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TRANSMISSION OF SMALLPOX IN ENDEMIC AREAS

by

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Introduction

At the start of 1969, 27 countries in the world were considered to be smallpox endemic areas, and these accounted for over 99 per cent of the world's smallpox.

By definition, an endemic area is one in which a certain minimum number of smallpox cases appear each year--we may say arbitrarily an average of at least 50 reported cases a year. What this means is that smallpox is constantly present in the area concerned and is being transmitted, even though the cases may not be detected and reported month by month.

This presentation will deal with some of the basic features of transmission of smallpox in an endemic area, and will be illustrated with data from studies that have been carried out in West Pakistan during the past four years. These were:

a. Epidemiologic investigations of smallpox in Sheikhupura District, West Pakistan, 1966-67. In these studies, an attempt was made by intensive surveillance to detect and characterize all outbreaks that occurred in a single rural district (population: 1.1 million) over a period of one year.

b. Survey of Lahore Municipal Corporation, West Pakistan, 1968-69. A survey of vaccination status and past smallpox experience of an urban population.

c. Epidemiologic studies in six districts of West Pakistan, 1968-69.

These investigations were carried out by the Pakistan Medical Research Center (University of Maryland International Center for Medical Research and Training), 6 Birdwood Road, Lahore, Pakistan, and were supported by Grant No. TW00142 (ICMRT) from the National Institutes of Health, Bethesda, Maryland, U.S.A. The studies of smallpox in Sheikhupura District, 1966-67, which provided the major part of the data referred to in this presentation, were conducted by Dr. D. B. Thomas and Dr. T. M. Mack, and are now in preparation for publication. Subsequent studies were conducted by Dr. G. G. Heiner, Dr. Nusrat Fatima, and Mr. Asghar Ali.

Transmission of Smallpox in Endemic Areas

1. Susceptibility of the population.

An apparently high level of vaccination (in terms of vaccination scar status) does not always mean that a population is adequately protected against smallpox. Even a relatively well-vaccinated population may have substantial numbers of unvaccinated susceptibles in the youngest age groups; and these may be more than enough to ensure transmission of disease and to sustain an endemic level of smallpox. Furthermore, an unknown but considerable number of persons who have been vaccinated have actually again become susceptible as their immunity has waned.

See Table 1. In a survey of Lahore, West Pakistan, in 1968-69, 90.1 per cent of persons examined were found to have vaccination scars, and 92.9 per cent had vaccination scars or a history of past smallpox; this represents a relatively high level of immunization. However, if one takes the converse of these figures, one finds that 60.6 per cent of infants, 15.6 per cent of children of age 1-4 and 4.6 per cent of children of age 5-9 were still fully susceptible.

2. What persons are most at risk?

In all endemic areas, children represent the majority of susceptibles--and hence the majority of cases. Table 2 gives a breakdown of all smallpox cases detected in a one-year period (1966-67) in Sheikhupura District, West Pakistan. 55.7 per cent of all cases were children of less than 10 years. Attack rates of school-age children (5-14 years) not attending school (and thus less accessible to vaccinators) were six times higher than attack rates of children attending school.

The majority of cases occur in the unvaccinated, but a considerable number of cases also occur in persons who have been vaccinated. In the Sheikhupura studies, 12.9 per cent of cases were known to have scars, and the total number was probably considerably higher.

Infants as a group should be considered as susceptible from birth. Studies in West Pakistan in 1968-69 indicate that maternal antibody protection is highly variable and therefore undependable. Cases have been noted in infants as young as two months.

3. Transmission of smallpox to contacts.

Once a case of smallpox appears in a locality, transmission occurs primarily among close contacts of the case; and the extent of spread to those contacts will largely determine the further course of the outbreak.

See Table 3. Among household and compound contacts of smallpox

cases in 47 outbreaks, the attack rate of unvaccinated contacts was 65.7 per cent, while that of previously vaccinated contacts was only 4.3 per cent. This demonstrates the highly protective effect of vaccination, even in persons who may have been vaccinated only in childhood. Preliminary results of these studies also appear to confirm the effectiveness of vaccination or revaccination soon after exposure.

