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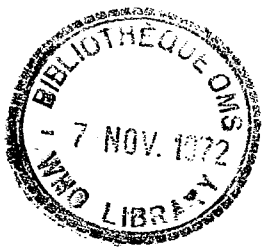

SMALLPOX SURVEILLANCE IN THE STRATEGY OF GLOBAL ERADICATION

by

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Smallpox surveillance represents the single most important component of the present global eradication effort. In fact, the ultimate success or failure of the eradication programme depends principally upon our capability to develop an effective surveillance system in each country and on a global basis. It is only within the past five years, however, that this has been fully appreciated.

In the past, a programme of smallpox eradication was considered to be virtually synonymous with a mass vaccination campaign. Originally, national programmes were so designed. Some were effective but many were not. When it became apparent that mass vaccination alone was often unsuccessful, programmes were enjoined to increase their targets for vaccination coverage from 80% to 100%[1]. The actual objective of the programme, "the eradication of smallpox" was obscured by an alternative goal, "vaccination of 100% of the population".

While total vaccination of the entire population is a worthy objective and, if successful, would assure eradication of smallpox, such coverage is logistically and practically impossible. In fact, as efforts are made to increase vaccination coverage beyond 80% to 85%, the costs and difficulties increase logarithmically while immunity levels increase only arithmetically. Even with 90% of the population vaccinated, smallpox transmission may still persist. On the other hand, it is known that some countries have become smallpox-free at a time when much less than 80% of their populations have been vaccinated. In the development of the global programme, it thus seemed more logical to reconsider the strategy in terms of the actual objective, "eradication of smallpox", and to determine how best to interrupt completely transmission of the disease rather than to focus attention solely on methods to vaccinate all of the people.

The most direct approach to eradication is to interrupt transmission of smallpox through the containment of outbreaks. We know that focal outbreaks of smallpox can be rapidly and effectively controlled. This has been repeatedly demonstrated when the disease has been introduced into non-endemic areas. Even in countries such as Ceylon or the United Kingdom, for example, where immunity levels are, in fact, poorer than in most presently endemic countries, outbreaks have been rapidly terminated by comparatively limited but specific containment measures. The explanation for this is quite simple. When a country becomes smallpox-free, the occurrence of a single suspect case is usually cause for considerable alarm; the problem is dealt with as a public health emergency. In endemic countries, however, health authorities and indeed the population as a whole are less concerned. They regard the disease as an inevitable occurrence. In endemic countries, the various sites which could report cases often do not do so or they report only after a long delay. By the time the problem is recognized, the outbreak has spread not only within their own health jurisdiction but to other areas. By increasing immunity levels in the population, this problem can be partially countered. In a more highly immune population, transmission is less rapid. This may compensate in part for slower and comparatively less complete reporting and less effective containment measures.

In considering the strategy of the programme, therefore, it appeared that the probability of any country becoming free of smallpox and remaining so was principally a function of two components - first the level of immunity in the population and, second, the capability of the health service to detect and contain outbreaks.

Least developed, and in some countries, virtually non-existent at the beginning of the eradication programme was the second principal component, surveillance - which, as we have defined it, includes the detection as well as the containment of outbreaks of the disease. In many endemic countries, immunity levels were already at moderately high levels and continuing vaccination programmes were in progress. Higher levels of immunity could be achieved comparatively simply by improving vaccine quality and storage and by augmenting supervision of vaccinators. In a few countries, intensive programmes of vaccination needed to be specially organized. In none, however, were programmes of smallpox surveillance and outbreak containment more than vestigial. This component of the programme was felt to be at least as important as the vaccination effort and, since it was virtually non-existent in most of the countries, we have felt that its development deserved more attention than the vaccination activities themselves.

Surveillance of smallpox is probably easier than for any other communicable disease. In smallpox, the infected person develops a distinctive rash which is wholly characteristic in the great majority of cases[2]; the rash is most dense over the face and hands, the unclothed readily visible portions of the body; persons with subclinical infections are rare and are of little importance since they do not appear to be able to transmit the disease to others.[3] In brief, the disease characteristics are such that there is little difficulty in detecting visually whether or not the virus is present in an area. The rash is sufficiently characteristic in the great majority of cases that laboratory confirmation is academic. In addition, in the instance of variola major, fully 75 per cent of cases are left with visible scars[4], most notable over the face. Thus, in Asian countries, for example, where variola major is the principal if not the only form of the disease, we can estimate the extent of past infection by simple surveys which determine the prevalence of the characteristic facial scars. By relating these observations to the age of the individual, we can also estimate the most recent period when infection was present. If, for example, none below the age of 15 years have facial scarring characteristic of smallpox, it may be inferred that there has been little or no infection in the area in the preceding 15 years.

The first requisite in surveillance, identification of where the disease exists, is thus comparatively simple.

Additionally, smallpox has several epidemiological characteristics which, as a group, are unique. In brief, these are as follows:

1. Smallpox is transmitted solely from man to man. There are no known animal reservoirs;[2,5] insects appear to play no role.

2. Detection and recognition of the disease is a comparatively simple matter, as previously noted. Persons with subclinical infection are rare and of little importance epidemiologically since they do not appear to be able to transmit disease.

3. The infected individual is capable of transmitting infection during a comparatively brief period - from emergence of the first lesions until the scabs have fallen off - a period of about four weeks. Following infection, he has essentially permanent, lifetime immunity.

