Ind. Jour. Med. Res., **56**, 12, December, 1968.

EPIDEMIOLOGICAL STUDIES IN SMALLPOX*. A STUDY OF INTRAFAMILIAL TRANSMISSION IN A SERIES OF 254 INFECTED FAMILIES.

A. R. RAO[1], E. S. JACOB[2], S. KAMALAKSHI[3], S. APPASWAMY[4], AND BRADBURY[5].

[Received for publication, September 8, 1967.]

INTRODUCTION.

THOUGH it is primarily the immunity status against smallpox that portects an individual from contracting the disease in the event of exposure to infection, yet it may not be the only factor. It is not uncommon to find unvaccinated persons escaping an attack of smallpox or developing a very mild type and equally it is not uncommon to find even fairly well vaccinated persons developing the disease and even succumbing to it. There appears to be, therefore, some other factors also playing a role in making a person susceptible or resistant to infection besides the vaccinial status and determining the pattern of transmission in smallpox.

The spread of smallpox in a family may vary from country to country or from place to place even in the same country. Similarly, it may differ from urban to rural areas. Therefore, our findings in this study may or may not be applicable to other areas, though they may project a general pattern of transmission in the infected families.

Further, this particular study was started nearly 14 months after implementation of smallpox eradication programme in Madras city. Especially during the later half of the period of study, the impact of the programme was so definitely felt that there were very few unvaccinated contacts available in the infected houses. Hence, again the results might have been influenced by the impact of the programme, and they might have been different in the pre-eradication days.

Madras city has been an endemic area for smallpox for several decades. From the data available for the last 50 years, there had been no year when the city was ever free from the disease. The average annual notification in recent years was ranging between 1,000 cases in non-epidemic years and about 4,000 cases in epidemic years. The smallpox eradication programme was started in October 1963 and since then, there has been an appreciable and gradual decline in the incidence of the disease. The present study was started on February 26th, 1965 and the report includes the data of cases studied up to 25th April, 1967, i.e. over a period of 26 months.

*This Project was sponsored and financed by the Indian Council of Medical Research, Medical Enclave, Ansari Nagar, New Delhi.

1. Health Officer, Corporation of Madras.
2. Assistant Research Officer, Indian Council of Medical Research.
3. Research Assistant, Indian Council of Medical Research.
4. Field Worker, Indian Council of Medical Research.
5. Junior Lady Health Visitor, Indian Council of Medical Research.

AIMS OF THE STUDY.

The aims of the study are to find out :—

1. the influence of the following factors on the pattern of IFT

(*a*) factors pertaining to the primary case (infecting source), such as the clinical type, vaccinial status, clinical outcome, age, sex, etc.

(*b*) factors pertaining to exposed familial contacts, such as the vaccinial status age, sex, etc.

(*c*) factors pertaining to the environment, such as the load of the unvaccinated in the infected family, the socio-economic conditions, meteorological conditions, and

2. the period of maximum infectivity of smallpox cases.

MATERIALS AND METHODS.

During the first 3 months up to May 28th 1965, since the number of admissions were many, only every 5th smallpox case was taken for study, but later on every case was taken as Index case. The following categories were taken as *Index cases* :—

1. All cases of smallpox that were admitted to I.D. Hospital.
2. All deaths due to smallpox detected at the burial ground and certified as such and all deaths due to smallpox that were brought to I.D. Hospital and certified as such.

Since the main purpose of this study was only to find out the pattern of transmission within the infected family, only those cases who are the first cases in the family have been taken as primary cases, and the following categories of Index cases have, therefore, been excluded for the purpose of this study only.

1. Index case with no contacts at all.
2. Index cases removed from institutions, such as hostels, dormitaries orphanages, etc., where there are no specific familial contacts and where there are facilities for immediate isolation of all the sick whatever be the sickness.
3. Contact smallpox cases (as defined below).
4. Co-primary cases (as defined below).
5. Cases where no detailed information was available.

Table I shows the details of exclusions under various categories.

TABLE I.

Index cases, exclusions and primary cases.

Total index cases		387
Cases with no contacts	36	
Cases from institutions	4	
Contact smallpox cases	52	
Co-primary cases	32	
Cases with no information available	9	
Total exclusions		133
Total primary cases for study		254

METHODS.

1. The relevent particulars of all cases of smallpox were collected and recorded in a specially prepared Index cards.
2. All the familial contacts of every Index case in the study were enumerated and all the relevent particulars of every contact were entered in the specially prepared contact cards.
3. Every contact was examined daily for the development of smallpox for a maximum period of 16 days from the date of last contact with the last case in the family.
4. Every attempt has been made to find out the first case in the family. In case of suspicious deaths, burial ground records, registers of the Registrar of Births and Deaths verified.
5. The exclusion of Index cases for study mentioned under 'Material for study' was done at the time of final analysis for arriving at the list of pimary cases.
6. The clinical classification of smallpox followed is Rao's classification (Rao *et al.*, 1966 and Melvin Ramsay *et al.*) (Text-figure).

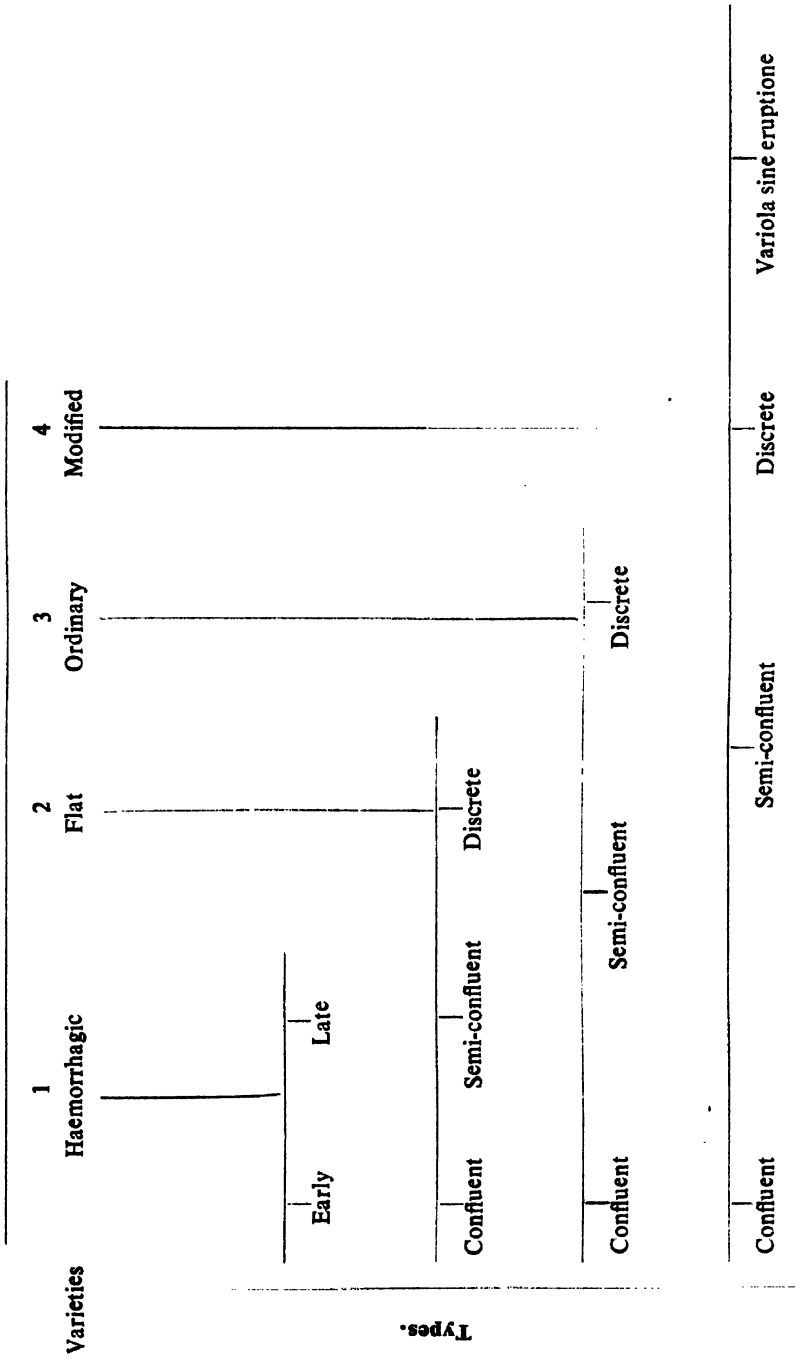
DEFINITIONS.