4. Characteristics of outbreaks.

Smallpox is not a highly infectious disease, and its spread both within a locality and between localities is usually low. In an endemic area, most of the outbreaks are small, most are of short duration, and many burn themselves out without further spread. On the other hand, the very fact that transmission is slow means that an outbreak may continue to smoulder for many months if not detected, thus representing a persistent focus of infection. This basically is how endemic smallpox is maintained.

See Table 4. In the studies in Sheikhupura District, more than a quarter of the 120 outbreaks detected consisted of one case only and over 60 per cent consisted of five cases or less. One third of the outbreaks had only import cases, with no further transmission; and in those where further transmission did occur, the average duration of an outbreak was 50 days. However, some of the outbreaks continued for two months, three months, and even longer.

5. Transmission of smallpox between localities.

The pattern of spread of smallpox will vary in different endemic areas. However, there is a general tendency for cities to serve as foci of infection and thus to generate a disproportionate number of outbreaks in surrounding areas.

See Table 5. Among outbreaks of known source in Sheikhupura District in 1966-67, more than a quarter could be traced directly to cities and more than half could be traced directly or indirectly to cities.

"Carriers" of smallpox between localities can also be identified. In Sheikhupura, 56 per cent of outbreaks of known origin were initiated by children under 15. At least 50 per cent and probably nearly 80 per cent of the outbreaks were caused by import cases who were unvaccinated. Furthermore, other studies suggest that the infectivity of unvaccinated cases (in terms of secondary cases attributable to them) is greater than that of cases who were previously vaccinated.

6. Seasonal incidence of smallpox.

Smallpox has a very marked seasonal pattern in endemic areas, although the exact pattern varies from region to region. Throughout West Pakistan, there is a peak in winter and early spring and a very

low ebb in summer and early fall. See Figure 1.

On the other hand, the course of smallpox outbreaks may be very erratic within a given country and from year to year. The disease may disappear temporarily from certain districts, and its reappearance will then depend both on the accumulation of sufficienct numbers of susceptibles and on the development of adequate foci of infection in adjacent districts. The lower the level of disease, the more important these factors become.

Conclusions

This examination of the patterns of transmission of smallpox in endemic areas has many obvious lessons for smallpox eradication:

1. Vaccination scar status is not always a reliable index of the susceptibility of a population to smallpox. Even in a relatively well-vaccinated population, there may be large groups of susceptibles, consisting primarily of unvaccinated infants and children but also including some vaccinated persons whose immunity has waned.

2. The value and importance of vaccination in preventing smallpox is amply demonstrated in studies of household contacts, who are the persons at highest risk. Attack rates in the unvaccinated are 15 times as high as in vaccinated contacts.

3. Studies in West Pakistan indicate that unvaccinated children who are not attending school constitute the major single group of susceptibles. Effective vaccination coverage of this group alone would eliminate about two-thirds of the potential smallpox cases in an area, and also the most important carriers of the disease between localities.

4. An eradication program should include an adequate emphasis on cities, since urban areas tend often to be persistent foci of infection and thus play a disproportionate role in generating smallpox outbreaks in surrounding areas.

5. The unique patterns of smallpox transmission provide excellent opportunities for eradication efforts. At any given time, only a relatively small percentage of localities in an endemic area are affected; and the spread of the disease is usually slow, both within a locality and between localities. Thus, with adequate surveillance and follow-up operations, it often is a relatively easy task to break the chains of transmission. The marked seasonal pattern of smallpox provides an additional advantage; the detection and control of only a few outbreaks during the months of low incidence may serve to forestall most or all potential outbreaks in an area during the following smallpox season.

TABLE 1

In a given population, what is the vaccination level--and what is the susceptibility level?