4. Transmission requires close contact between infected and susceptible individuals and most commonly occurs in the home, the hospital or school.

5. Epidemics develop comparatively slowly. Between each generation of cases, there is a period of two to three weeks. In most circumstances, the infected individual transmits disease to not more than 2 to 5 other persons.

It is precisely these characteristics which permit the surveillance activities in a smallpox eradication programme to be as highly effective and practicable as they are. The significance of these characteristics is better appreciated as one considers the manner in which the transmission of smallpox is sustained.

Since smallpox is transmitted solely from man to man and since the infected individual can only transmit the disease over a period of four weeks or less, it is apparent that a "chain of infection" is required if the disease is to remain endemic in an area. For smallpox to persist, an infected person with clinically apparent disease must infect a second person who similarly must develop clinically apparent illness and so on to subsequent generations. Since there is a lapse of two to three weeks between generations of cases, we can by simple arithmetic determine that the most tenuous chain of transmission in a country requires that at least 15 to 25 cases occur annually. If fewer cases than this are recorded, only two explanations are possible: reporting is incomplete, or the cases represent reintroductions of smallpox. It is also apparent that when any country reaches the level of perhaps 200 to 500 cases in a year, there are few chains of infection extant and that fairly simple containment procedures should readily and rapidly be able to interrupt subsequent transmission.

Transmission most commonly occurs as a result of close contact as in a household, hospital or school. Contrary to common belief, casual contact as might occur in markets or on public transportation comparatively infrequently results in transmission. Noted below are illustrative outbreaks.

Locale of infection	United Kingdom 1961-1962[6]	Sweden 1963[7]	Kuwait 1967[8]	Abakaliki Nigeria 1967[9]	Bawku Ghana 1967[10]
Imported	5	1	1	1	?2
Household (or compound)	17	13	1	30	58
Hospital and other medical	39	13	32	0	0
Market	0	0	0	1	3
Other and unexplained	6	0	8	0	5
	67	27	42	32	68

Despite the fact that in each of these outbreaks, there were a number of patients who were ambulatory following the onset of illness and in casual contact with many persons, comparatively few cases occurred which could not be readily traced to household or hospital contact. Often disregarded in the tracing of cases, the hospital can be an important source as illustrated in the first three outbreaks. Although in the outbreaks cited above, contact in schools played no apparent role, studies in Brazil have shown that the schools may also be instrumental in some circumstances in disseminating infection throughout a community[11]. Since hospitals are few in number in endemic countries, it is evident that most individuals must acquire infection through household contact as, in fact, they do. Since the infected person rarely transmits disease to more than 2 to 5 additional persons, the disease spreads comparatively slowly, usually among other household residents, neighbours and visiting relatives. Not unexpectedly, then, smallpox occurrence is characterized by highly localized focal outbreaks involving a comparatively few houses or a few villages in an area. This is quite the reverse of the common belief that when smallpox occurs in a country, it is a widely dispersed infection with single cases scattered over an extensive geographic area.

In this context, it is interesting to note recent observations in India and Pakistan, two countries which account for two-thirds or more of all recorded cases of smallpox. In Pakistan, during the course of one year, an intensive surveillance programme was conducted in a rural district of 1.2 million persons.[4] During the period, 1 040 cases occurred, an incidence as high as that observed anywhere in the world. However, throughout the course of the entire year, only 170 of the 1 700 villages (10%) were infected with smallpox. In December 1967, an assessment survey in a highly endemic district of India,[12] similarly revealed that during the course of the year only 101 of 2 331 towns and villages were afflicted with smallpox. At no time were more than 20 (1%) of the villages afflicted and, at the seasonal low point of smallpox, only seven villages recorded disease. Thus, even in these highly endemic areas, smallpox occurred not as a widely dispersed sporadic disease but as concentrated pockets of infection sustained by a tenuous chain of transmission. Prompt case investigation coupled with active efforts to trace infection sources and comparatively simple containment activities could have had a major impact on disease incidence and might well have terminated all transmission. One effective epidemiological team in each of these Districts could have dealt with the problem.

Vaccination programmes conducted during past years undoubtedly have had a decided influence in reducing the proportion of susceptibles and thus reducing the probability of further spread. Successful vaccination confers substantial protection for many years and undoubtedly is partially protective for at least 10 to 20 years. Although the duration of protection conferred by a single successful vaccination is unknown, recent data show almost universally that 85% to 95% or more of all cases have no scar of vaccination to confirm the fact that they had been successfully vaccinated. Although many individuals state they have been vaccinated in the past, such a history is of dubious value considering that in 1967, at the beginning of the eradication effort, less than 20% of the vaccine in use in endemic areas met the prescribed potency standards. The impact of prior vaccination is most vividly illustrated by studies conducted by Rao and his colleagues in Madras.[13] They found that among 103 unvaccinated family contacts, 37% contracted the disease while among 1 108 who had at some time been vaccinated,

only 1% contracted smallpox.

Age	Frequency of smallpox among vaccinated and unvaccinated contacts - Madras[13]			
	No. of unvaccinated* contacts	No. of cases of smallpox	No. of previously vaccinated contacts	No. of cases of smallpox
0-4	57	23	118	0
5-14	18	4	287	2
15-44	15	9	543	10
45+	13	2	160	1
	103	38 (37%)	1 108	13 (1%)

* Unvaccinated at time of exposure.

Further, those previously vaccinated who did contract smallpox were far less effective in transmitting it than were those individuals who were unvaccinated.

