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Pattern of intrafamilial transmission of smallpox in Calcutta, India

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The pattern of intrafamilial transmission of smallpox in Calcutta was studied in 43 index cases, 3 of which were haemorrhagic, 14 confluent, and 26 discrete. They had 741 contacts. The attack rate in vaccinated contacts was significantly less than in unvaccinated contacts, but there was no such difference in the case rates caused by severe and mild index cases. Females had higher attack rates than males, the difference being more marked among the vaccinated. The vaccination status of the index cases seemed to affect their secondary case rates. The incidence of secondary cases among contacts living in the same room as a patient and in other rooms in the same compound was practically equal.

The likelihood of an individual acquiring smallpox depends primarily on his level of naturally or artificially acquired immunity, but the disease pattern in the area where he lives will depend on various environmental factors as well as the relative susceptibility of the population living in that area. It is natural, therefore, that the pattern will vary from place to place.

Calcutta, a city of multistoreyed buildings interrupted by slum areas, has been known as a home of smallpox for decades. Because there is no dearth of susceptible persons in the city, infection usually involves several members of a family or several houses in a locality. In the work presented here, the spread of the disease amongst family members was studied after detection of a number of cases.

MATERIALS AND METHODS

Studies were made of the families of 43 virologically proved smallpox cases, of whom 38 had been admitted to the Infectious Disease Hospital, Calcutta, and the rest detected during visits to the affected areas during 1971 and 1972. The first case in each family was termed the index case. Usually, the index case was detected at the time of hospitalization, but in a few instances the family outbreak was detected at the time of hospitalization of secondary cases and the index cases were examined during convalescence.

The particulars of all index cases were collected and recorded on specially prepared index cards. All family contacts of index cases were enumerated and particulars of every contact were noted. The word " contact " is used here to denote a person belonging to the family of a smallpox case living in the same house or compound as the index case. The affected families were visited frequently to detect new cases occurring for a period of 1 month after the onset of fever of the index case in the family. The day of onset of the disease was calculated from the day of onset of fever. The term " secondary case " in this study denotes only first-generation cases.

Persons with vaccination marks were termed " vaccinated ". No attempt was made to elicit a history of revaccination or time of primary vaccination, as reliable information on these points could not be procured. Persons with no mark of primary vaccination or vaccinated less than 7 days before our visit were considered to be " unvaccinated ".

As an indication of severity of the disease, the index cases were divided into 3 categories—" haemorrhagic ", " confluent ", and " discrete "—according to the criteria used by Sarkar & Mitra (6), the haemorrhagic cases being the most severe and the discrete cases the least. For the purpose of comparison of secondary attack rates when the number of haemorrhagic cases was small, the haemorrhagic and confluent cases were grouped together as severe cases and the discrete cases as mild.

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The areas affected by smallpox were generally slum areas where the houses consisted of compounds or open spaces surrounded by 5–7 rooms, each living room being occupied by a "family" (multiple family compound). Very rarely, a family had more than 1 room or a separate compound (single family compound). The members of all the families in each compound mixed freely amongst themselves.

RESULTS

Table 1 shows the vaccination status and type of illness of the index cases, while Table 2 shows the secondary case rates of the haemorrhagic, confluent, and discrete cases. Fig. 1 shows the interval between the onset of index cases and that of the secondary cases. It will be seen that, although the latter occurred between the 12th and 18th days, 87.03% of them were manifested between the 13th and 16th days. That there is a gradient in the attack rates of the haemorrhagic, confluent, and discrete index cases is evident from Table 2, the overall attack rates being 17.7%, 16.0%, and 13.3% respectively. But its significance cannot be assessed as the number of contacts per index case of the groups that were compared varied greatly (30.0, 14.3, and 17.3 respectively). The basic assumption in comparing groups is that the number of contacts exposed to the index cases should be roughly the same.

To overcome this difficulty, the families were divided into 2 groups, those living in single family compounds and those in multiple family compounds (Table 3). Though the 2 groups are not comparable

Table 1. Clinical type and number of vaccinated and unvaccinated index cases studied

Type of index case	Vaccinated	Unvaccinated	Total
Haemorrhagic	0	3	3
Confluent	2	12	14
Discrete	13	13	26
Total	15	28	43

