within each separate vaccination category, attack rates were of approximately the same magnitude in all age-groups except for infants and unvaccinated adults. Infants represented a clear exception, with attack rates distinctly lower than those of older children of similar vaccination status. In the case of unvaccinated adults, no conclusions can be drawn, because of the small number of such contacts and the greater possibility of errors of history.

No apparent effect of sex on attack rates was noted (Table 2). Girls showed a slightly higher rate in the 10-14 year age-group and a lower rate in the 15-19 year age-group, but these differences also reflect slight differences in vaccination status between males and females in the two age-groups.

Index case factors

Associations of secondary attack rates with certain characteristics of the source case were also apparent (Table 4).

Children between the ages of five and 14 proved to be the most effective transmittors of disease to their contacts. Attack rates among contacts of cases in these age-groups were significantly higher than among contacts of cases in the infant and toddler age-groups ($p < .001$), a difference possibly related to the greater mobility of the older children.

Secondary attack rates were also clearly associated with variations in vaccination status of the index case. Persons unvaccinated or probably unvaccinated prior to illness proved to be more infective, causing disease in 21.3 per cent. of their contacts, as compared to only 5.8 per cent. of contacts of cases previously vaccinated, a significant difference ($p = .008$). Similarly, greater severity of illness resulted in higher secondary attack rates. Contacts of index cases of the confluent and semi-confluent lesion density Classes 1 and 2 had a significantly higher attack rate than contacts of index cases of lesion density Classes 3, 4 and 5 ($p = .017$). It seems likely that the difference in infectivity between previously unvaccinated and vaccinated cases also reflects a difference in severity of illness. On the other hand, attack rates were essentially the same among contacts of cases who died and contacts of those who survived.

We have also examined the relationship of index case characteristics to attack rates in vaccinated contacts alone, since these represent relatively immune persons in whom slight differences in the infective challenge might be decisive. Attack rates were again significantly higher in the contacts of older children than in the contacts of children under five ($p = .008$). Unvaccinated and probably unvaccinated index cases transmitted disease to more of their vaccinated contacts (5.5 per cent.) than did vaccinated index cases (2.1 per cent.), although the difference in this instance was not statistically significant. However, greater severity of illness of the index case was again clearly associated with higher secondary attack

rates. Vaccinated contacts of index cases of lesion density Classes 1 and 2 had a significantly higher attack rate than contacts of index cases of Classes 3, 4 and 5 ($p = .002$). In fact, smallpox was transmitted to vaccinated contacts only by cases in Classes 1 to 3 and by those who died before examination, while no secondary cases occurred among vaccinated contacts of cases in Classes 4 or 5.

Exposure factors

One would expect to find little variation in exposure potential within a compound. There were in fact only minor differences in overall attack rates among household and compound contacts of index cases, and among contacts in large and small compounds (Table 5). However, even within the limits of the compound, the effect of certain differences in exposure patterns was clearly detectable. Contacts who had "constant" exposure, e.g. mothers, other female relatives and young children, showed significantly higher attack rates than persons whose exposure was only "daily" (p .001). Contacts whose duration of exposure was seven days or more showed significantly higher attack rates than persons exposed for less than seven days ($p = .036$).

Modifying effects of vaccination

In addition to its role in reducing the incidence of disease in contacts, the effect of vaccination was apparent in modifying the course and outcome of illness.

It can be seen in Figure 1 that in the second-generation of cases, i.e. those occurring within 21 days of first exposure, cases in previously vaccinated persons tended to occur slightly later than those in the unvaccinated. In fact, the mean exposure-illness interval was 13 days in unvaccinated second-generation cases and 16 days in vaccinated second-generation cases, a significant difference by the t test (p .05). Furthermore, a significantly higher proportion of unvaccinated second-generation cases occurred within 14 days of first exposure ($p = .016$), suggesting early infection. This difference may indicate that a larger virus challenge is needed to produce illness in individuals who are partially immune, and thus that these persons sometimes may require exposure on several occasions before such a dosage is received.