Frequency of transmission from unvaccinated and previously vaccinated cases to vaccinated and unvaccinated contacts, Madras, India[13]						
	Contacts					
	Vaccinated			Unvaccinated		
	No.	No. developing smallpox	%	No.	No. developing smallpox	%
Case - previously vaccinated	527	2	0.4	32	9	28
Case - unvaccinated	619	12	1.9	71	29	41

This observation is consistent with laboratory studies which have shown that the quantity of virus excreted by a patient correlates with the number of lesions present in the mouth.[14] Individuals who have previously been vaccinated tend to have fewer lesions both on the skin and on the mucous membranes and so excrete less virus and have greater difficulty in infecting others. Those with significantly attenuated illnesses and few lesions, the group which may be troublesome diagnostically, are fortunately of less epidemiological significance for this reason.

As the unvaccinated play the major role in perpetuating smallpox transmission, the strategy of eradication campaigns has focused particularly on identification of which groups are especially poorly vaccinated. The word "group" is stressed for

it is obvious that unvaccinated individuals widely scattered throughout a well-vaccinated community do not encounter sufficient susceptibles to sustain the chain of transmission of smallpox for very long and the disease soon dies out. A group of major concern in most countries are those in the lower socio-economic stratum in the cities and towns. Significant numbers in the lower socio-economic group are poorly vaccinated migrants, often from rural areas, who enter the cities and settle among other migrants in densely crowded quarters. Smallpox is readily transmitted under such circumstances. As the migrants travel back to the rural areas, either permanently or to visit, they carry the disease with them. In the previously mentioned study in Pakistan[4], it was found that almost two-thirds of all outbreaks in the rural areas originated from major urban centres. Vaccination programmes in urban areas have rarely in the past made provision for intensive and repeated vaccination campaigns in this highly mobile, rapidly changing group.

A second principal group of concern is children. In most countries, two-thirds or more of all cases occur among those less than 15 years of age. Several studies have shown that young children in particular are excellent vectors of the disease. While those attending schools are readily vaccinated, pre-school children and older children who are not attending school are frequently poorly vaccinated. As children tend to move more actively throughout a community than do their elders, they transmit infection more widely and often serve to transmit the disease between houses or compounds.

Other high-risk groups serving as a reservoir of infection may be identified in the course of a programme so that continuing vaccination activities may be more intelligently directed. How may this be done? Clearly, the most efficient approach is through surveillance - by determining among which groups cases are occurring and the manner by which disease is spread from place to place. Two examples may help to illustrate this, albeit in a negative way. In western Africa, considerable energy and expense were initially directed to secure good vaccination coverage of the very large groups of nomadic herdsmen who roam the Sahel. Epidemiologic studies, however, determined that although these nomads were sometimes responsible for transmission of smallpox from one area to another, they did not serve as a continuing reservoir for the disease. The reservoir of smallpox was clearly shown to be the sedentary population with whom they came in contact. The programme strategy was modified, with considerable savings, to assure good coverage of the sedentary groups while accepting less satisfactory coverage of nomads. A similar situation prevailed in Afghanistan where heroic efforts were initially made to vaccinate women in purdah, a most difficult group to reach. Epidemiologic studies revealed, however, that almost 90% of cases were occurring among children. Few cases occurred among adult women who apparently were not only secluded from the outside world but from exposure as well. In each of these examples, surveillance was intelligently applied to govern the direction of the vaccination programme itself.

But, in the developing countries today, how can a surveillance programme be expected to function? Repeatedly, we are told that medical personnel are nil, that there is no one who can report cases of smallpox and that there are great uncharted sparsely populated areas in which there are few or no government authorities at all. If we keep in mind certain of the characteristics of smallpox epidemiology which we have discussed and bear in mind that there must be a chain of transmission for the

disease to sustain itself, the problem may be seen to be much less impossible than would first appear. In the least developed countries, one consistently finds a surprising number of widely distributed government and mission hospitals, aide posts and the like which regularly attend to persons who are ill. In several endemic countries, malaria workers visit all houses over very large areas every 30 days. The first step, therefore, in the surveillance operation is to identify those who can report suspect cases, to enlist their support and to promote regular and prompt reporting from each as to whether or not smallpox cases have been observed. In endemic areas, diagnosis is not usually a serious problem - even the local populace is frequently astute in smallpox diagnosis. This simple network may be augmented by reports of suspect cases received from schoolteachers, village development workers, village headmen, etc. At the same time, the reporting network is being set up, mobile investigation and outbreak containment teams should be created, preferably headed by a physician, although such as a competent health inspector or nurse can do an excellent job. In highly endemic areas, one team may be required to cope with problems in a population area as small as perhaps 1 to 2 million persons. As incidence falls, one team may be sufficient for an area encompassing 5 to 25 million persons. These teams can serve to investigate cases promptly, to undertake containment measures and to trace the source of infection of cases. If the incidence of disease is high, such a team may be able to take action only in a proportion of the outbreaks, but as incidence falls, an increasingly greater proportion of cases and outbreaks can be attended to. The activities of such a team will serve automatically to stimulate reporting and the team itself will be engaged in case finding. Obviously all cases will not initially come to recognition. Outbreaks may occur in remote villages and be undetected. But, keeping in mind that for smallpox to persist as an endemic disease, an uninterrupted chain of infection is necessary. It is apparent that outbreaks in remote areas will either die out or come to recognition when the sources of infection of subsequent cases are sought. As noted previously, smallpox does not erupt as a sudden conflagration involving thousands of cases overnight but, rather, outbreaks evolve comparatively slowly with intervals of two to three weeks between generations of cases and with comparatively few becoming infected from each successive case. Thus, although four, five or six generations of cases are missed, an outbreak even at that point in time is numbered not in thousands but, at most, by a few hundreds of cases or less and is manageable by isolation, rapid widespread vaccination and tracing of infection sources. As noted in the examples of the districts in India and Pakistan, comparatively few epidemiological "fire-fighting" teams are required - the cost of such teams is negligible compared to the costs necessary to increase immunization levels country-wide by even 5 or 10 per cent.

