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Principles and lessons from the smallpox eradication programme*

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The eradication of smallpox required a unique, fully collaborative international effort on the part of WHO and Member States. In the course of the programme, many lessons were learned in its organization, execution and evaluation which have implications for other international activities. Most important among these was the need to establish measurable objectives and to evaluate progress and performance in terms of these; to establish procedures for quality control both of vaccines and performance; to recruit the best possible personnel and support them; and to assure an on-going programme of problem-oriented research which can facilitate activities and resolve apparently paradoxical observations. The inherent capacities of national health services to execute their smallpox eradication programmes was gratifying. It encouraged the belief that other, more complex health measures could be undertaken. Although this would necessitate that adequate numbers of competent leaders be recruited and given delegated responsibility, such persons were usually found to be available although often inexperienced. WHO's roles in catalysing and orchestrating this great effort were critical. Its potential for promoting other efforts in disease prevention and health promotion was apparent although still only partially realized.

INTRODUCTION

Smallpox is the first disease to have been eradicated through concerted and determined global action. Although an important achievement, this successful effort has broader implications for health policy in demonstrating the impact which a community-based prevention programme can have, the considerable resources which can be mobilized for such an effort, the value of establishing measurable goals and monitoring disease incidence in programme execution, and the remarkable cost-benefit implications of prevention programmes. In part because of smallpox eradication, increased emphasis is being given to disease prevention and health promotion programmes throughout the world. Specific, measurable goals in national and local health programmes are being more widely identified and used in management, and surveillance and sample survey techniques, elaborated during smallpox eradication, are being employed increasingly.

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Smallpox eradication was not achieved, however, until more than 175 years after Edward Jenner's assertion that the inoculation of cowpox virus as a vaccine could eliminate smallpox from the earth (*1*). Although the vaccine virus had been promptly and widely distributed and motivation was high to vaccinate against the universally-feared disease, smallpox continued to spread. Government and health structures were inadequate to mount sustained programmes and unsuccessful vaccinations were common because of unsatisfactory vaccine. Through the nineteenth and early part of the twentieth centuries, millions of cases occurred, one-fifth or more of which resulted in death; no country was entirely spared. With the improvement of health systems and vaccine, the industrialized countries finally became free of endemic smallpox during the 1940s. However, because of frequent importations, costly national vaccination programmes continued as well as the requirement that all travellers be vaccinated. In the developing countries, smallpox continued to spread, all but unchecked.

In 1958, a delegate of the USSR to the World Health Assembly proposed that global smallpox eradication be undertaken by WHO and this was unanimously approved in 1959 by the Twelfth World Health Assembly. At that time, 60% of the world's population lived in areas where smallpox was endemic. During the next 7 years, some progress was made in improving vaccine quality and a number of countries became free of smallpox, but the disease, often in epidemic form, continued to be widespread. To augment the eradication effort, delegates at the Nineteenth World Health Assembly in 1966 allocated special funds for an intensified programme which commenced in January 1967. They proposed a 10-year goal for the achievement of eradication. At that time, an estimated 10–15 million cases of smallpox were occurring annually in 31 endemic countries or territories with a population of more than 1000 million. Given that programmes would have to be conducted in most of the world's least developed countries, that disruptions due to civil strife, famines and floods were inevitable, and that more than a century and a half had already elapsed since the discovery of a vaccine, the goal was an optimistic one. Nevertheless, the last endemic case occurred just 10 years, 9 months and 26 days after the programme began.

The strategy of the programme was twofold: to vaccinate at least 80% of the population and to establish systems for surveillance (case detection) and containment of outbreaks. Between 1967 and 1971, WHO-supported national programmes were able to be initiated in all endemic countries and in others at special risk of imported cases. All programmes functioned within the public health structure and each differed from others in order to cope best with different epidemiological patterns of smallpox, national administrative practices and sociocultural conditions.

Global smallpox incidence began to decline rapidly, in part because of the provision of adequate quantities of heat-stable freeze-dried vaccine of assured potency. The earliest successes occurred in a contiguous bloc of 21 western and central African countries, whose programmes began in January 1967 with support from the U.S. Communicable Disease Center (now the Centers for Disease Control). Although these countries included some of the world's poorest and most heavily infected, they became smallpox-free in only three-and-a-half years. Smallpox eradication staff discovered that smallpox spread less rapidly and easily than had been believed and they demonstrated that the detection and containment of outbreaks deserved greater emphasis.

By the end of 1971, smallpox had been eliminated from all but 3 countries in eastern and southern Africa and the occurrence of Brazil's last cases in April 1971 marked the eradication of smallpox in the Western Hemisphere. Well-executed programmes emphasizing the detection and containment of outbreaks stopped transmission in Bangladesh (then East Pakistan) in 1970 and in Indonesia and Afghanistan in 1972.

Setbacks occurred or were first confirmed in 1972. That year Bangladesh became reinfected following civil war and the return of vast numbers of refugees; Botswana was swept by an epidemic as a result of cases entering from South Africa; and it became known with certainty that Iran had become endemic in 1970 and Iraq in 1971. By late 1973, however, special campaigns had succeeded in eliminating smallpox from all newly reinfected countries except Bangladesh.