1. Index case	:	As defined under 'Materials and Methods'.
2. Primary case	:	An Index case which happens to be the first case in the family.
3. Day of attack	:	The first day of onset of fever of smallpox.
4. Co-primary case	:	A contact (as defined below) of primary case who developed smallpox either on the same day as the primary case or on any day within 12 days after the day of attack of primary case.
5. Contact	:	One who is a member of the family or who is living with the family of the primary case and who had been staying in contact with primary case in the same house as the primary case but who is not a co-primary case.
6. Contact smallpox	:	A contact (as defined above) who has developed smallpox on or after 12th day of the day of attack of the primary case (Explanation :* (*i*) This definition assumes that no case of smallpox is infective before the day of attack, i.e. during the incubation period. (*ii*) This definition also assumes that the incubation period of smallpox is not less than 12 days).

**Note* :—This particular aspect is discussed in the last section.

TEXT-FIGURE.

Clinical classification of smallpox.



7. The vaccinated	:	A person who bears marks of vaccination done at any time during the life, but not after the attack of the primary case and those who have evidence of a previous attack of smallpox.
8. The unvaccinated	:	A person who has no evidence of vaccination but includes one who has been vaccinated for the first time after exposure to the primary case, i.e. during the incubation period.
9. Incubation period	:	The incubation period of smallpox for the purpose of this study was taken as 12 days.
10. Generation time	:	The generation time of smallpox is the period of maximum infectivity of smallpox patient calculated from the day of infection (not the day of disease) and during which period a smallpox case is most likely to infect the maximum number of susceptible contacts and produce the first generation cases of smallpox in the contacts.

Note.—Day of infection is the day on which the patient probably got infected and this is calculated from the day of attack assuming 12 days as incubation period.

ABBREVIATIONS.

IC	:	Index case
PC	:	Primary case
PCF	:	Families of primary case
FTO	:	Families of primary cases where further transmission has occurred from the primary case to the contacts.
FTR	:	Family transmission rate, i.e. the percentage of the families of primary case where further transmission occurred from the primary case.
IFT	:	Intrafamilial transmission
C	:	Contacts
CS	:	Contact smallpox cases
CTR	:	Contact transmission rate, i.e. the percentage of the total contacts who developed smallpox.
VC	:	Vaccinated contacts
VCS	:	Vaccinated contact smallpox cases.
VCR	:	Vaccinated contact rate, i.e. the percentage of the contacts who were found vaccinated.

VCTR	:	Vaccinated contact transmission rate, i.e. the percentage of vaccinated contacts who developed smallpox.
UC	:	Unvaccinated contacts
UCR	:	Unvaccinated contact rate, i.e. the percentage of contacts who were found unvaccinated.
UCS	:	Unvaccinated contact smallpox cases
UCTR	:	Unvaccinated contact transmission rate, i.e. the percentage of unvaccinated contacts who developed smallpox.
IP	:	Incubation period
PV	:	Primary vaccination
PVIP	:	Successful primary vaccination done after exposure to the primary case.
RV	:	Revaccination
CFR	:	Case fatality rate
E1	:	Families with income of more than Rs. 300/- per month
E2	:	Families with income of Rs. 300/- and below per month
LO	:	Families with no homes to live—the Homeless
L1	:	Families with only one living room.
L2	:	Families with more than one living room.

RESULTS AND DISCUSSION.

General.—Altogether families of 254 primary cases were studied. These families had 1,249 contacts. The general pattern of intrafamilial transmission is shown in Table II.

TABLE II.

General pattern of intra-familial transmission.

PCF	254
FTO	36
FTR	14·2
C	1249
CS	52
CTR	4·2
VC	1146
VCR	91·8
VCS	14
VCTR	1·2
UC	103
UCR	8·2
UCS	38
UCTR	36·9

Factors pertaining to the primary case (source of infection) and their influence on the pattern of IFT of smallpox in the infected families :

General.—Though every case of smallpox is infectious yet the infectivity, i.e. capacity to infect, seems to depend upon :

1. The ambulatory nature of the case.
2. The degree of severity of enanthem, especially on the mucous membranes of nose and nasopharynx.
3. The stage at which the case is isolated or dead.

The degree of exposure to which the contacts are subjected to may depend upon the age, sex and severity of primary case, since on these mostly depends the approach of the contacts towards the patient. Considering these as the important determinants in the intrafamilial transmission, the following features pertaining to the primary cases were studied.

TABLE III.

The pattern of intrafamilial transmission of smallpox with reference to vaccinial status and clinical variety of primary case.

	VACCINATED :					UNVACCINATED :				
	Hgic.	Flat.	Ord.	Mod.	Total.	Hgic.	Flat.	Ord.	Mod.	Total.
PCF	6	2	93	19	20	3	4	126	1	134
FTO	..	..	9	1	10	..	1	25	..	26
FTR	..	..	9·7	5·3	8·3	..	25·0	19·8	..	19·4
C	34	11	449	65	559	15	22	659	3	690
CS	..	..	10	1	11	..	1	40	..	41
CTR	..	..	2·2	1·5	2·0	..	4·5	6·1	..	5·9
VC	34	11	421	61	527	13	21	583	2	619
VCR	100·0	100·0	93·8	93·8	94·1	86·7	95·5	89·7	66·7	89·7
VCS	..	..	2	..	2	..	1	11	..	12
VCTR	..	..	0·5	..	0·4	..	4·8	1·9	..	1·9
UC	..	..	28	4	32	2	1	67	1	71
UCR	..	..	6·2	6·2	5·9	13·3	4·5	10·3	33·3	10·3
UCS	..	..	8	1	9	..	..	29	..	29
UCTR	..	..	28·6	25·0	28·1	..	..	43·3	..	40·1

Clinical variety.—Table III shows the pattern of transmission with reference to clinical variety and the vaccinial status of primary case.

3·5 per cent (9/254) of primary cases belonged to the most fatal type, viz. the 'haemorrhagic'. These 9 cases had 49 contacts ; 4·1 per cent of whom were unvaccinated, yet there was no transmission at all. The number of cases being few, no definite conclusions can be drawn from this. However, since the frequency of occurrence of haemorrhagic smallpox, in general, is about 3·5 per cent and even in this study it is 3·5, the difference in the pattern of transmission between the haemorrhagic and non-haemorrhagic should be considered as significant.

2·4 per cent (6/254) belonged to the 'flat' type, the most severe form of the non-haemorrhagic. There were 33 contacts of whom one was unvaccinated and transmission occurred only in a single vaccinated contact.

TABLE IV.

The pattern of intrafamilial transmission of smallpox with reference to the clinical type and clinical outcome primary case.