Interruption in the chains of transmission of smallpox can occur very rapidly. The most notable example in the current eradication effort is that of the countries of western and central Africa (fig. 1). In this area with a population of 120 million persons, distributed over an area larger than India or Brazil, with health services and medical resources far less than either country, a programme of smallpox eradication began in 1967. Some countries, in fact, did not commence until 1968. From various surveys, reporting in many areas was estimated to be less than 5 per cent at the beginning of the programme. Systematic vaccination and surveillance activities were begun more or less simultaneously. By the time that 80% of the systematic vaccination programme was completed, smallpox incidence had fallen to nil.

The last confirmed cases of smallpox occurred, in fact, in May 1970, little more than three years after the programme had begun. Most noteworthy among the countries in this area are Guinea and Sierra Leone, which in 1967 recorded a higher incidence of smallpox than any other countries in the world. Their programmes began in January 1968 and less than 18 months later, both were smallpox-free.

Does this mean that every last person or every last village had been vaccinated? Definitely not! Systematic vaccination served to reduce transmission to the point where surveillance measures were able to interrupt the chain of infection but it was surveillance which represented the specific and definitive weapon in the campaign.

That surveillance is the key to the eradication programme I believe should, by now, be clear. Let me go one step further and say that if the responsible authorities in all endemic countries were to comprehend fully the importance of this measure and were to take definitive action along the lines noted, global smallpox eradication within a period of three years could be a practical reality.

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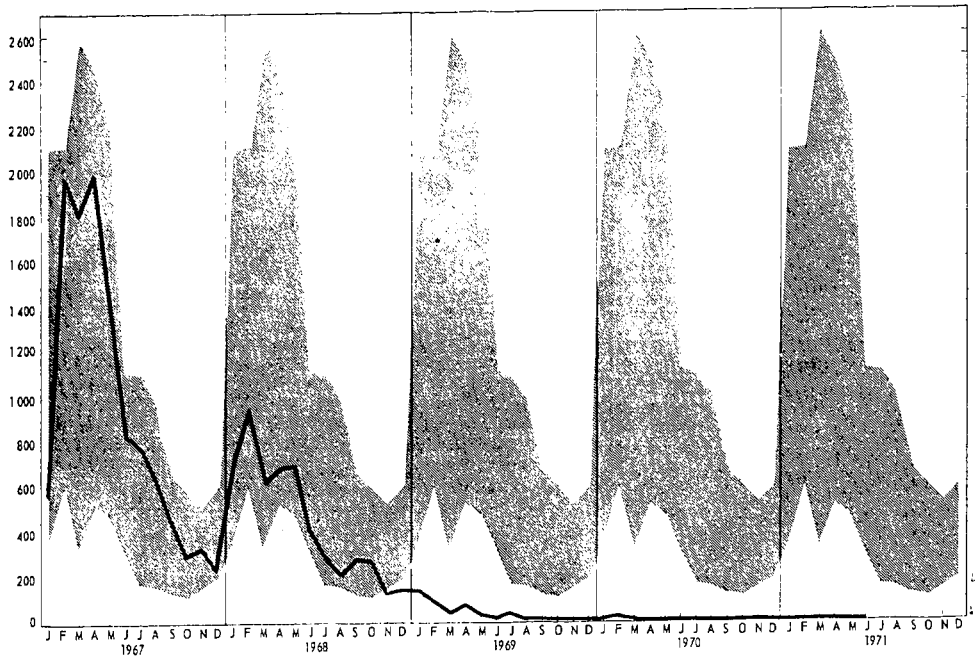
FIG. 1

SMALLPOX INCIDENCE: AFRICA, WEST AND CENTRAL 1967-1971



The grey area represents the range between the highest and lowest incidence reported during the five-year period 1962-1966

ANNEX I

SURVEILLANCE - CONTAINMENT OPERATIONS

PRINCIPLES AND OPERATIONAL PROCEDURES

I. Purpose

II. Epidemiological and other relevant considerations

III. Steps in the surveillance - containment operations

IV. Return visit to the area

V. Surveillance in areas already vaccinated in a systematic programme

VI. Composition of the team and administrative relationships

VII. Forms for use in reporting results

I. Purpose: to investigate every suspect case of smallpox notified through conventional reporting channels or through other sources such as malaria personnel, news media, etc;

to confirm the diagnosis;

to determine the source of infection and to trace the chain of transmission;

to detect other cases in the immediate area;

to contain the outbreak through:

isolation of cases at home or in hospital;

vaccination of household contacts;

vaccination of other residents in the area and special groups at risk such as those in schools and hospitals.