The effect of vaccination in reducing severity of illness is demonstrated in Table 6. The proportion of vaccinated cases in lesion density Classes 1 to 3 was significantly lower than those of known unvaccinated cases ($p = .036$) or of vaccinated and probably unvaccinated cases ($p = .017$). None of the vaccinated cases was classified as confluent or semi-confluent (Classes 1 and 2).

Case-fatality ratios are presented in Table 7. No variation by age was apparent. However, the case-fatality ratio among persons unvaccinated or probably unvaccinated was 20.5 per cent., while no deaths occurred among previously vaccinated cases.

Post-exposure vaccination

Fifty-two of the 464 contacts in the study were vaccinated or revaccinated by the local public health authorities within seven days after exposure (not including four contacts who received primary vaccination without take). Only one secondary case occurred among these 52 contacts, compared to 90 cases among 412 contacts not vaccinated after exposure or vaccinated more than one week after first exposure (Table 8). The numbers of contacts in the separate subgroups of pre-exposure vaccination status are too small for statistical analysis. However, in all subgroups, there was a lower attack rate in those vaccinated or revaccinated after exposure.

Unvaccinated contacts who escaped

The overall attack rate among unvaccinated and probably unvaccinated contacts was 76.8 per cent. Thus almost one-fourth of the apparently fully susceptible contacts (22/95) did not develop smallpox, despite the close and continued exposure characteristic of a village compound. While this tends to support the hypothesis of the relatively low infectivity of smallpox, individual contacts involved were carefully examined for possible alternative explanations.

Of the 22 contacts, two were given successful primary vaccination within one week of first exposure, which may have conferred adequate protection. Eleven of the contacts (including one of the two vaccinated after exposure) were infants, ranging in age from one week to 10 months at the time of first exposure, at least some of whom may still have been passively protected by maternal antibody. Three other contacts were adults. One of these was a 50-year-old man who had no scar and gave a negative history of vaccination; however, since it is unlikely that a susceptible individual in a heavily endemic area could survive to that age without infection, it seems more probable that his history was erroneous, and that he had had a mild and forgotten or misdiagnosed case of smallpox as a child or had been successfully vaccinated without production of a detectable scar. The same explanation might possibly apply to the two other adults, women of 21 and 28 years, both of whom gave a history of vaccination but had no scars.

For the remaining seven contacts, there appears to be no reasonable explanation for their escape, other than lack of effective exposure. These seven consisted of four boys of one year of age, two girls of age three and one girl of age six; four of them had a history of vaccination, but none had scars. The fact that most were barely beyond infancy, rather than older and more mobile children, tends to support the hypothesis of insufficient exposure.

One must also consider the 21 third-generation cases in the study. Nineteen of whom were unvaccinated or probably unvaccinated. Thirteen of the 19 had no scar, three died before examination, two were of uncertain scar status due to confluent disease and one was not examined but had a negative history of vaccination. Why did these apparently susceptible contacts escape the first wave of infection?

Three of the 19 were infants, of age two, three and four months, who may well have been protected on first exposure by waning maternal antibody. Of the remaining 16 contacts, only two lived in the same house as their index cases; the other 14 were compound contacts and not immediate family members. Thus their temporary escape can probably best be explained on the basis of initially insufficient exposure. Although overall attack rates among household and compound contacts in this study were very similar, other studies in the same area have shown significantly higher attack rates in household as compared to compound contacts.[13,14]

Vaccinated contacts who developed smallpox

It is also of interest to examine reasons why a few vaccinated individuals nevertheless develop smallpox. In the present study, there were 16 cases among persons with pre-exposure vaccination confirmed by detectable scars. It is apparent that all these cases had insufficient immunity to resist the infective challenge. However, it is also clear that the cases cannot be explained simply by the gradual, long-term waning of immunity. Six of the 16 were adults, of whom the three oldest were of age 45, but 10 were children, ranging in age from one to 12 years. Five of the six adults gave a history of primary vaccination only, and one reported revaccination; six of the 10 children had had primary vaccination only and four had been revaccinated.

There were no obvious differences between these 16 individuals and other contacts in residence status, relationship to the index case and exposure patterns. However, as noted previously, the index cases by whom these contacts were infected showed more than average severity of illness, which may in turn have resulted in greater infectivity. All but one of the index cases of these contacts were unvaccinated or probably unvaccinated, and all were of lesion density Classes 1 to 3 or died before examination.