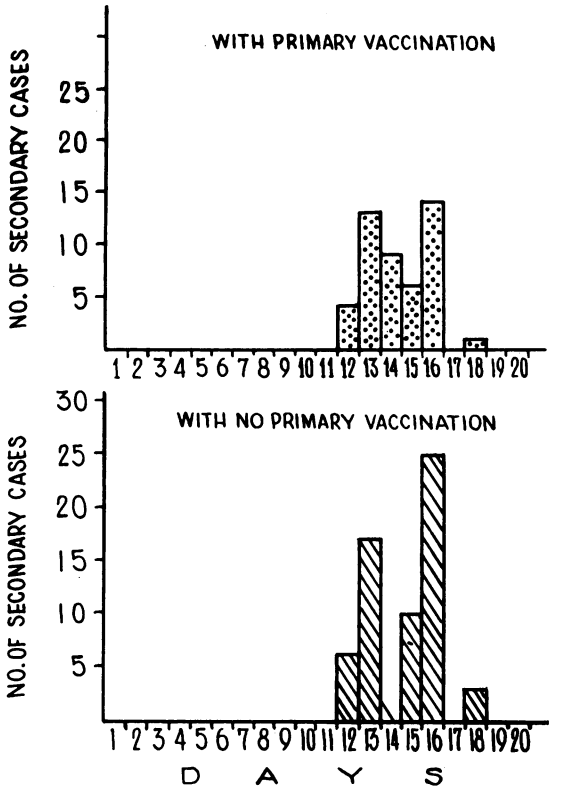

Fig. 1. Interval between onset of illness of the index case and of secondary cases, according to the pre-exposure vaccination status of the latter.

Table 2. Number of contacts and secondary cases, by type of index case

Type of index case	No. of index cases	Total no. of contacts	No. of secondary cases	Overall attack rate (%)	Average no. of contacts per index case	Proportion of contacts previously vaccinated (%)
Haemorrhagic	3	90	16	17.7	30	88.8
Confluent	14	200	32	16.0	14.3	88.0
Discrete	26	451	60	13.3	17.3	89.8
Total	43	741	108	14.5	17.2	89.2

Table 3. Average number of contacts per index case in single family compounds and multiple family compounds

Type of index case	Single family compounds			Multiple family compounds		
	No. of index cases	No. of contacts	No. per index case	No. of index cases	No. of contacts	No. per index case
Haemorrhagic	0	0	0	3	90	30.0
Confluent	9	53	5.9	5	147	29.6
Discrete	13	58	4.5	13	393	30.2
Total	22	111	5.0	21	630	30.0

because of the difference in the number of contacts per index case, secondary attack rates from haemorrhagic, confluent, and discrete cases within each group can be compared, because the average number of contacts per index case within the group is more or less the same. It is logical that an index case in a multiple family compound might have more close contacts with persons from other families than a case in a single family compound. Hence, all subsequent comparisons are shown separately for single family and multiple family compounds.

Secondary attack rates according to the severity of the index cases among vaccinated and unvaccinated contacts in single family and multiple family compounds are shown in Table 4. In both groups there were highly significant differences ($\chi^2 = 36.6$, $P < 0.05$; $\chi^2 = 263.8$, $P < 0.05$) in the attack rates between the vaccinated and unvaccinated contacts, but there was no such difference in the secondary attack rates caused by severe (haemorrhagic and confluent) and mild index cases, in either vaccinated or unvaccinated contacts ($\chi^2 = 1.24$, $P > 0.05$ and $\chi^2 = 0.06$, $P > 0.05$ in the vaccinated and unvaccinated groups respectively in single family compounds; $\chi^2 = 0.012$, $P > 0.05$ and $\chi^2 = 1.35$, $P > 0.05$ in the 2 groups in multiple family compounds).

Tables 5 and 6 show the attack rates among male and female vaccinated and unvaccinated contacts in different age groups, arranged according to type of compound. Numbers are too small in the single family compound group in the lower ages, and no consistent pattern in secondary case rates according to age group of the contacts is found. Attack rates were consistently higher among females than males in almost all age groups. Among the vaccinated contacts in the multiple family compounds, the rate of 4.7% among males was significantly lower than the female rate of 9.8% ($\chi^2 = 5.3$, $P < 0.05$). Among the unvaccinated contacts in both types of compounds the attack rates in males and females were more or less the same.