II. Epidemiological and other relevant considerations

National reporting of smallpox cases in all endemic countries is acknowledged to be incomplete. While total reporting for any disease is unlikely to be achieved in any country, a number of steps can be taken which will significantly improve the completeness of reporting. The more complete and accurate the count of cases, the better is our knowledge of the extent and location of the disease problem and the better able we are to cope with the disease. In smallpox, this is particularly true.

Many cases which come to the attention of authorities at peripheral levels are not reported to state or national authorities simply because of lack of interest and the knowledge that no action or assistance results from such reporting. In brief, reporting is regarded as a "statistical exercise". Other cases of smallpox are cared for at home and never brought to the attention of medical personnel.

Experience has shown that when special assistance is promptly provided in response to the report of cases of a disease, reporting of recognized cases rapidly improves. By this means, it is made apparent to those concerned that there is a reason for reporting and that some assistance will be provided in response to the submitted reports. Many other cases, for whom medical attention has not been sought, may be discovered through comparatively simple case-detection techniques.

To investigate all smallpox cases in a state or country which records perhaps 200-500 cases per year, would seem, at first, to be a formidable task, requiring a great many personnel. If smallpox cases were randomly and widely scattered throughout the area, the task would indeed be difficult. Epidemiological studies in Asia, Africa and Brazil consistently show, however, that most cases occur in localized clusters or outbreaks; that the disease normally spreads comparatively slowly from one area to another and that at any given time no more than a small percentage of the towns or villages in a wide geographic area experience infection. Partly this may be attributed to the fact that in most countries, vaccination has been performed for many years and the population as a whole already enjoys a moderate level of immunity. The spread of smallpox is thus partially retarded by this immune barrier. Additionally, as will be described, smallpox itself spreads comparatively slowly. It does not erupt and spread rapidly as influenza or measles. For these reasons, a single epidemiological team of two to five persons can be expected to deal effectively with as many as 200-500 reported cases per year. Each outbreak, if reasonably effectively contained, interrupts or partially interrupts the chain of transmission. The reservoir of infection is decreased. The probability that other outbreaks will originate from this source is also decreased. If containment measures are competently carried out, fewer and fewer outbreaks can be expected. As this segment of the eradication programme is proceeding, the continuing programme of systematic vaccination serves to expand the immune barrier and acts also to decrease the spread of infection. The two segments of the programme attack the smallpox problem from two different vantage points and together can rapidly reduce the incidence of smallpox to "0".

In the investigation of cases and in the containment measures taken, several epidemiological features of the disease are of particular importance. Of greatest importance is to keep in mind that smallpox spreads from person to person in a continuing chain of transmission. The infected individual normally has a very noticeable and distinctive rash. In most outbreaks it has been found that 85-90 per cent. of cases are sufficiently typical to present no problem in diagnosis. Recent studies also show that those with mild, atypical illnesses transmit infection much more poorly than those with more severe, typical illnesses. Thus, the failure to detect the comparatively few mild atypical cases rarely has serious epidemiological implications. In brief, the chain of transmission of smallpox can usually be readily identified. Sub-clinical cases are infrequent and since they are incapable of transmitting infection to others, they are of academic interest only.

In the spread of smallpox, one individual with evident, readily diagnosable lesions infects one or several others who become ill between seven and 17 days later with similar readily diagnosable disease. An infected individual rarely succeeds in infecting more than two to five others even in crowded areas in which few of the contacts are immune. Since two to three weeks must elapse between each generation of cases, it is evident that outbreaks of significant size require many weeks or months to emerge. Accordingly, the spread of smallpox in an area proceeds slowly. Thus, even though notifications have been delayed, prompt containment action can still be effective in aborting major outbreaks.

Transmission of smallpox from one individual to another normally requires very close contact. Generally, it has been found that 80 per cent. or more of cases contract infection through household contact, either as a family member or visitor to the household, in schools or in hospitals, either as a patient, staff member or hospital visitor. Surprisingly, transmission in aeroplanes, buses, trains and markets has been infrequent, even when obviously infected persons have travelled or circulated freely. These characteristics obviously serve to make the process of tracing the chain of infection and case-detection far simpler than in other diseases which are transmitted more readily.

III. Steps in the surveillance-containment operation

A well-trained surveillance-containment team should in most instances be able to investigate an outbreak and carry out necessary containment operations within two to five days. In small outbreaks, the teams may require no local assistance. In large outbreaks, other health personnel and volunteers may be required to assist. Whenever possible, however, the team should incorporate senior local health personnel in all stages of the investigation as an educational exercise and to assure better follow-up after the team has departed.

The separate steps in investigation and containment are discussed below more or less in the order that they are normally carried out and under the headings initially described at the beginning of this discussion.

A. To investigate each suspect case of smallpox reported through conventional reporting channels or through other sources such as malaria personnel, news media, etc.

Every effort should be made to obtain promptly reports of cases from recognized reporting sources, i.e. hospitals, health centres, aid posts, etc. Existing channels of communication should be examined to determine how best reports may be sent to reach national and intermediate health authorities with the least possible delay. Telephone, radio, telegraph, or special messenger service is often employed. When the cases are comparatively few in number, telephone, telegraph or radio communication becomes vital. In the course of investigations, hospitals, health centres and other facilities may be visited to strengthen their understanding of the need for prompt, regular reporting whether or not all cases have been seen. Other potential sources of information should be sought. Malaria surveillance workers and other types of village development workers may be of help. In one country, malaria workers are provided with pre-addressed red cards. When a suspect case is seen, the patient's name and address are noted on the card and the card is despatched by messenger to the local health centre for action. News media are frequently of help and, if assistance is specifically solicited, will normally co-operate effectively.