DISCUSSION

There has been considerable variation in attack rates reported in studies of family contacts, despite the general similarity of study design. Studies by Rao and associates in Madras,[1] Thomas et al. in rural East Pakistan[2] and Mack et al. in rural West Pakistan[3] reported attack rates of 37, 41 and 88 per cent., respectively, in unvaccinated contacts, compared to 70.3 per cent. in the present study. The corresponding attack rates in vaccinated contacts were 1.3, 7.9 and 7.2 per cent. and 4.8 per cent. in the present study.

Many factors may contribute to such differences. One must consider the possibility of virus strain variations, climatic differences, the overall immune status of the study populations, types of housing and patterns of social intercourse that affect exposure, and whether or not isolation of contacts and/or post-exposure vaccination were carried out. Finally, there may be differences, not always apparent in the reports, in the definition of susceptibles and in the handling of those persons whose vaccination status can for various reasons not be determined. In Rao's study, unlike the others, most of the index cases were hospitalized and thus isolated from their contacts, and this may partly explain the low attack rates that he reported. In the previous studies in East and in West Pakistan and in the present investigation, the populations consisted of rural villagers and the study designs were similar; it seems possible, therefore, that the pronounced climatic difference between the humid eastern and dry western portions of Pakistan might in part account for the relatively low rates in the former and high rates in the latter. Rogers demonstrated a correlation of low smallpox incidence with months of high absolute humidity in the Indian subcontinent[15] and in England and Wales,[16] and MacCallum and McDonald found that increased relative humidity was associated with decreased survival time of variola virus in raw cotton,[17] suggesting that lower incidence of disease in a humid climate may be related to a reduced viability of virus.

The present study was conducted in a relatively homogeneous rural population in West Pakistan, in which there was no isolation of contacts from cases and in which vaccination during outbreaks played a minor role. For the above reasons, attack rates cannot be compared to those found in other areas without appropriate qualifications. However, certain conclusions of general applicability may be made.

Smallpox in the unvaccinated

Since an unvaccinated individual is fully susceptible, he will obviously develop smallpox if adequately exposed to infective virus. However, it is apparent that close exposure is essential, as demonstrated in this study by the fact that many suceptible contacts escaped illness even in the crowded conditions of a rural village compound. Some of these individuals probably were not in fact susceptible, but 10 per cent. or more unvaccinated contacts appear to have escaped simply because they were not effectively exposed.

Vaccination and immunity

Vaccination provides a solid degree of protection. Vaccine-protection ratios in this study were 88.8 per cent. with primary vaccination only and 95.7 per cent. with revaccination, excluding persons probably unvaccinated and persons vaccinated after exposure.[a] Post-exposure vaccination and revaccination appeared to enhance this protection. In those instances where vaccinated contacts did develop disease, illness tended to be less severe and there were no deaths. Furthermore, vaccinated cases appeared to be less infective, causing fewer secondary cases among their contacts. These findings confirm reports in previous studies of reduced mortality,[6,9-11] morbidity[4,9,11,12] and infectivity[1] in vaccinated cases.

The secondary attack rate in unvaccinated and probably unvaccinated contacts was 76.8 per cent., and perhaps closer to 90 per cent. among true susceptibles, and one must assume that an approximately equal proportion of vaccinated contacts received a similar virus challenge. Lowered attack rates in the vaccinated thus indicate that these individuals were able to contain infection. In serologic studies conducted in the same study area, we found that at least 40 per cent. of vaccinated household and compound contacts of overt smallpox cases subsequently showed serologic evidence of inapparent infection, and there was additional evidence that more highly immune persons may have neutralized the infecting dose even before an anamnestic response had been elicited.[13] Why then do some vaccinated contacts develop overt disease? Presumably these cases represent persons with relatively low levels of immunity. In addition, there is evidence that the size of the virus dose plays an independent part in determining transmission. In the serologic studies mentioned, the incidence of inapparent infection was clearly associated with intensity of exposure, as reflected in residence status, relationship to the index case, number of overt cases in the compound and exposure patterns of the contact. In the present study, all secondary cases in vaccinated contacts derived from index cases with the more severe clinical forms of disease. This association of infectivity with severity of illness has also been noted in previous studies.[1,2,18]

