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SMALLPOX SURVEILLANCE IN THE STRATEGY OF GLOBAL ERADICATION

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Smallpox surveillance represnts 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 three 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 per cent to 100 percent. The actual objective of the programme, "the eradication of smallpox" was obscured by an alternative goal, "vaccination of 100 per cent 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 per cent to 85 per cent, the costs and difficulties increase logarithmically while immunity levels increase only arithmetically. Even with 90 per cent 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 per cent 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 transsion 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; 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. In brief, the disease characetristics 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, 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 infecuon by sunple 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 reserviors; 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 tenous chain of transmission in a country requires that at least 1*5 to 25 cases occur annually. If fewer cases than this are recorded, only two explanation 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 procedure 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 transmis-

Locale of infection	Locale of infection of cases in five outbreaks				
	United Kingdom 1951-1962	Sweden 1963	Kuwait 1967[8]	Abakaliki Nigeria 1967[9]	Pawku Ghana 1967[10]
Imported	5	1	1	1	12
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

sion. Noted below are four illustrative outbreaks.

Despite the fact that in each of these outbreaks, there were a number of patients who were ambulatory following the onest of illness and in casual contact with many persons, comparatively few cases occurred w hich 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 play ed no apparent role, studies in Brazil have shown that the schools may also be instrumental in some circumstances in disseminating infection throughout a comunity. 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 3 a dditional 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 countres 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. During the period, *1040 cases occurred, an incidence as high as that observed anywhere in theworld. However, through out the course of entire year only 170 of the 1700 villages (10 per cent) were infected with smallpox. In December 1967, an assessment survey in a highly endemic district of India, similarly revealed that during the course of the year only 101 of 2331 towns and villages were afflicted with smallpox. At no time more were than 20 (1 per cent), 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 widely dispersed sporadic disease but as concentrated pockets of infection sustained by a tenous 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 per cent to 95 per cent or more of all cases have no scare 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 per cent 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. They found that among 103 unvaccinated family contacts, 37 per cent contracted the disease while among 1*, 108 who had at same time been vaccinated, only 1 per cent contracted small pox.

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Frequency of smallpox among vaccinated and unvaccinated contacts—Madras[12]

Age	No. of unvaccinated* contacts	No. of cases of smallpox	No. of previously vaccinated contacts	No. of cases of smallpox
0-4	57	27	118	0
5-14	18	4	287	2
15-44	15	9	543	10
45+	13	2	160	1
	103	38(37%)	1108	13(1%)

*Unvaccinated at time of Exposure further those Previously vaccinated who did contract smallpox were forless effective in transmitting it then Cere those incividuals who were unvaccinated.

Frequency of transmission from unvaccinated and previously xaccinated cases to vaccinated and unvaccinated contacts, Madras, India[12]

	contacts					
	Vaccinated			Unxaccinated		
	No.	No. developing smallpox	%	No.	No. developing smallpox	%
Case-previously vaccinated	527	2	0.4	32	9	28
Case-unveccinated	619	12	1.9	71	29	41

This observation is consistent with laboratory studies which have shown that the quantity of virus excrated by a patient correlates with the number of lesions present in the mouth. Individuals who have previously been vaccinated tend to have fewer lesions both on the skn and on the mucous membranes and so excrete less virus and have greater difficulty in infecting others. Those with significantly attenuated illnesses and few lessions, 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 througout 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 crowed 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 prviously mentioned study in Pakistan, 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 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, preschool 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 reservior of infection may be identified in the course of a programme so that continuing vaccination activities may be more intalligently 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 per cent 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 authoritics 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 last developed countries, one consistantly 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, preferrably 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 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 less than 3 years ago. Some countries, in fact, did not commence until less than two years ago. 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. With somewhat less than 75 per cent of the systematic vaccination programme now completed, smallpox incidence has fallen almost to nil and is expected to be nil, in fact within a matter of months. Since last October all cases have been investigated and outbreaks promptly contained. At this time, there are less than 50 cases per month being detected

outbreaks now being investigated can virtually always be traced to previous known foci. Most noteworthy among the countries in this area 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, less than 18 months ago. Both are now believed to be smallpox-free.

Does this mean that every last person or every last village has been vaccinated ? Definitely not ! Systematic vaccination has served to reduce transmission to the point where surveillance measures have been able to interrupt the chain in infection but it is surveillance which represents 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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