In September 1973, greatly intensified campaigns began in the 5 remaining endemic countries (Bangladesh, Ethiopia, India, Nepal, and Pakistan). New tactics and additional resources were required to cope with smallpox in the extensive, densely populated areas of Asia. With special contributions from Sweden, tens of thousands of permanent and temporary health staff were deployed in well-supervised, house-to-house search and containment programmes. By late 1974 transmission was stopped in Pakistan, and in 1975 in the other Asian countries. Additional personnel and resources were thereafter shifted to Ethiopia. There, the milder form, variola minor, spread tenaciously across a vast, sparsely-settled area with few roads or health services and with widespread civil strife. Aided by local volunteers and assisted by helicopters, Ethiopian health staff contained the last

outbreak in August 1976. However, civil warfare and the consequent exodus of refugees served to infect neighbouring Somalia. Experienced staff and resources were mobilized from many countries, and the world's last outbreak, on 26 October 1977, was contained.

Additional measures were now required for health authorities in all countries to be sufficiently confident of eradication so as to stop vaccination. Thus, surveillance and special search activities were conducted for at least 2 years in every country after the last known case had occurred. At that time WHO-appointed International Commissions visited these countries and verified the absence of smallpox. Finally, a WHO Global Commission, through a variety of studies, satisfied itself that eradication had been achieved, its conclusions being endorsed by the Thirty-third World Health Assembly in May 1980.

It has been suggested that the smallpox eradication programme should serve as a template for other disease control or eradication campaigns. This is not feasible because each disease has its own epidemiological characteristics and methods for control which require strategies and tactics specific to that disease. However, the rapid progress in eradicating smallpox after so many decades of persistent transmission provides principles and lessons which have implications for other health initiatives. This review, a condensation of the last chapter of the book *Smallpox and its eradication* (2), sets forth the most important observations.

POLITICAL COMMITMENT AND PROGRAMME DEVELOPMENT

For a global programme against a disease to be undertaken, universal political commitment is necessary and, for this purpose, the World Health Assembly and the World Health Organization are essential. The World Health Assembly uniquely provides the necessary forum for countries to agree on global health policies. The World Health Organization, alone among the international organizations, has the requisite scientific expertise and channels of communication with the national authorities for the monitoring and coordination of health programmes.

The decision in 1959 to undertake global smallpox eradication encouraged a number of countries to begin or to intensify their own special programmes with some support from bilateral agencies, but most national authorities gave little priority to the programme. Two principal factors compromised the effort: (1) the failure of the World Health Assembly to allocate special funds in support of the programme and the decision of WHO to provide only limited resources from its regular budget; and (2) the existence in South America and parts of southern and eastern Africa of the milder variola minor which caused few deaths and was therefore not a priority health problem.

The allocation by the Nineteenth World Health Assembly in 1966 of special funds for smallpox eradication signalled a change in interest. Bilateral and national commitments were stimulated; additional WHO staff were able to be recruited; and special resources for national programmes could be provided. However, national government support for smallpox eradication, as expressed through approval of the programme in the Assembly, did not translate quickly into national initiatives. WHO could not compel a Member State to meet the responsibilities to which it had pledged itself. Rather, it had to rely on moral suasion. WHO staff were required to take an active role in advocating the initiation of programmes, sometimes through publicity and meetings and sometimes through special discussions with heads of state or other senior national officials. This required a larger WHO smallpox eradication staff than the 5–6 persons available between 1959 and 1966.

At first, many senior WHO and national staff believed that generalist managers rather than epidemiologists and other professionals were sufficient for the task. The needs, as first perceived, were straightforward—to procure sufficient vaccine and to organize vaccination programmes. The challenge, however, was more complex. The vaccination programmes had to be adapted to different administrative, sociocultural and geographical situations and to widely differing health systems. Mechanisms had to be developed to monitor and assess the programme, in terms of not only vaccinations performed but also the impact on disease incidence. A better understanding of smallpox epidemiology was needed to improve strategies and tactics. Better methods of vaccine production and improved vaccination instruments were required. It was also important to determine that there was no natural reservoir for smallpox and to demonstrate that the clinically similar and virologically related disease, human monkeypox, was not a serious threat to the programme. These tasks were ultimately accomplished utilizing WHO professional staff which seldom numbered more than 100 persons the world over.

THE IMPORTANCE OF A SPECIAL PROGRAMME

Smallpox eradication could not have been achieved were it not a targeted and time-limited special programme with funds specially allocated for it, both in the WHO budget and in most national budgets, and

with full-time technical staff responsible for its supervision. Some argue, however, even today, that categorical programmes reflect poor health policy, serving only to divert resources and attention from the development of primary health care systems (*3*). That such programmes can make important contributions to the development of national health services was demonstrated by the smallpox eradication programme. In part, this is because it functioned within the existing national health structure rather than as an entirely separate entity, as was the case with the earlier malaria eradication campaign. It was thus obliged to work with and through the existing health services and to coordinate its activities with other programmes.