Clinical variety of primary case.	HAEMORRHAGIC :			FLAT :			ORDINARY :			MODIFIED :			Total.
Result of PC.	Deaths.	Surv.	Total.	Deaths.	Surv.	Total.	Deaths.	Surv.	Total.	Deaths.	Surv.	Total.	
PCF	8	1	9	6	..	6	51	169	219	..	20	20	254
FTO	..	..	..	1	..	1	11	23	34	..	1	1	36
FTR	..	..	..	16·7	..	16·7	21·5	13·7	15·5	..	5·6	5·6	10·2
C	42	7	49	33	..	33	272	827	1099	..	68	68	1249
CS	..	..	..	1	..	1	17	33	50	..	1	1	52
CTR	..	..	..	3·0	..	3·0	6·3	4·0	4·5	..	1·7	1·7	4·2
VC	41	6	47	32	..	32	254	750	1004	..	63	63	1146
VCR	97·6	85·7	95·9	97·0	..	97·0	93·4	90·7	91·2	..	92·6	92·6	91·8
VCS	..	..	..	1	..	1	5	8	13	..	..	..	14
VCTR	..	..	..	3·1	..	3·1	1·9	1·1	1·3	..	..	..	1·2
UC	1	1	2	1	..	1	18	77	95	..	5	5	103
UCR	2·4	14·3	4·0	3·0	..	3·0	6·6	9·3	8·6	..	7·4	7·4	8·2
UCS	..	..	..	..	..	..	12	25	37	..	1	1	38
UCTR	..	..	..	..	..	..	66·7	32·4	38·9	..	20·0	20·0	36·9

86·2 per cent (219/254) belonged to the 'ordinary' type of smallpox. 8·6 per cent of their contacts were unvaccinated and the transmission rates are all comparatively high in the contacts of this particular type.

7·9 per cent (20/254) of the cases belonged to the mildest type, the 'modified'. Of the 68 contacts of these cases, 7·4 per cent were unvaccinated, but the CTR was only 1·7 per cent the, lowest transmission rate recorded in the non-haemorrhagic type. There were no cases under type V, variola sine eruptione in this study.

There is a suggestion that the severest and the mildest type of smallpox are likely to transmit less infection to their contacts, whereas the moderately severe types, the 'flat' and the 'ordinary', seem to transmit infection to maximum extent to the familial contacts. The possible explanation for these variation may be that the haemorrhagic are so sick that they cannot move, they less frequently develop enanthem before they die and they are removed very early to the hospital before they could transmit infection. The 'modified' though very ambulatory, majority of them do not have enanthem and so perhaps did not transmit much infection. Whereas the other two types—'flat' and 'ordinary'—have the greater capacity to infect because they have all the three requisite factors needed for successful transmission.

Vaccinial status.—Taking the type 'ordinary' where the maximum transmission occurred, the CTR in contacts of the unvaccinated cases was 6·1 per cent (40/650) in contrast to only 2·2 (10/499) in those of vaccinated cases. This indicates that the vaccinated smallpox cases are less infective or are responsible for less transmission of the disease than the unvaccinated.

However, the load of the unvaccinated was more in the families of unvaccinated than those of vaccinated. That may also account for this difference, but the transmission even in the vaccinated contacts of the unvaccinated is nearly 4 times more than that in vaccinated contacts of the vaccinated cases, the rates being 1·9 (11/583) and 0·5 (2/421) respectively. This, therefore, suggests that vaccinated cases in general may be less infective.

Clinical outcome.—Table IV shows the pattern of tranmission with reference to the clinical outcome of the primary case. The contact transmission rate in the contacts of the deaths is 5·2 per cent (18/347) ; comparatively higher than that in the contacts of survivals, 3·8 per cent (34/902). In the 'ordinary' type, where the transmission was maximum, all the transmission rates are significantly higher in the contacts of deaths. However, this does not apply to the haemorrhagic, where 8 out of 9 died, without any transmission.

Table IV*a* shows the transmission rate in the contacts of deaths of smallpox that have occurred at home, and that in the contacts of deaths that have occurred in the Hospital.

In the case of haemorrhagic, all were hospital deaths and there was no transmission. In the 'flat', 5 were the hospital deaths and these had 26 contacts, 4·6 per cent of them were unvaccinated and still there was no transmission. Only one 'flat' case was

a home death with 7 contacts and all of them were vaccinated, and one of them developed smallpox.

With the 'ordinary' type, 35 were hospital deaths, and they had 177 contacts, 5·1 per cent of whom were unvaccinated. There were 16 home deaths who had 95 contacts, 9·5 per cent of whom were unvaccinated.

TABLE IV*a*.

The pattern of intrafamilial transmission of smallpox with reference to hospital deaths and house deaths under each clinical type.

	HAEMORRHAGIC :		FLAT :		ORDINARY :		MODIFIED :	
	Hospital death.	House death.	Hospital death.	House death.	Hospital death.	House death.	Hospital death.	House death.
PC	7	1	5	1	35	16	..	..
FTO	...	..	..	1	4	7	..	..
FIR	..	..	..	100·0	11·4	43·7	..	..
C	39	3	26	7	177	95	..	..
CS	..	..	..	1	4	13	..	..
CTR	..	..	..	14·3	2·3	13·7	..	..
VC	38	3	25	7	168	86	..	..
VCR	97·4	100·0	96·4	100·0	94·9	90·5	..	..
VCS	..	...	..	1	..	5	..	..
VCIR	..	..	..	14·3	..	5·8	..	..
UC	1	..	1	..	9	9	..	..
UCR	2·6	..	3·6	..	5·1	9·5	..	..
UCS	...	..	..	..	4	8	..	..
UCTR	..	..	..	..	44·4	88·9	..	..

All the transmission rates are significantly higher in contacts of home deaths. Though there is difference in the unvaccinated contact load, the increase in the transmission is far more in the vaccinated contact of the house deaths.

A question can be raised whether the duration of contacts was more in the home deaths. Mean duration of stay at home of the patients in home deaths of this type, was 10·9 days as against 8·3 days with the hospital deaths. But this study has definitely shown that maximum transmission occurred before 7th day of the disease, and hence this slight difference in the duration of the stay of the patient at home cannot account for the vast difference in the transmission rates in the contacts of home deaths and hospital deaths.

Hence there is some epidemiological evidence to indicate that there is greater transmission of infection with fatal cases, and further it is more marked with home deaths than with hospital deaths and this may be the result of fear, stress and strain on the part of the host as a result of the calamities in their midst.

Age.—This study showed (Table V) that the maximum transmission has occurred in the contacts of primary cases belonging to the age group 5 to 14 irrespective of the vaccinial status.

Sex.—Though there is slightly greater transmission in contacts of female primary cases, yet with reference to the age and sex, both in males and females, the particular age group 5 to 14 again transmitted infection to greater number of contacts, and between the two sexes it is the male child that transmitted more.

It is not known why this particular age group has transmitted more infection. Of course, amongst the contacts of this age group, there is greater percentage of unvaccinated, whether that is the reason for the increased transmission or not, is not clear. However, when compared to children under 4 years, these children of the age group 5 to 14 usually take the disease easy, they are more ambulatory and they attract children of the same age group as well as adults, to come and keep company with them, thus free mixing up of contacts with the case might have enhanced the transmission rates. Further, the members of the families also are likely to be more atttached to the children of this age group and move more freely with them than with others.

The same Table shows the transmission rates with reference to the sex of the contacts and age of the primary case. It is seen that more female contacts of primary cases of the age group 0 to 4 developed smallpox than male contacts. This is understandable since most of the children under 4 years are looked after by females.

All these indicate that the pattern of transmission also depends upon the nature of the infecting case, its clinical type, vaccinial status, clinical outcome, and even age and sex.

Factors pertaining to the exposed contacts (host) and their influence on the pattern of IFT of smallpox in the infected families :

General.—Perhaps these factors are the most important determinants in transmission of smallpox, principally the vaccination immunity, the age and sex of exposed contacts.

The 254 infected families studied had a total of 1,249 contacts. The mean number of contacts per case was 4·9. The median fell between 5 and 6 and the mode was 4.

Fourteen per cent of the contacts belonged to the age group 0 to 4 and 35 per cent to 5 to 14 and the remaining 61 per cent were adults beyond the age of 14. About 55 per cent of the contacts were males. About 92 per cent of the male and 90 per cent of female contacts were found vaccinated at least once.