(Data from vaccination survey of Lahore Municipal Corporation, West Pakistan, 1968-69, preliminary findings. All figures are percentages of persons examined.)

a. Persons with vaccination scars:

Age	Percentage with scars
Less than 1	39.4
1-4	84.1
5-9	94.4
10-19	96.6
20 and above	91.1
Total	90.1

b. Overall level of immunization:

Age	Percentage with vaccination scars or history of smallpox
Less than 1	39.4
1-4	84.4
5-9	95.4
10-19	97.8
20 and above	96.5
Total	92.9

c. Persons with definite susceptibility:

Age	Percentage with no vaccination scars and no history of smallpox
Less than 1	60.6
1-4	15.6
5-9	4.6
10-19	2.2
20 and above	3.5
Total	7.1

d. Persons who may be susceptible (vaccinated persons whose immunity has waned):

Unknown.

TABLE 2

What persons are most at risk? Who are the smallpox cases?

(Data from studies of smallpox in Sheikhupura District, West Pakistan, 1966-67.)

a. Distribution of cases by age:

Age	Cases	
	No.	% of total
Less than 1	58	6.5
1-4	201	22.4
5-9	241	26.8
10-19	229	25.5
20 and above	169	18.8
Total	898	100.0

b. Attack rates per 10,000 by school attendance* for children of age 5-14 years:

Attending School	No. Cases	Attack Rate
Yes	28	3.0
No	349	19.2
Unknown	4	---
Total	381	13.9

* Based on 1961 census

c. Distribution of cases by vaccination status:

Vaccination Status	Cases	
	No.	% of total
Scar	134	12.9
No scar	543	52.2
Probably no scar*	164	15.8
Unknown	199	19.1
Total	1,040	100.0

* Cases which died or had confluent lesions preventing examination for vaccination scars.

TABLE 3

Transmission of smallpox to contacts

(Data from studies of smallpox in West Pakistan, 1968-69.)

Attack rates by vaccination status for household and compound contacts of the first case in 47 outbreaks:

Vaccination Status	No. Contacts	No. Secondary Cases	Attack Rate (%)
Scar	277	12	4.3
No scar	70	46	65.7
Uncertain*	16	16	---
Not examined	50	5	10.0
Total**	413	79	19.1

* Died or had confluent lesions preventing examination for vaccination scars.

** 30 contacts with history of previous smallpox excluded.

TABLE 4

What are the characteristics of outbreaks?

(Data from studies of smallpox in Sheikhupura District, West Pakistan, 1966-67.)

a. Size of outbreaks: Distribution of outbreaks by number of cases:

No. Cases	Outbreaks	
	No.	% of total
One case only	33	27.5
2-5	40	33.3
6-10	26	21.7
More than 10	21	17.5
Total	120	100.0

b. Duration of outbreaks: Distribution of outbreaks by duration in days:

Duration in Days	Outbreaks	
	No.	% of total
Less than 10 days (import cases only; no transmission)	40	33.3
10-19 days	16	13.3
20-39	28	23.3
40-59	12	10.0
60-99	13	10.8
100 and above	11	9.2
Total	120	100.0

TABLE 5

Transmission of smallpox between localities

(Data from studies of smallpox in Sheikhupura District, West Pakistan, 1966-67.)

a. Source of outbreaks: Distribution of outbreaks of known source by size and location of source locality:

Source	Outbreaks	
	No.	% of total
Direct urban source*	20	27.8
Indirect urban source	18	25.0
Direct or indirect urban source	38	52.8
Other	34	47.2
Total with known source	72	100.0

* Urban = localities with more than 100,000 population

b. "Carriers" of smallpox: Distribution of import cases by age and sex (in outbreaks of known origin):

Age and Sex	Import Cases	
	No.	% of total
Under 15 (both sexes)	42	56.0
15 and above (male)	22	29.3
15 and above (female)	11	14.7
Total	75	100.0

c. "Carriers of smallpox: Distribution of import cases by vaccination status (in outbreaks of known origin):

Vaccination Status	Import Cases	
	No.	% of total
Scar	6	8.0
No scar	37	49.3
Probably no scar*	22	29.3
Unknown	10	13.3
Total	75	100.0

* Cases which died or had confluent lesions preventing examination for vaccination scars.

Figure 1

Seasonal Distribution of Smallpox Cases
in Sheikhupura District, West Pakistan,
1966-67