Most important in improving reporting, however, is the action of the team itself in demonstrating its willingness to investigate immediately and to take appropriate action on the basis of reports received from any source. Knowledge of this activity soon becomes widely known. A circular notice distributed to all peripheral health units as well as periodic news releases serve further to call attention to the need for prompt reporting and the containment activities being taken.

For surveillance-containment operations, an "outbreak" is defined as one or more cases which are epidemiologically related and occur in a given geographic area. To term one case an outbreak would appear, on the surface, to be extreme. Experience has shown, however, that on investigation, one case commonly leads to many more. Whether one case or many, the fact that the virus has been introduced into a community is an episode of importance to the programme and so is termed an outbreak.

B. To confirm the diagnosis

As a first step in the investigation, the diagnosis must be confirmed. In areas with a modest or large number of cases, the clinical diagnosis alone is relied upon. When in doubt, a suspicious illness should always be considered to be smallpox and dealt with as such. In moderately endemic areas, it is of little practical importance if a few cases of varicella or herpes, for example, are erroneously diagnosed as smallpox.

In countries or in areas where cases occur only sporadically, specimens for laboratory study should always be collected. When only one case has been reported and the diagnosis is in doubt, contacts should be examined as well as the individual from whom infection was contracted. While diagnosis of the initially reported case may be confusing, other cases among contacts and particularly in the individual from whom infection was acquired may readily clarify the diagnosis.

Another step of considerable value which may provide an answer to the diagnosis is to vaccinate the suspect case. If at six to eight days, he exhibits a major response, his illness was not smallpox. If there is an equivocal response to vaccination, the illness may have been smallpox or he may have been recently successfully vaccinated or the vaccine and/or technique employed was faulty. The response to vaccination, however, is a simple test and one which is often forgotten.

If on laboratory study, variola virus is detected, the outbreak is, of course, considered to be smallpox. If no virus is isolated, the question of diagnosis remains uncertain. Specimens which have been collected may have been improperly handled or some error may have been made in the laboratory. Failure to isolate virus on laboratory study does not exclude the diagnosis of smallpox. All factors would need to be carefully weighed in reaching a final conclusion.

In general, however, when the diagnosis is uncertain, it is best to be conservative and to diagnose the case as smallpox and immediately to take all necessary appropriate actions to contain the spread.

If, on investigation, it is clear that the case reported is not smallpox, the individual reporting the case should be complimented for being particularly alert and he should be requested to report as promptly the next time if he has any question about the diagnosis of a case. If the individual reporting is criticized by the investigation team, he may be reluctant on subsequent occasions to report even the most obvious smallpox infections.

C. To determine the source of infection and to trace the chain of transmission

The individual with smallpox or suspect smallpox necessarily has been in close contact with someone with a similar rash approximately seven to 17 days before. Frequently, the infected person is fully aware of who served to infect him. If he does not know, five sources should be checked:

1. Other household residents with some form of rash seven to 17 days before.

2. Visitors to the household during the period seven to 17 days before.

3. School (if a school-attending child).

4. Hospital (if a visitor or patient in the hospital during the period seven to 17 days before onset).

5. Suspect cases of chickenpox, particularly those who have died.

If none of these provide an indication, the source of infection may have to be considered "unknown", representing one of the few who have contracted infection through close contact in some other place.

In turn, the source of infection of each previous generation of cases should be determined. Tracing of infection sources in this manner may lead to significant outbreaks in other towns, other provinces or states or other countries, which otherwise would not have come to light until much later.

If the infection source is in another town within the general area of operation of the team, this town should be visited and other cases sought. If the source of infection is outside the area of the team's responsibility, the national smallpox programme and the area concerned should be notified promptly so that others may investigate the infection source.

Theoretically the chain of transmission could be traced back over months or even years. In practice, however, it is usually of limited value to endeavour to trace back the chain of transmission more than perhaps three to four months before the date of investigation.

D. To detect other cases in the immediate area

In a town or village or in a given area of a large city, several sources may be quickly checked to detect additional cases which may not have been revealed through contact tracing.

1. The patients - frequently patients are aware of other cases in the neighbourhood or among friends.

2. School - school teachers normally will know of cases among students.

3. Hospital - if a hospital is present in the area, this should always be checked.

4. Civil authorities, religious leaders, and other health personnel, including malaria workers.

Each case so detected is interviewed to determine the probable source of infection and queried about knowledge of other cases. Although some cases may be missed by case-finding in this manner, usually this will not be many.

In areas which experience few cases or which have been smallpox-free, house to house surveys may be necessary to assure that all cases have been detected. In endemic areas, however, such time-consuming techniques should not normally be employed.

E. To contain the outbreak

1. Isolation of cases at home or in the hospital

Where hospital facilities are satisfactory, hospital isolation is desirable. It is noted, however, that hospital provisions for isolation are often poor. Not only is the patient poorly cared for but frequently transmission to many additional persons occurs. If the patient is isolated in a hospital, all patients and staff should be vaccinated; the patient should be confined to a special area and not be allowed to mix with others; visitors to the hospital should be severely restricted to those recently successfully vaccinated.

In many instances, hospital facilities are grossly inadequate and there is considerable resistance on the part of patients to enter the hospital. If such isolation is enforced, many cases may be "hidden" to avoid enforced hospitalization. In such circumstances, isolation at home is far more satisfactory and community co-operation in case-finding is better.