It seems clear that there is a broad spectrum of immunity to smallpox, ranging from full susceptibility to solid protection, and that this immunity is relative to other factors. Strength of the virus challenge, immune status of the contacts and exposure patterns all appear to play a role. Under conditions of effective exposure, the vast majority of contacts will become infected, regardless of their immune status. Most of the unvaccinated will develop overt smallpox. Most of the vaccinated will escape clinically recognizable disease, of whom many subsequently show serologic evidence of subclinical infection and others presumably overcome the virus challenge without a detectable immunologic response. A few of the vaccinated will develop overt smallpox. It is evident that the occurrence of overt cases will be determined not solely on the basis of their levels of immunity but also on the basis of the virus dose to which they are exposed.

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[a] Vaccine-protection ratio = (Expected number of secondary cases in vaccinated contacts - Actual number of secondary cases in vaccinated contacts) / Expected number of secondary cases in vaccinated contacts. Expected number of secondary cases in vaccinated contacts = Observed secondary attack rate in unvaccinated contacts x Number of vaccinated contacts.

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TABLE 1. SECONDARY ATTACK RATES BY PRE-EXPOSURE VACCINATION STATUS OF CONTACTS

Pre-exposure vaccination status	No. of contacts	No. of cases	Attack rate (%)
Unvaccinated and probably unvaccinated*	95	73	76.8
Vaccinated			
Primary only	143	11	7.7
Primary and revaccination	183	5	2.7
Total vaccinated	331	16	4.8
Not examined	38	2	5.3
Total	464	91	19.6

* Includes 74 persons without vaccination scars, 15 who died before examination and six whose scar status could not be determined because of confluent lesions (see text).

TABLE 2. SECONDARY ATTACK RATES BY AGE AND SEX OF CONTACTS

Age (years)	Males			Females			Total		
	No. of contacts	No. of cases	Attack rate (%)	No. of contacts	No. of cases	Attack rate (%)	No. of contacts	No. of cases	Attack rate (%)
< 1	10	3	30.0	11	4	36.4	21	7	33.3
-4	33	20	60.6	32	19	59.4	65	39	60.0
5-9	39	12	30.8	43	13	30.2	82	25	30.5
10-14	30	2	6.7	26	6	23.1	56	8	14.3
15-19	23	4	17.4	15	1	6.7	38	5	13.2
⩾ 20	108	5	4.6	94	2	2.1	202	7	3.5
Total	243	46	18.9	221	45	20.4	464	91	19.6

TABLE 3. SECONDARY ATTACK RATES BY AGE AND PRE-EXPOSURE VACCINATION STATUS OF CONTACTS

Age (years)	Unvaccinated and probably unvaccinated*			Vaccinated		
	No. of contacts	No. of cases	Attack rate (%)	No. of contacts	No. of cases	Attack rate (%)
1	18	7	38.9	2	0	0.0
1-4	42	36	85.7	22	3	13.6
5-9	20	19	95.0	57	5	8.8
10-14	6	6	100.0	49	2	4.1
15-19	4	4	100.0	30	0	0.0
20	5	1	20.0	171	6	3.5
Total	95	73	76.8	331	16	4.8

* Includes 74 persons without vaccination scars, 15 who died before examination and six whose scar status could not be determined because of confluent lesions (see text).

TABLE 4. amended to consider only first-generation secondary cases, i.e. cases whose onset of illness occurred less than 22 days after first exposure to an index case.