Table 7 shows the vaccination status of the index cases (discrete cases only) in relation to secondary case rates. Because the number of vaccinated index cases amongst severe cases was too small to make any comparison (see Table 1), this aspect was studied in respect of discrete index cases only, where the number of cases was equal for the two groups. It is

Table 4. Secondary case rate according to severity of index case and vaccination status of contacts

Severity	No. of index cases	Vaccinated			Unvaccinated		
		No. of contacts	No. of cases	Rate (%)	No. of contacts	No. of cases	Rate (%)
Single family compounds							
Confluent	9	45	6	13.3	8	6	75.0
Discrete	13	48	3	6.3	10	7	70.0
Total	22	93	9	9.7	18	13	72.2
Multiple family compounds							
Haemorrhagic and confluent	8	211	14	6.6	26	22	84.6
Discrete	13	357	24	6.7	36	26	72.2
Total	21	568	38	6.7	62	48	77.4

Table 5. Secondary case rates in single family compounds, according to age and sex

Age group	Vaccinated			Unvaccinated		
	No. of contacts	No. of cases	Rate (%)	No. of contacts	No. of cases	Rate (%)
Males						
0–4	5	0	0	0	0	0
5–14	9	1	11.1	4	4	100.0
⩾15	40	2	5.0	7	4	57.1
Total	54	3	5.6	11	8	72.7
Females						
0–4	4	2	50.0	4	3	75.0
5–14	12	2	16.7	2	1	50.0
⩾15	23	2	8.7	1	1	100.0
Total	39	6	15.4	7	5	71.4

Table 6. Secondary case rates in multiple family compounds, according to age and sex

Age group	Vaccinated			Unvaccinated		
	No. of contacts	No. of cases	Rate (%)	No. of contacts	No. of cases	Rate (%)
Males						
0–4	53	2	3.8	14	9	64.3
5–14	82	5	6.1	6	6	100.0
⩾15	209	9	4.3	11	7	63.6
Total	344	16	4.7	31	22	71.0
Females						
0–4	19	2	10.5	15	13	86.7
5–14	60	6	10.0	5	5	100.0
⩾15	145	14	9.7	11	8	72.7
Total	224	22	9.8	31	26	83.9

evident from Table 7 that secondary attack rates among the contacts of vaccinated patients were lower than among contacts of the unvaccinated, but this difference is not statistically significant ($\chi^2 = 2.21$, $P > 0.05$ and $\chi^2 = 1.21$, $P > 0.05$ for vaccinated contacts in single family and multiple family compounds respectively). An attempt is made in Table 8 to compare the attack rates among contacts living in the same room as the index cases and those living in other rooms in the same compounds. There was no significant difference in the attack rates between these 2 groups of contacts, either vaccinated or unvaccinated ($\chi^2 = 1.60$, $P > 0.05$ for the vaccinated contacts and $\chi^2 = 0.55$, $P > 0.05$ for the unvaccinated contacts).

DISCUSSION

The spread of smallpox infection depends upon various factors such as the number of persons coming in contact with the case, their age and vaccination status, the duration of contact, and the clinical type of the index case. Most of these factors are related to people's living conditions, which vary

Table 7. Vaccination status of index case (discrete cases only) in relation to secondary cases

Vaccination status of index case	No. of cases	No. of vaccinated contacts	No. of secondary cases	Rate (%)	No. of unvaccinated contacts	No. of secondary cases	Rate (%)
Single family compounds							
Vaccinated	4	91	11	12.1	3	1	33.3
Unvaccinated	9	33	1	30.0	7	6	85.7
Total	13	124	12	9.7	10	7	70.0
Multiple family compounds							
Vaccinated	9	166	13	7.8	33	23	70.0
Unvaccinated	4	91	11	12.1	3	3	100.0
Total	13	257	24	9.3	36	26	72.2

Table 8. Infection rate (multiple family compounds) in contacts living in the same room as index cases and those living in other rooms

	No. of vaccinated contacts	No. of cases	Rate (%)	No. of unvaccinated contacts	No. of cases	Rate (%)	Total contacts	No. of cases	Rate (%)
In the same room	79	8	10.1	21	15	71.4	100	23	23.0
In other rooms	489	30	6.1	41	33	80.5	530	63	11.9

from place to place. However, it is important to know the pattern of spread of smallpox in any place, if its eradication from that place is contemplated.

In Calcutta, as in many other endemic cities, the real home of smallpox is usually the areas inhabited by people of the lower socioeconomic groups, where resistance to vaccination and unhygienic living conditions, especially overcrowding, help in the maintenance and spread of infection.