For home isolation, all the family should be vaccinated or re-vaccinated and instructed to admit no visitors. Instructions should be issued that the patient must remain in isolation until every last scab has separated. Although late in the illness the patient may feel perfectly well, he remains a potential source of infection to others so long as scabs remain on his body. It is noted for guidance that the last scabs to separate are on the palms and soles of the feet.

2. Vaccination of household contacts

Transmission is most frequent in the home, either to family members or to other visitors. At the time the patient is examined, all household contacts should be vaccinated. Visitors to the household during the period that the patient has had a rash should also be sought and vaccinated.

3. Vaccination of other residents in the area and special groups at risk such as those in schools and hospitals

(a) Other residents in the area - to prevent further spread of the disease, a barrier of protection should be afforded all residents in the immediate vicinity of cases. It has been noted that villages or segments of towns where transmission occurs, normally have a lower level of immunity than others in which no transmission occurs. Simply, the occurrence of cases in an area is a warning of sorts that there is a special need for vaccination in the area. If a town or village of 1000-2000 persons is affected, the entire town can be vaccinated in one to two days as an emergency effort, employing the collecting point system. If in a rural area, all residents within perhaps a kilometer of the case should be vaccinated. In a large urban area, vaccination of a thousand persons or so in the adjacent blocks should be undertaken, using the collecting point system. Vaccination of a large number in this manner serves to impede further spread of the virus; additionally, emergency programmes, given the stimulus of cases in the area, can often achieve greater coverage than a programme without such a stimulus.

(b) Schools - if cases have occurred among schoolchildren, all attending the school, including teachers, should be vaccinated.

(c) Hospitals - if patients have been isolated in the hospital, all in the hospital, including staff (physicians, nurses, laundry workers, labourers), and patients, should be vaccinated. Throughout the world, it has been common experience that hospitals serve as a major focus for the transmission of disease throughout the community.

IV. Return visit to the area

After the steps noted have been taken, few cases should occur. Those cases which do occur should be among persons vaccinated during the containment operation, but who were too far advanced in their incubation period for vaccination to have had an effect.

If the investigation and containment operation is undertaken with the assistance of local personnel, the responsible health authority should be instructed to record subsequent cases which may occur and to continue to carry out special measures when indicated, such as isolation of patients, vaccination of contacts, etc.

To ensure that the programme has been effective in containing spread of the disease, the team should plan to visit the area one to two weeks later and thereafter, if possible, every two weeks until no further cases are detected. However, if the team is very much occupied, priority should be given to investigation/containment of newly-reported cases.

V. Surveillance in areas already vaccinated in a systematic programme

Normally, a few suspect cases will be reported in areas already vaccinated in a systematic vaccination programme or in areas believed to be smallpox-free. Every suspect case in such areas must be promptly, thoroughly and carefully investigated. Procedures as outlined above are equally applicable in these areas. The basic difference is that all such cases should be regarded as a public health emergency. Many of these suspect cases may be patients with chickenpox or herpes; some, however, may be smallpox. If detected early and if prompt containment action is taken, the outbreak may be easily contained. If effective containment measures are not employed or if investigations are markedly delayed, many personnel and many months may be required to eliminate the disease. In areas systematically vaccinated, a few cases may occur among migrants and a few close contacts. If larger outbreaks are detected, more exhaustive investigations are required to determine whether or not the programme had achieved a satisfactory coverage in the area and, if not, why such was the case, or, if satisfactory coverage had been achieved, to ascertain whether or not the vaccine was potent and vaccinator technique satisfactory. Such studies are necessarily more elaborate. More complex investigations of this sort may require special assistance from the national level.

VI. Composition of the team and administrative relationships

The duties of a surveillance-containment team are more demanding than those of an ordinary vaccination team. The team leader must frequently exercise independent judgement and administrative skills. The team, therefore, must be carefully selected and should be composed of competent, energetic and responsible persons.

The team leader may be a physician, a senior health inspector, former vaccination supervisor, etc. Whatever the category, he must be someone who has the stamina and interest to spend a great deal of time in travel and one who has good basic intelligence, willingness to learn and an inquisitive sense. Experience has shown for example, that a competent health inspector is more certain to do a credible job than a mediocre physician. Since the various techniques and information regarding smallpox can be taught in a comparatively short period, previous experience in smallpox eradication work, although helpful, is not requisite.

A "second in command" who can assume responsibility for organizing special vaccination efforts is important. If local resources are reasonably plentiful and vaccinators can be easily obtained on the spot, the team leader and his "second in command" might constitute the entire team or, if additional vaccinators are likely to be required at the scene of the outbreak, two or three vaccinators may be incorporated into the team itself. Whatever, the team itself should be able to be transported in a single vehicle. This ensures necessary mobility.

At the beginning, a one to two week training programme should be provided and arrangements made for the team to investigate two or three outbreaks under the direct guidance of an instructor.

The number of teams required in a country is difficult to assess. It will depend on the magnitude of the smallpox problem, ease of travel, etc. However, even in highly endemic areas, one team can usually deal readily with all outbreaks in a population of two to four million persons. If there is little smallpox and transport is reasonable, one team may suffice for a population of 10-20 million or more.