4·2 per cent (52/1249) of the contacts developed smallpox contracting the infection from the primary case in the family. Forty-four per cent of the total contacts smallpox cases were children in the age group 0 to 4 years and 11 per cent belonged to the age group 5 to 14 and the remaining 45 per cent of the cases were amongst the adults. Twenty-three per cent contact smallpox cases died as against 25·6 per cent of the primary case.

Age.—Irrespective of vaccinial status (Table VI) the contact transmission rate was highest in children of 0 to 4 age group with 13·1 (22/176) and lowest with 1·9 (6/311) in children of the age group 5 to 14. Amongst the adults, the transmission rate was slightly more in those of the age group 15 to 44 than that in those beyond 45 years.

But with reference to the vaccinial status, there was no smallpox at all in the 119 vaccinated contacts in the age group 0 to 4. The transmission rate in the vaccinated increased with the increasing age. Amongst unvaccinated there is not much difference in the different age groups.

Sex.—In general between the sexes there is no significant difference in the smallpox incidence. The transmission rates being 4·4 (26/576) and 3·8 (26/681) respectively in female and males.

Even with reference to vaccinial status, the difference in transmission between sexes were not significant.

With reference to the age and sex, there was slightly greater transmission in females 4·6 (11/236) than that in males 2·3 (8/345) in the age group 15-44. This is not statistically significant yet there is a suggestion that adult women of this age group are more susceptible to small pox than men of the same age group. In general, the transmission was a little more in males, in children under 14 years, in adults beyond 14 years the pattern is reversed—it is slightly more in female sex.

Vaccinial Status.—Apart from the influence of vaccinial status on IFT that has been described, following further details of vaccinial condition of contacts were considered, to see whether they have abearing on the IFT.

In this study (Table VII) of the 103 unvaccinated contacts exposed to infection, in the 254 infected families, 61 were successfully vaccinated after exposure and of these only 29·5 per cent (18/62) developed smallpox as against 47·6 per cent (20/42) of the remaining children who were not vaccinated even after exposure. Though the difference is not statistically significant it indicates the possibility that successful vaccination even after exposure may reduce the incidence to some extent.

Three per cent (38/1249) of the total contacts had evidence of previous attack of smallpox and of these, one developed second attack (Modified type). This contact was a woman aged 45 years who had smallpox about 35 years ago. She has definite pitting on the face. She was a close contact of a child 11/12 old who died at home of ordinary confluent type on 14th day.

18·5 per cent (212/1146) of the total vaccinated contacts had both primary vaccination scars as well as marks of successful revaccination said to have been done within 2 years before exposure to infection, and none developed smallpox. 2·6 per cent (30/1146) of the vaccinated contacts had marks of primary vaccination as well as revaccination said to have been done beyond 2 years before esposure, and of these 1 developed smallpox. (Modified type). This contact again was a woman aged 35 years who had 5 marks of primary vaccination and 2 marks of revaccination done 3 years before exposure, a contact of a child 2½ years old who developed cordinary confluent attack and died at home on 10th day.

From the data available in this study there is no definite correlation between the number of insertions of primary vaccination and transmission rates, however, upto the age of 14 years, there is some difference between single insertion and multiple insertions, CTR for single insertion group was 1·7 as against only 0·4 for multiple insertion group. This difference is not present beyond 14 years age.

TABLE

The pattern of intrafamilial transmission of smallpox with

Sex of PC.		Males:					Females:				
Age of PC.		—4	—14	—44	45+	Total.	—4	—14	—44	45+	Total.
PCF	..	37	24	65	9	135	35	22	56	6	119
FTO	..	4	7	7	1	19	5	5	7	..	17
FTR	..	10·8	29·3	10·8	11·1	14·1	14·3	22·7	12·5	..	14·3
		Sex of contacts									
C	..	202	125	252	43	622	179	123	293	32	627
CS	..	4	14	8	2	28	9	8	7	..	24
CTR	..	2·0	11·2	3·2	4·7	4·5	3·9	6·5	2·4	..	3·7
VC	..	192	103	236	40	571	166	105	274	30	575
VCR	..	95·0	82·4	93·6	93·0	91·1	92·7	85·4	93·5	93·8	91·7
VCS	..	1	4	1	..	6	4	2	2	..	8
VCTR	..	0·5	3·9	0·4	..	1·1	2·4	1·9	0·7	..	1·4
UC	..	10	22	16	3	51	13	18	19	2	52
UCR	..	5·0	17·6	6·4	7·0	8·2	7·3	14·6	6·5	6·2	8·3
UCS	..	3	10	7	2	22	5	6	5	..	16
UCTR	..	30·0	45·5	43·8	66·7	43·1	38·5	33·3	26·3	..	30·8

, V.

reference to age and sex, of primary case and sex of contacts.

TOTAL MALES AND FEMALES :

0—4			5—14			15—44			45 and above.			Total.		
72 9 12·5			46 12 26·1			121 14 21·6			15 1 6·7			254 36 10·2		
Male.	Female.	Total.	Male.	Female.	Total.	Male.	Female.	Total.	Male.	Female.	Total.	Male.	Female.	Total.
180	201	381	137	111	248	322	223	545	42	33	75	681	568	1249
2	11	13	13	9	22	9	6	15	2	..	2	26	26	52
1·1	5·4	3·4	9·5	8·1	9·0	2·8	2·7	2·8	4·8	..	2·7	3·8	4·4	4·2
173	185	358	112	96	208	305	205	510	39	31	70	629	517	1146
96·1	82·1	94·0	82·1	86·5	83·9	94·7	97·1	93·6	92·9	93·9	93·3	92·4	90·2	91·8
1	4	5	2	4	6	3	...	3	..	...	...	6	8	14
0·6	2·1	1·4	1·8	4·1	2·9	0·98	..	0·6	..	..	..	0·95	1·5	1·2
7	16	23	25	15	40	17	18	35	3	2	5	52	51	103
3·9	7·9	6·0	18·2	13·5	16·1	5·3	2·9	6·4	7·1	6·1	6·7	7·6	9·8	8·2
1	7	8	11	5	16	6	6	12	2	..	2	20	18	38
14·3	43·7	34·8	44·0	33·3	40·0	35·3	33·3	34·3	66·7	..	40·0	38·4	35·3	36·6

TABLE VI.

The pattern of intrafamilial transmission of smallpox with reference to age, sex and vaccinial status of contacts.

Age	0—4 :			5—14 :			15—44 :			ABOVE 45 :			TOTAL :		
Sex.	Male.	Female.	Total.	Male.	Female.	Total.	Male.	Female.	Total.	Male.	Female.	Total.	Male.	Female.	Total.
C	78	98	176	167	144	311	345	236	581	91	90	181	581	568	1249
CS	13	10	23	3	3	6	8	11	19	2	2	4	26	26	52
CTR	12·8	10·2	13·1	1·8	2·1	1·9	2·3	4·6	3·3	2·2	2·2	2·2	3·8	4·6	4·2
VC	48	11	119	157	136	293	337	229	566	87	81	168	629	517	1146
VCR	61·5	72·4	67·7	94·0	94·4	94·2	97·7	97·0	97·4	95·6	90·0	92·8	92·4	91·0	91·8
VCS	..	..	..	1	1	2	4	6	10	1	1	2	6	8	14
VCTR	..	..	..	0·6	0·7	0·68	1·2	2·6	1·8	1·1	1·1	1·2	0·95	1·5	1·2
UC	30	27	57	10	8	18	8	7	15	4	9	13	52	51	103
UCR	38·5	38·0	32·3	6·4	5·9	5·9	2·4	3·1	2·6	4·6	11·1	7·2	8·2	9·9	8·2
UCS	13	10	23		2	4	4	5	9	1	1	2	20	18	39
UCTR	43·3	31·1	40·4	20·2	25·0	22·2	50·0	71·4	60·0	25·0	11·1	15·4	38·5	35·3	36·9

TABLE VII.