The fact that different clinical types of smallpox cases, indicating a varying severity of attack, have different capabilities of spreading the disease has been reported by many investigators (1, 3, 5, 9). In India, Rao et al. (4) found that most of the severe (i.e., haemorrhagic) and the mildest cases spread less than the ordinary and the " flat " cases. On the other hand, several other workers have emphasized the infectiousness of the milder cases (2, 8). In the present study, no significant difference in secondary case rates was found between the severe (haemorrhagic and confluent) and mild (discrete) groups of index cases (Table 3). It is difficult to reconcile this finding with those of some other workers. One reason may be that different clinical classifications were used. However, from the data presented by previous workers, the basis of their conclusions is not always clear. From the detailed paper of Rao et al. (4), it appears that the haemorrhagic cases studied did not cause any secondary cases and 6 " flat " cases (severe) only produced 1 secondary case, whereas the ordinary and modified (milder) cases produced proportionately more secondary cases. In the series of Thomas et al. (9), the severe cases were only patients who died, and therefore the data are not strictly comparable with other studies. On the other hand, as there is no mention of the number of index cases of each degree of severity in the series of Heiner et al. (1), proper assessment of the authors' statement that severe cases spread more is not possible. In the data given by Mack et al. (3), as the number and vaccination status of the persons coming in contact with the severe and mild cases are not mentioned, the potential for spreading the disease, which depends on these 2 factors, again cannot be properly assessed. In secondary case rate studies of this kind, it is important to remember that the

number of contacts per index case of groups that are being compared should not vary greatly, because the basic assumption in comparing groups is that the exposure of contacts to the index case is roughly the same. This aspect seems to have been overlooked in some of the works mentioned. Furthermore, in studies of this kind, only first-generation secondary cases arising from index cases should be taken into account, as has been done in the present study. This criterion was followed by Thomas et al. (9), but the point is not clear in the reports of some other workers. Although haemorrhagic and confluent patients were found to contain more virus in their secretions (7), this does not seem to have materially influenced the spread among their contacts.

The disease spread significantly more among females than males (Tables 5 and 6). Rao et al. (4) reported a similar experience, although the difference in their series was not statistically significant. The reason why females are more affected appears to be that they have fewer outdoor activities and so have a likelihood of prolonged contact with patients in the houses. When the data were analysed according to age, a higher incidence in females was noted in all age groups. Considering just vaccinated individuals in all age groups in the multiple family compounds, there was a significant difference in the attack rate between males and females. In other words, the duration of contact referred to above seems to have had a bearing only on vaccinated subjects. No consistent pattern of age preference for the secondary cases was evident.

It has been found previously that smallpox cases with primary vaccination marks spread the disease less than unvaccinated patients (1, 4). Although no statistically significant difference was observed in the present study (see Table 7) in respect of the discrete group of index cases, the consistency of the difference suggests that vaccinated individuals do transmit infection less frequently; with larger numbers of cases, the tests of statistical significance might confirm this. For statistical reasons, as already noted, the spread of the disease by vaccinated and unvaccinated haemorrhagic and confluent cases could not be analysed.

Living in the same room as a smallpox patient or in different rooms in the same compound does not seem to influence the spread of infection in either vaccinated or unvaccinated contacts, as Table 8 shows. Heiner et al. (1), in their studies in Pakistan villages, also found that the attack rates among household and compound contacts were very similar. This finding is not unexpected; because of the proximity of the rooms of different families and the intimate mixing of the inhabitants of each compound, all may be considered to constitute a single family.

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RÉSUMÉ

MODALITÉS DE LA TRANSMISSION INTRAFAMILIALE DE LA VARIOLE À CALCUTTA (INDE)

Afin d'étudier les aspects de la transmission intrafamiliale de la variole à Calcutta, on a effectué une enquête dans les familles de 43 cas indicateurs. Parmi ces derniers, 22 vivaient dans des maisons unifamiliales et 21 dans des habitations abritant plusieurs foyers. Trois d'entre eux étaient atteints de variole hémorragique, 14 de variole confluente et 26 d'une forme légère et localisée de l'affection; les sujets ayant été en contact avec ces malades étaient respectivement au nombre de 90, 200 et 451 parmi lesquels on a enregistré 16, 32 et 60 cas secondaires.

On a noté une différence très nette du taux d'apparition de la maladie entre contacts vaccinés et non vaccinés, mais pas de différence entre contacts, vaccinés ou non, selon la gravité ou la bénignité du cas primaire. Les cas secondaires ont été régulièrement plus nombreux parmi les sujets de sexe féminin que parmi les sujets de sexe masculin dans tous les groupes d'âge, et cette

différence a été plus sensible parmi les contacts vaccinés. Les cas indicateurs vaccinés ont transmis l'infection moins fréquemment que les non vaccinés, la différence n'étant pas statistiquement significative. Le taux d'atteinte secondaire a été presque identique parmi les contacts vivant dans la même pièce que les malades et parmi ceux occupant d'autres parties du logement.

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