Within a programme, the administrative relationship of the team is most important. The teams should be responsible to those in charge of smallpox eradication activities at the national or state level (in countries with very large states). This preserves the necessary administrative mobility of the teams and generally ensures better supervision. In the past, several countries have assumed that responsibility for activities of case

investigation and containment could and should be assumed by local medical officers. While it is desirable to encourage local health officials to do all possible in the investigation and containment of outbreaks, experience has shown that when full responsibility is left to them, the results are generally unsatisfactory. Local officials are often busy and preoccupied with other duties; some are not particularly competent in the clinical diagnosis of smallpox; and few have a very clear concept as to how investigation and containment activities should be carried out. Whatever is done at local level, the special teams should also carefully investigate the outbreak to ensure that all steps have been taken. In the process, they may serve to educate local health personnel to ensure that the task is properly performed on the next occasion.

The teams must be prepared to move quickly and special administrative and budgetary arrangements to permit this are often necessary. For each day that is lost, the probability of successful containment of an outbreak is diminished. When the delay between case notification and investigation by the team is much prolonged, local officials inevitably gain the impression that prompt notification is not important. As an objective, the teams should be en route to an outbreak not more than 24 hours after notification.

VII. Forms for use in reporting results of team activity

For each case and outbreak investigated the teams should prepare some form of report so that it can be determined what has been found and what has been done. The report should be as simple as possible but must include items of data vital for the surveillance operation. If properly constructed, it also may serve as a sort of "check list" for the team to ensure that all steps have been taken.

Draft forms are shown as Appendices I and II. Appendix I is an individual case investigation form. Each investigation in a province may be consecutively numbered for reference and, similarly, each case in the outbreak. In addition to noting basic identifying information, certain additional points are included as a reminder to the investigator and as useful information for future analysis. Principal probable sources of infection are itemized. The investigator is requested to indicate whether infection was acquired locally or elsewhere. If infection has been acquired elsewhere, further tracing should be carried out either by this team or another. Finally, provision is made to indicate how the case was discovered. By comparing the proportion of cases already reported through routine notification methods with the total of cases discovered, an estimate of the completeness of notification may be obtained.

Appendix II "Résumé of Investigation" provides a simple tabular analysis to summarize certain of the observations and to report what has been done. Information for reference purposes is provided in the upper right corner. Information regarding cases is summarized in the table. A section is provided to summarize the method by which cases were discovered as a reminder that all cases discovered through the investigation should be recorded in the official records of smallpox morbidity. Provision might also be made for summary analysis of "sources of infection" if so desired. In recording vaccinations performed, investigators may, in the course of vaccination, use single tally sheets for each category noted. For households, a sheet might be prepared on which is entered in one column the numbers of contacts in each infected household and in the second column, the number vaccinated. For vaccination in schools, hospitals and the community, simply the number vaccinated may be recorded.

It is recognized that much more elaborate data could be gathered and more detailed reports prepared. Keeping in mind, however, that the objective of the system is to require the minimum possible number of records and to ensure that the teams spend a maximum of time on the work at hand, the summary sheets noted should serve in most programmes to guide the investigators in their work while providing necessary information to superiors.

APPENDIX I

CASE INVESTIGATION FORM

STATE/PROVINCE _____

INVESTIGATION NO. _____

CASE NO. _____

NAME _____ AGE _____ SEX _____

DISTRICT _____ VILLAGE _____

DATE OF ONSET OF RASH _____
DAY MONTH YEAR

VACCINATION SCAR PRESENT
(VACCINATED BEFORE EXPOSURE) ☐ YES ☐ NO

CONDITION OF PATIENT

☐ RECOVERING

☐ DEAD

☐ OUTCOME UNCERTAIN

SOURCE OF INFECTION

☐ ANOTHER MEMBER OF HOUSEHOLD

☐ A VISITOR TO HOUSEHOLD

☐ PATIENT VISITED AN INFECTED HOUSEHOLD

☐ HOSPITAL

☐ SCHOOL

☐ OTHER _____

☐ UNKNOWN

PATIENT WAS INFECTED IN TOWN/VILLAGE WHERE HE RESIDES

☐ YES

☐ NO _____
(INDICATE WHERE INFECTED)

METHOD BY WHICH CASE WAS FOUND

☐ ROUTINE NOTIFICATION

☐ INVESTIGATION OF OTHER CASES

☐ OTHER _____

APPENDIX II

RESUME OF INVESTIGATION

STATE/PROVINCE _____

INVESTIGATION NO. _____

DISTRICT _____

VILLAGE _____

DATES OF INVESTIGATION _____

TEAM _____

I. RESUME OF CASES

AGE	CASES			DEATHS	VACCINATION SCAR PRESENT		
	SEX						
	M	F	TOTAL		YES	NO	?
<1							
1-4							
5-14							
15-44							
45+							
?							
Total							

II. METHOD BY WHICH CASES WERE FOUND

	NO.
ROUTINE NOTIFICATION	_____
INVESTIGATION OF OTHER CASES	_____
OTHER	_____
TOTAL	_____

III. VACCINATIONS PERFORMED TO CONTROL OUTBREAK

A. HOUSEHOLD MEMBERS AND CLOSE CONTACTS

NO. _____ NO. VACCINATED _____

B. SCHOOLS

NAME	NO. VACCINATED
_____	_____
_____	_____
_____	_____
_____	_____

C. HOSPITAL

NAME _____ NO. VACCINATED _____

D. COMMUNITY

NAME _____ NO. VACCINATED _____

TOTAL _____