The pattern of intrafamilial transmission with reference to vaccinial status with number of vaccination scars and age.

Age group.	0—4 :			5—14 :			15—44 :			45 AND ABOVE :			TOTAL :		
Vaccinial status :	C.	CS.	CTR.	C.	CS.	CTR.	C.	CS.	CTR.	C.	CS.	CTR.	C.	CS.	CTR.
Unvaccinated	16	10	62·5	7	2	28·6	11	7	63·6	8	1	12·5	42	20	47·6
PVIP	41	13	31·7	11	2	18·2	4	2	50·0	5	1	20·0	61	18	29·5
Total unvaccinated	57	23	40·4	18	4	22·2	15	9	60·0	13	2	15·5	108	38	36·9
Previous attack of smallpox	1			6			23			8	1	12·5	38	1	2·6
PV+RV within 2 years	11			70			109			22			212		
PV+RV beyond 2 years				4			18	1	5·5	8			30	1	3·3
PV 4	16			81	1	1·2	207	7	3·4	60			364	8	2·2
PV 3	4			18			49			20			91		
PV 2	60			83			128	1	0·8	38	1	2·6	209	2	0·75
PV 1	27			31	1	3·2	32	1	3·1	12			102	2	1·96
Total vaccinated	119			293	2	0·7	566	10	1·8	168	2	1·2	1146	14	1·2
Grand Total	176	23	13·1	311	6	1·9	581	19	3·3	181	4	2·2	1249	52	4·2

Factors pertaning to the environment and their influence on the pattern on intrafamilial transmission of smallpox in the infected families :

General.—The word environment is used here in a general sense and it includes the socio-economic conditions under which the family lives, and also the meteorological conditions. People who get smallpox in general are poor class of people belonging to the low and middle income group of families. The density of population in several areas of the city is very high and there are several houses in these areas where even 10 to 15 families live in a single house, and each family occupying usually one room. The size of the family is so large in many that most of the inmates sleep outside on the pial or even on the road during non-rainy and summer months. For this part of the report we have not considered any families other than the infected one, though others are living in the same house hold with common entrance and in majority of instances with even common toilet and bath.

TABLE VIII.

The pattern of intrafamilial transmission of smallpox with reference to the unvaccinated load.

	NIL UC.	One UC. per family.	Two UC per family.	More than 2 UC per family.	Total.
PCR	181	56	11	6	254
FTO	6	18	7	5	36
FTR	3·3	32·0	63·6	83·3	14·2
C	833	301	76	39	1249
CS	6	19	11	16	52
CTR	0·7	6·3	14·4	41·0	4·2
VC	833	245	54	14	1146
VCR	100	81·4	71·1	35·9	91·8
VCS	5	4	·1	3	14
VCTR	0·7	1·6	1 9	21·4	1·2
UC		56	22	25	103
UCR		18·6	28·9	64·1	8·2
UCS		15	10	13	38
UCTR		26·8	45·5	52·0	36·9

The load of the unvaccinated in the infected families.—Table VIII shows that with the increasing UCR the transmission rates have also correspondingly increased but the increase in transmission is not only amongst the unvaccinated contacts but even the VCTR has increased from 0·7 in the group with no unvaccinated contacts per family to 21·4 in families with more than 2 unvaccinated contacts. This indicates that the greater the unvaccinated contacts in a family the greater the possibility of not only the unvaccinated contacts developing smallpox but also the vaccinated contacts. It looks as though the presence of more unvaccinated contacts, lowers the herd immunity in the family in general, making even the vaccinated, more susceptible.

Another aspect of the influence of the unvaccinated load is seen from Table IX. In 85·8 per cent (219/254) of the total families studied there was no further transmission at all and the UCR in these families was 4·8 per cent. 11 per cent (28/254) had only 1 contact smallpox and the UCR in these families was 17·0 per cent. 1·6 per cent (4/254) had more than 2 contact smallpox cases and the UCR in them was 47·0. The remaining 1.6 (4/254) had more than 2 contacts smallpox cases and the UCR in them was 50 per cent. From this also it is clear that there is correlation between the UCR and the number of contact smallpox in the families. Here, again, the increase in contact smallpox cases was not only in the unvaccinated but also in the vaccinated contacts. This aspect is of great interest, indicating the possibility that the overall family immunity can be reduced by addition of more and more susceptibles, perhaps this is equally applicable to a community.

TABLE IX.

The pattern of intrafamilial transmission of smallpox with reference to unvaccinated load and multiplicity of contact of smallpox cases.

	Families of primary cases where no transmission has occurred.	Families of primary cases where 1 contact developed smallpox.	Families of primary cases where 2 contacts developed smallpox.	Families of primary cases where more than 2 contacts developed smallpox.	Total.
Average size of families in each group	6·0	6·9	5·3	10·0	6·3
PCF	218	28	4	4	254
C	1031	165	17	36	1249
CS		28	8	16	52
CTR		17·0	47·0	44·4	4·2
VC	882	137	9	18	1146
VCR	95·2	83·0	53·0	50·0	91·3
VCS		9	1	4	14
VCTR		6·6	11·1	22·2	1·2
UC	49	28	8	18	103
UCR	4·8	17·0	47·0	50·0	8·2
UCS		19	7	12	38
UCTR		67·8	87·5	667	36·9

Economic status.—For the purpose of this study, families were divided into two economic groups only, the higher income group E1 families with a total monthly income of above Rs. 300/- and the lower income group E2 families with a monthly income of Rs. 300/- and less.

12·2 per cent (31/254) of the families belonged to the group E1. The average number of contacts per family was 6·8 in this group and 4·6 in the lower income group. The UCR is far more in the lower income group with 9·1 (94/1038) as against 4·3 (9/211) in the group E1 ; which shows the poorer class of people usually escape vaccination.

TABLE X.

The pattern of intrafamilial transmission of smallpox with reference to the economic status and living condition. of the infected families.

	Economic 1 :				Economic 2 :				Total E 1 and E 2 :			
	L0	L1	L2.	Total.	L0.	L1.	L2.	Total.	L0.	L1.	L2.	Total.
PCF		10	21	31	15	158	50	223	15	168	71	254
FI		1	5	6	5	21	4	30	5	22	9	36
FTR		10·0	23·8	19·3	33·3	13·3	8·0	13·5	33·3	13·3	12·7	14·2
C		65	146	211	45	684	309	1038	45	749	455	1249
CS		1	7	8	9	31	4	44	9	32	11	52
CT R		1·5	4·8	3·8	20·0	4·5	1·3	4·2	20·0	4·9	2·4	4·2
VC		62	140	202	26	624	294	944	26	686	434	1146
VCR		95·4	95·9	95·7	58·8	91·2	95·2	90·9	58·8	91·6	95·4	91·8
VCS			2	2	1	10	1	12	1	10	3	14
VCTR			1·4	0·99	3·8	1·6	0·3	1·2	2·8	1·5	0·7	1·2
UC		3	6	9	19	60	15	94	19	63	21	103
UCR		4·6	4·1	4·3	42·2	8·8	4·8	9·1	42·2	8·4	4·6	8·2
UCS		1	5	6	8	21	3	32	8	22	8	38
UCTR		33·3	83·3	66·6	42·1	35·0	20·0	34·1	42·1	34·9	38·1	36·9

Table X shows the transmission rates. They are, in general, higher in the E2 group, though E1 group had higher FTR and UCTR. The difference may not be significant. However, there is an indication that the unvaccinated of the higher economic group are more susceptible than their counter parts of the lower economic group.

Economic status and living accommodation.—The families are divided into three categories as regards their living accommodation, L0 who have no homes at all ; L1 who have only one living room and L2 who have more than one living room. Table X shows the pattern of transmission with reference to economic status and living conditions.