TABLE 4. - a
SECONDARY ATTACK RATES BY CHARACTERISTICS OF THE INDEX CASE*

Characteristic of index case	Secondary attack rate (per cent.)*					
	All contacts			Vaccinated contacts only		
	No. of contacts	No. of cases+	Attack rate (%)	No. of contacts	No. of cases+	Attack rate (%)
Age of index case (years):						
<1	13	0	0.0	12	0	0.0
1-4	130	13	10.0	93	1	1.1
5-9	176	31	17.6	115	6	5.2
10-14	56	18	32.1	36	5	13.9
15-19	47	6	12.8	36	2	5.6
⩾ 20	42	2	4.8	39	0	0.0
Vaccination status of index case:						
Unvaccinated	177	24	13.6	120	2	1.7
Unvaccinated and probably unvaccinated+	390	63	16.2	271	13	4.8
Vaccinated	52	3	5.8	48	1	2.1
Lesion density of index case:						
1	21	1	4.8	17	1	5.9
2	131	24	18.3	93	8	8.6
3	107	15	14.0	74	2	2.7
4	89	11	12.4	66	0	0.0
5	11	1	9.1	8	0	0.0
Died before examination	83	14	16.9	61	3	4.9
Not examined	22	4	18.1	12	0	0.0
Total	464	70	15.1	331	14	4.2

* Attack rates are based only on numbers of first-generation secondary cases, i.e. cases whose onset of illness occurred less than 22 days after first exposure to an index case.

+ Includes contacts of nine index cases who died before examination and eight index cases whose scar status could not be determined because of confluent lesions.

TABLE 5. SECONDARY ATTACK RATES BY EXPOSURE FACTORS

Exposure factor	No. of contacts	No. of cases	Attack rate (%)
Residence status of contact:			
Same house as index case	258	45	17.4
Same compound as index case	206	46	22.3
Size of compound:			
≤ 5 contacts	56	10	17.9
> 5 contacts	408	81	19.9
Pattern of exposure:			
Constant	302	81	26.8
Daily	160	10	6.3
Intermittent	2	0	0.0
Duration of exposure:			
≥ 7 days	449	91	20.3
< 7 days	15	0	0.0

TABLE 6. DISTRIBUTION OF SECONDARY CASES BY PRE-EXPOSURE VACCINATION STATUS AND LESION DENSITY CLASS*

Pre-exposure vaccination status	Lesion density class					Total
	1	2	3	4	5	
Unvaccinated and probably unvaccinated+	6	8	10	21	12	57
Vaccinated	0	0	1	9	3	13

* Excludes 15 cases who died before examination, three surviving cases who were not examined and three cases seen too late for classification by lesion density.

\+ Includes 51 cases without vaccination scars and six cases whose scar status could not be determined because of confluent lesions (see text).

TABLE 7. CASE-FATALITY RATIOS BY AGE AND PRE-EXPOSURE VACCINATION STATUS

	No. of 2° cases	No. of deaths	Case-fatality ratio
Age (years):			
<1	7	1	14.3
1-4	39	7	17.9
5-9	25	5	20.0
10-14	8	1	12.5
15-19	5	0	0.0
⩾ 20	7	1	14.3
Pre-exposure vaccination status:			
Unvaccinated and probably unvaccinated*	73	15	20.5
Vaccinated	16	0	0.0
Not examined	2	0	0.0
Total	91	15	16.5

* Includes 74 persons without vaccination scars, 15 who died before examination and six whose scar status could not be determined because of confluent lesions (see text).

TABLE 8. SECONDARY ATTACK RATES BY PRE- AND POST-EXPOSURE VACCINATION STATUS OF CONTACTS

Pre-exposure vaccination status	Not vaccinated after exposure*			Vaccinated within seven days after first exposure		
	No. of contacts	No. of cases	Attack rate (%)	No. of contacts	No. of cases	Attack rate (%)
Unvaccinated and probably unvaccinated+	93‡	73	78.5	2	0	0.0
Vaccinated						
Primary only	124	10	8.1	19	1	5.3
Primary and revaccination	161	5	3.1	27	0	0.0
Total vaccinated	285	15	5.3	46	1	2.2
Not examined	34	2	5.8	4	0	0.0
Total	412	90	21.8	52	1	1.9

* Contacts vaccinated later than seven days after first exposure were considered as not vaccinated after exposure.

\+ Includes 74 persons without vaccination scars, 15 who died before examination and six whose scar status could not be determined because of confluent lesions (see text).

‡ Includes four contacts who received unsuccessful primary vaccination after exposure.

FIGURE 1. INTERVALS FROM FIRST EXPOSURE TO ONSET OF ILLNESS OF SECONDARY CASE, BY PRE-EXPOSURE VACCINATION STATUS