5·9 per cent (15/254) were homeless and 66·1 per cent (168/254) had only one living room the others have more than 1 living room. The homeless had the maximum number of unvaccinated contacts. The transmission rates were higher in the homeless and lowest in the families with better accommodation with more than 1 room to live in. The UCTR again is a little more in L2 Group.

With reference to economic status, in the lower income group E2, the pattern is typical there is a decrease in all transmission rates, with increase in accommodation. But the same is not the case with group E1. In this all transmission rates are higher in families with better accommodation. The particular sub-group E1 L2 are fairly well to do people, who have separate individual houses, whereas in E1 L1 group they live in a single room in over crowded houses, but their income is more because more members of family earn. Whether this high transmission in E1 L2, when compared with E1 L1, was due to lack of basic immunity in them or not cannot be stated definitely. The figures being small, no definite conclusions can be drawn but there is an indication that well to do people living in independent houses who do not come in contact with others freely, to have less basic immunity, in general and so they are more susceptible to smallpox unless they are periodically protected. This requires further study. On the one hand, overcrowding in lower economic group increases the transmission but at the same time, may raise the basic immunity because of close living with either vaccinated persons or subminial expousre to infection with either vaccinia or variola viruses.

Person Load per living room.—To arrive at the combined influence of the living accommodation as well as the size of the family the person load per living room of each family is calculated and its influence on transmission rate pattern is shown in Table XI. Leaving alone the homeless, the transmission was lowest in families with 2·9 persons and below per room and was maximum with 6 to 8·9 persons per living room. It is seen that the transmission is not highest in families with a load of 9 and above. This is because in all such oversized families, not all persons actually sleep inside and hence are not likely to come in close contact with the case. This is noticed in both the economic groups. It is interesting to note, for the same person load 3 to 5·9 all the transmission rate in the group E1 are markedly higher than those in group E2. Under similar conditions of living accommodation the higher economic group seems to fare worse than the lower economic group which aspect is of great significance requiring further study.

TABLE XI.

The intrafamilial transmission of smallpox with reference to living accommodation as reported by person load per living room.

Economic status.	E1 :					E2 :					E1 and E2 :					Homeless.	Grand Total.
Person load per living room.	2·9 and less.	3—5·9.	6—8·9.	9 and above.	Total.	2·9 and less.	3—5·9.	6—8·9.	9 and above.	Total.	2·9 and less.	3—5·9.	6—8·9.	9 and above.	Total.		
PCF ..	14	10	3	4	31	37	103	53	15	208	51	113	56	19	239	15	254
FTO ..		3	1	..	4	1	10	13	3	27	1	13	14	3	31	5	36
FTR ..		30·0	33·3		12·7	2·7	9·7	24·3	20·0	12·9	1·96	11·5	25·0	15·8	12·9	33·3	14·2
C ..	93	62	18	38	211	143	414	294	141	992	236	476	312	179	1203	46	1249
CS ..		7	1		8	1	10	21	3	35	1	17	22	3	43	9	52
CTR ..		11·3	5·5		3·8	0·7	2·4	7·1	2·1	3·5	0·4	3·5	7·0	1·7	3·6	19·5	4·2
VC ..	93	56	17		202	139	386	259	133	917	232	442	276	169	1119	27	1146
VCR ..		90·3	94·5	94·7	95·7	97·2	93·2	88·1	92·2	92·4	98·3	92·8	88·4	94·4	93·0	58·7	91·8
VCS ..		2			2		4	7		11		6	7		13	1	14
VCTR ..		3·6			0·99		1·03	2·7		1·2		1·35	2·5		1·15	3·7	1·2
UC ..		6	1	2	9	4	28	35	8	75	4	34	36	10	84	19	103
UCR ..		9·7	5·5	5·3	4·3	2·8	6·8	11·9	7·8	7·6	1·7	7·2	11·6	5·6	7·0	41·3	8·2
UCS ..		5	1		6	1	6	14	3	24	1	11	15	3	30	8	38
UCTR ..		33·3	100		66·7	20·0	21·4	40·0	37·5	32·0	25·0	32·4	41·7	30·0	35·7	42·1	36·9

Meteorological conditions.—Smallpox was known to be a seasonal disease. In Madras, usually there are two peaks, a high peak in the 1st quarter of the year and a low peak in the 3rd quarter, though every month has a few cases. Though some authors have attributed the seasonal variation to certain meteorological conditions like the absolute humidity, rainfall etc. the monthly admission of smallpox cases at Infectious Diseases Hospital, Madras do not wholly confirm their observations. As far as this study is concerned Table XII shows the details of transmission with reference to the different months of the year along with meteorological conditions. As can be seen from the statement, there is no correlation between the transmission and meteorological conditions. November with heavy rainfall and high humidity is associated with the maximum transmission and similarly the cool and dry month February also.

As has been stated already, the transmission is related to person load per living room. This person load is likely to change from month to month depending upon the weather conditions. For instance, the maximum rains occur in November and December due to North East Monsoon, similarly number of rainy days are more in August and September due to South East Monsoon though rain is not heavy. January and February are the cold months in Madras. Whether these have any influence on the transmission is shown in Table XIII. The transmission rate were definitely high in the rainy months and winter months. Thus, after all the seasonal variations may be only due to again overcrowding forced by weather conditions and not due to the direct effects of the climatic factors.

One more factor that may also play an important role is again the load of the unvaccinated. There seems to be some correlation between the UCR and transmission rates. UCR is changing from month to month and it is maximum in the months of November and February when the transmission rates also were high. Why in certain months more unvaccinated are there, is not known. Even births do not occur uniformly throughout the year. It has been observed over decades that the maximum number of births occur always in the last quarter of the year whether this is responsible for increase in the UCR in November or whether accumulation of susceptible is due to the acceptance of vaccination in certain months of the year by the people due to the religious reasons or social customs has to be considered.

However, the so called seasonal variation may be after all, man made and may not have anything to do with seasons and meteorological factors. If every child is protected as soon as after birth as possible the seasonal trend can be broken.

The infective period of smallpox case.—A smallpox patient is reasonably be considered as potentially infectious from the 1st day of fever till the last scab falls off. But when and how long the cases are really infective, when one could expect the maximum transmission of infection to occur in the families is very important, requiring carefull and detailed consideration. The Graph shows that majority of the susceptible contacts in an infected house got infected in the early stage of the disease of the primary case and not in the later stages. This does not mean that if a susceptible contact is exposed to a scabbing case of smallpox, he is not likely to get infected. Of the 254 primary cases with 1,249 contacts, there were 52 contact smallpox cases (as per the definition given

TABLE XII.

The pattern of intrafamilial transmission of smallpox with reference to seasons and meteorological conditions.

	January.	February.	March.	April.	May.	June.	July.	August.	September.	October.	November.	December.	
Mean Rain fall in millimeter.	12·6	4·6	..	15·1	40·8	55·2	95·6	189·3	164·6	155·6	489·1	219·5	
Mean Relative Hummidity (%).	79·5	83·6	78·0	74·5	63·5	63·0	67·5	77·5	80·0	82·5	85·0	83·0	
Mean Maximum Temperature 0°C.	28·6	30·0	32·8	33·2	37·5	36·0	34·8	33·2	33·0	31·3	29·6	28·3	
Mean Minimum Temperature 0°C.	21·9	22·0	23·4	25·5	27·8	26·7	25·8	24·9	24·9	24·1	23·1	22·1	
PCF	5	17	36	26	27	42	38	25	11	6	14	7	254
FTO		4	5	6	3	4	2	6	1	1	3	1	36
FTR		23·5	13·9	23·7	11·1	9·5	5·3	24·0	9·1	16·7	21·4	14·3	14·2
C	18	83	159	130	115	208	222	134	58	30	49	43	1249
CS		10	5	7	4	7	2	7	1	1	7	1	52
CTR		12·0	3·1	5·4	3·5	3·4	0·9	5·2	1·7	3·3	14·3	2·1	4·2
VC	18	74	145	121	106	192	211	118	56	28	36	41	1146
VCR	100	89·2	91·2	93·1	92·2	92·3	95·0	88·1	96·6	93·3	73·5	95·3	91·8
VCS		4	3	2	1	1	1	1			1		14
VCTR		5·4	2·0	1·7	0·9	0·5	0·5	0·8			2·8		1·2
UC		9	14	9	9	16	11	16	2	2	13	2	103
UCR		10·8	8·8	6·9	7·8	7·7	5·0	11·9	3·4	6·7	26·5	4·7	8·2
UCS		6	2	5	3	6	1	6	1	1	6	1	38
UCTR		66·7	14·3	55·6	33·3	37·5	9·1	37·5	50·0	50·0	46·2	50·0	36·9

earlier) of these two appear to be the 2nd generation cases. Twenty-six per cent (13/50) of the first generation cases have got infected on single day, i.e. the fifth day of the disease of the primary case and 82 per cent (41/50) of the total first generation cases got infected within first six days of the disease of the primary case and no first generation cases got infected beyond the 13th day of the disease of the primary case. This shows that the infection is transmitted through mostly nasopharyngeal droplets as well as the various discharges since by 6th day usually the lesions on the body do not break down releasing any virus. This is partly in agreement with the findings of Downie *et al.* (1961) where virus was isolated from throat washings from the 3rd day of fever of the case and up to the 13th day. Similarly, Downie *et al.* (1965) also found that there is plenty of virus in the saliva in cases who had enanthem even as early as 5th day of fever as evidenced by positive culture of circumoral skin swabs and pillow cover swabs. Thus there is epidemiological evidence and laboratory evidence indicating that the patients void a lot of virus during the first week and so are most infective during that period.

TABLE XIII.

The pattern of intrafamilial transmission of smallpox with reference to the weather conditions.

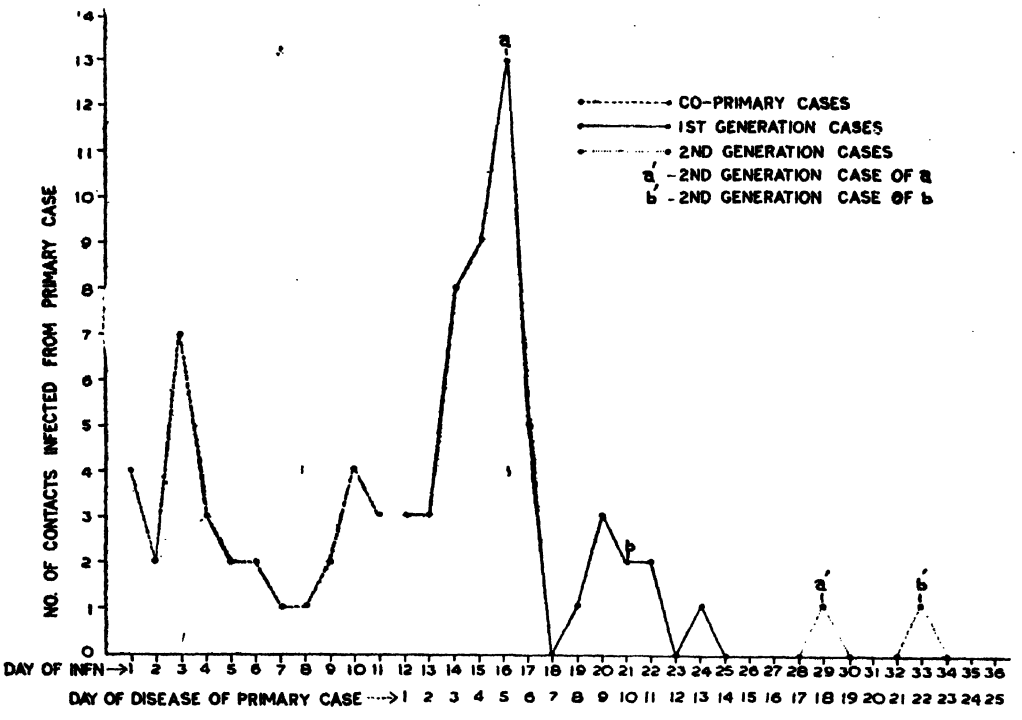
	Cold January & February.	Dry and hot March & July.	Rainy South West Moonson—August to October.	Rainy North East Monsoon—November to December.	Total.
PCF	22	169	42	21	254
FTO	4	20	8	4	36
FTR	18·2	11·2	19·0	19·0	14·2
C	101	834	222	92	1249
CS	10	25	9	8	52
CTR	9·9	3·0	4·1	8·7	4·2
VC	92	775	202	77	1146
VCR	91·2	92·9	91·0	83·7	91·8
VCS	4	8	1	1	14
VCTR	8·3	1·3	0·5	1·3	1·2
UC	9	59	20	15	103
UCR	8·9	7·1	9·0	16·3	8·2
UCS	6	17	8	7	38
UCTR	66·7	28·8	40·0	46·7	36·9

Second generation cases are usually rare in smallpox since all the contacts are as a rule protected on the occurrence of the primary case. But in this study, 2 such cases have occurred who escaped vaccination and who have been in closer contact of the first generation case than with the primary case.

In this study there have been 31 cases of smallpox amongst the familial contacts of the primary case who have been infected before the day of onset of the disease of the primary case. Hence, these were considered as co-primary cases, having been probably infected from a common source, which is extrafamilial. However, we find the maximum

number of co-primary cases have got infected in the first 4 days of the incubation period of the primary case. This high increase in the occurrence of co-primary cases can be explained by two ways.

GRAPH.
The infectivity of smallpox cases



1. If we assume that there is a common source for these primary and co-primary cases, it stands to reason that the original source has infected the maximum number of contacts during the first 4 days of the disease of the common primary source, since a similar pattern has been found in the case of the contact smallpox cases of this study.

2. It may also be possible that a case of smallpox may be infective, during the first 4 days of the incubation period, which has resulted in the infection of higher number of co-primary cases during these four days. It is rather difficult to substantiate this, though monkeys infected by Variola aerosols, have been reported to void virus through nasopharynx during incubation period. If that is so, these so called co-primary cases, or at least part of them, after all, may be actual contact smallpox cases having got infected from the intrafamilial source itself, especially in the first 3 to 4 days of incubation. However, this can be proved one way or other only by culturing throat washings and nasopharyngeal discharges of all the contacts of smallpox patients every day during incubation period and screening whether any of them give positive result for Variola virus during the incubation period and later develop the disease. But even

this may not conclusively prove since nasopharyngeal droplets and throat washings may be negative and still the virus may be multiplying down below the respiratory tract.

From epidemiological point of view this is of great interest. However, since we are not sure about the infectivity of incubating smallpox patients, we can only say with certainty that a smallpox patient is likely to transmit the disease to maximum number of susceptible familial contacts, during the period between the 12th to 17th day of infection, which corresponds to the 1st to 6th day of the disease of the primary case. This period of smallpox case can be considered as the 'Generation time' of smallpox since during this period maximum number of first generation cases of smallpox get infected from the primary case. There is a possibility that a case of smallpox may be infective during the first 4 days of the incubation period through nasopharyngeal droplets or discharges with maximum possibility on 3rd day of infection but there is no definite proof for this assumption.

SUMMARY AND CONCLUSIONS.

1. As a part of the Epidemiological study, the pattern of intrafamilial transmission of smallpox in the contacts in an infected family was studied and reported in the present paper. A series of 254 primary cases with their familial contacts have been studied. These 254 cases have a total of 1249 contacts of whom 103 were unvaccinated. 4·2 per cent of the exposed contacts developed smallpox, with 1·2 per cent amongst the vaccinated and 36·9 per cent in the unvaccinated. This indicates even on an intimate exposure to infection, in a closed family, vaccination offers fair degree of protection.

2. The aim of this study was to find out whether any other factors play a role in transmission of smallpox besides the vaccinial status. These factors may be associated with

(*a*) the source of infection (primary case)

(*b*) the host, i.e. the exposed contacts and

(*c*) the environment i.e. the socio-economic conditions of the family and also the meteorological conditions.

a. Factors associated with the source of infection (primary case).—

(*i*) Though not conclusive yet there is an indication that the severest type the 'haemorrhagic' and the mildest type the 'modified' transmit less infection to their contacts. Whereas the 'ordinary' and 'flat' transmit the most. It looks as though the prsence of enanthem on the mucous membranes of the mouth and nose, and the ambulatory nature of the patients, the stage of disease at which the patient is isolated, or dead, seem to determine to a certain extent the transmission of infection.

(*ii*) Smallpox cases amongst the vaccinated have been found to transmit infection to less people than the case amongst the unvaccinated. Whether vaccinated cases void less virus, or the virus that is voided by them is less invasive and less infective, than that voided out by unvaccinated cases is not known. This aspect requires substantial proof by laboratory means though there is some epidemiological evidence.

(*iii*) Excluding the haemorrhagic there was an indication that the transmission of infection is more in the contacts of fatal cases than in those of survivals and amongst the fatal cases the transmission is significantly higher in the contacts of house deaths than in the contacts of hospital deaths. Perhaps, fear, stress and strain as a result of the death of case of smallpox at home does play some role causing some temporary hormonal disturbances which predispose to infection.

(*iv*) Though the age and sex of a smallpox case should not determine transmission pattern, yet this study revealed that children of the age group 5 to 14 transmitted the disease to far greater number of contacts when compared to persons of other age groups. In the same age group between the sexes the male children transmitted more than the female.

b. Factors pertaining to the host.—(*i*) Though the transmission was significantly high in the children of the age group 0 to 4 yet with reference to vaccinial status, not even a single child in this age group amongst the vaccinated, contracted the disease, in spite of close exposure. This gives an indication that the primary vaccination in infancy confers fairly good amount of immunity upto the age of 4 beyond which that protection wanes out with the increase in the age group with the result that 3 per cent of adult contacts amongst the vaccinated contracted the disease on exposure. In the unvaccinated there is no significant difference in the transmission rates in the different age groups.

(*ii*) There is slight increase in the transmission rates in females in general but the difference is not significant. However, there is a suggestion that adult women of age group 15 to 44 are more susceptible to smallpox when compared to the men of the same age group.

(*iii*) There was no transmission of smallpox in such of those contacts who had not only the primary vaccination marks but also the marks of revaccination said to have been done within 2 years before exposure. But of the contacts who had primary vaccination and successful revaccination said to have been done beyond 2 years one developed the disease. So, a successful revaccination once in 2 years confers solid immunity. In this series of 1,249 contacts there was one second attack of smallpox, a woman who was aged 45 years who had the first attack of smallpox 35 years back. There is no significant difference in the transmission rate between the contacts with single primary vaccination scars or multiple scars though multiple insertions appear to protect more in persons under the age of 14 when compared to single insertion.

Successful primary vaccination even after exposure seems to offer some degree of protection against the disease.

c. Factors pertaining to the environment.—(*i*) There is a strong suggestion that the greater the number of unvaccinated contacts per family, the greater is the transmission rate. Not only the unvaccinated contact transmission rate increased with the increase in the unvaccinated load, but the vaccinated contact transmission rate also increases correspondingly with the increase in the UCR. This suggests the possibility that the

increase in the unvaccinated contacts in the family reduces the overall family immunity, thereby making even the vaccinated more susceptible to infection.

(*ii*) In general it has been found the transmission rates are higher in the lower economic group and in those who live in overcrowded single room quarters. It is also seen that the transmission rate increases with the increase in the size of the family only to a certain limit of 6 to 9 beyond which transmission falls down.

(*iii*) The load of the unvaccinated was uniformly higher in the lower economic group than in the families with better economic status and accommodation. But yet the transmission of smallpox amongst the unvaccinated is more in the higher economic group and families with better accommodation. Though the differences may not be statistically significant yet there is a suggestion that it is possible that people who live in independent houses have less basic immunity when compared to those who live in the houses with several tenants living.

(*iv*) There is no evidence to show that the transmission of smallpox has any relationship with the meteorological conditions like the temperature, humidity etc., but yet it is not uniform every month. There is a suggestion that the transmission may be influenced by over crowding in certain seasons of the year due to weather conditions. For instance the transmission is maximum in the rainy months of November, December and cold months of January and February, whereas it is the lowest in hot months of March to July. Hence it is possible that the seasonal pattern of transmission may be due to the weather conditions that force people to crowd into the rooms. Another factor that may also be responsible for the increased transmission during certain months of the year is that the unvaccinated contact rate in families also changes from month to month. When it is high, the transmission also is high. Thus, it looks as though the so called seasonal variation is only man-made and has nothing to do with the meteorological conditions of the atmosphere and this can be easily broken if every child is vaccinated as soon after birth as possible.

3. *The infective period of smallpox.*—Eighty-two per cent of the first generation cases of smallpox have been infected from the primary case during the first 6 days of the disease of the primary case. And no first generation case got infected after the 13th day of the disease of the primary case and nearly 26 per cent of the 1st generation cases were infected on a single day i.e. 5th day of the disease of the primary case. All these go to prove that infection is mostly transmitted through nasopharyngeal droplets and majority of the susceptible contacts get infected within the first one week of the disease of the primary case.

In this study there have been 31 co-primary cases. These were considered as co-primary because they developed the disease within 12 days of the day of attack of the primary case probably getting infected from a common extrafamilial source. When the day of infection of co-primary case is plotted against the day of infection of the primary case maximum number of contacts got infected during the first four days especially on the 3rd day of infection of the primary case. A suggestion is made that a case of smallpox could be infective during the early part of the incubation

period when the virus multiplies in broncheoles and alveoli of lungs, before it enters the Retticulo endothelial system.

Hence, if we consider the day of infection of the primary case as base line, maximum number of susceptible contacts in the infected families get infected between the 12th to 17th day of infection corresponding to the 1st to 6th day of disease of the primary case. There is also an indication that a case of smallpox can be infective during the 3rd day of infection. Anyhow this requires further study and Laboratory confirmation.

The authors wish to acknowledge with thanks the excellent guidance given by Dr. Cockburn, Virus Division, W.H.O. Head Quarters, Geneva ; Dr. Ignatovish, SEARO, New Delhi ; Col. B.L. Taneja, Director-General, Indian Council of Medical Research, New Delhi, and all his senior Staff. The authors wish to thank Shri J.A. Ambasankar, I.A.S., Commissioner, Corporation of Madras, for his excellent encouragement and for the permission to undertake this study. Special thanks are due to Srimathi A. Lalitha for her active assistance in preparing the paper and maintenance of records.

REFERENCES.

MELVIN RAMSAY, A., and RONAL, T.D. EMOND. (1967) 'Infectious Diseases', 34 and 35. Heinemann Medical Books Limited, London.

RAO, A.R., MCFADGEAN, J.A., and KAMALAKSHI, S. (1966) An isothiazole thiosemicarbazone in the treatment of variola major in man. *Lancet*, 1068-1072.

DOWNIE, A.W. MEIKLEJOHN, L.ST. VINCENT, RATNAKANNAN, N. R. RAO, A.R., KRISHNAN, G.N.V., and KEMPE C.H. (1961) Studies on the virus content of mouth washings in the acute phase of smallpox. *W.H.O. Bulletin*, 25, 49-53.

DOWNIE, A. W., MEICKLEJOHN, M., ST. VINCENT, L. RAO, A.R., SUNDARABABU., and B.V., KEMPE, C.H. (1965) The recovery of smallpox virus from patients and their environment in a smallpox hospital. *Ibid.*, 33, 615-622.