Participation of existing health staff in vaccination, reporting and containment activities was required everywhere because of the small numbers engaged full-time in smallpox eradication. This meant that the programme had to provide special training because, in most countries, basic health service units seldom offered vaccinations of any type and, even where they did, the use of improperly stored vaccine and poor technique were common. Vaccine distribution systems had to be established and gradually other vaccines began to be used. The basic health services network was the foundation of the disease reporting structure and, in all countries, it had to be greatly improved through staff training and supervision. In consequence, many thousands of health staff obtained experience in the execution of vaccination programmes and in field epidemiology; often the only field supervision they received was provided in the course of their smallpox eradication work. Many are now successfully applying these methods, such as the use of surveillance systems for management and assessment, sample survey techniques to measure performance, and the use of disease recognition cards to aid in case detection, in programmes against other diseases.

Three important observations with respect to special programmes emerged from the smallpox eradication experience: (1) the provision of community-wide disease control services requires strategies and management systems for which traditional health care delivery systems are ill-equipped; (2) special programmes for important health problems offer the advantage of attracting both resources and community support; and (3) significant improvements in efficiency and supervision can be realized, which offset the additional costs of a special programme.

Providing community-wide services

In practice, most health officials tacitly accept the fact that traditional health care systems, comprising health centres and hospitals, are ill-equipped to deliver health services which must reach all or most persons in a community. These health care systems have been designed primarily to provide curative services to those who seek help. Because it is well known that only a small proportion of the population visit traditional health care units to receive preventive services, special outreach methods are required. However, few in the health care system possess the necessary management skills to design or implement programmes for community-wide delivery of services. Thus, even prior to the global smallpox eradication programme, most endemic countries assigned special teams to provide smallpox vaccination. Similarly, special teams and programmes were created to deal with tuberculosis, yaws and malaria, as well as for vector control, family planning, and other problems requiring the delivery of services throughout the population.

The inadequacy of traditional health care structures in dealing with community-wide disease control programmes was amply confirmed in the smallpox eradication programme. Health centres, for example, were customarily directed by personnel whose training and preoccupation were with curative medicine, whose management skills were limited and who rarely left the health centres. Few centres gave vaccinations of any type; cases of smallpox were only occasionally reported and then usually with great delay; outbreaks were rarely contained. Likewise, hospitals performed poorly, often augmenting smallpox transmission because of inadequate or non-existent isolation procedures; even the hospital personnel themselves were often unvaccinated.

Thus, a specially dedicated and trained professional staff was necessary at all levels to design and coordinate the smallpox eradication programme; to develop reporting and surveillance systems; to undertake case-detection and containment measures; and to train local health staff. There was a need to seek the support of village leaders and, through them, the acceptance and participation of the population.

These observations have important implications in the strategy for providing primary health care. Such care is usually regarded as a closely related set of services, all delivered in a similar manner, but experience suggests that it would be better conceptualized as consisting of two different but complementary components. One is the primarily curative activities; the second is intended to reach individuals throughout a community and includes preventive interventions (such as immunization or family planning) and curative ones (such as oral rehydration therapy). The traditional health care system may serve as the base for both functions but different types of programmes, different personnel skills and different methods of assessment are

required for each activity. Traditional, curative services can be provided in established health units by clinically-trained physicians and nurses and are usually appraised in terms of the training of the practitioners, the quality and sophistication of facilities, and the numbers treated. Community-wide programmes require active outreach by persons skilled in management and health education in order to ensure acceptance; the provision of services at a site and time convenient to their clients; and methods such as surveillance to measure success in terms of reduced morbidity, mortality or fertility.

Attracting resources and community support

Special-purpose programmes to achieve certain specific objectives, usually within a finite period of time, are generally better supported and financed than programmes with less explicit goals. Experience shows that a programme to eradicate smallpox or to prevent poliomyelitis, for example, has more popular appeal than one to develop the basic health services. Such special-purpose programmes are especially important because it is almost always more difficult to obtain support for public health programmes than for curative medical services. This reflects the reality which is that political leaders are usually more readily persuaded to provide funds for the more tangible curative services (hospitals and health centres) than for community-based programmes; the physicians most often consulted on priorities in health care are usually clinicians who lack a public health perspective; and those who have the greatest need for community-based health services are usually the most disadvantaged and least influential. Special-purpose programmes which command attention thus provide a balance to the traditional biases in the allocation of health resources.

On a global scale, WHO's Expanded Programme on Immunization is another illustration of the potential for heightened support of community-based health programmes with special objectives. Its goal, established in 1977 (resolution WHA30.53), is to provide six vaccine antigens to children worldwide by 1990. This effort was augmented by UNICEF's Child Survival and Development Revolution Programme in 1983, by the endorsement of the United Nations in 1985 and by resources made available by Rotary International Foundation's PolioPlus Program. National governments have responded with special programmes and international support of unprecedented magnitude has been mobilized. As a result, levels of immunization coverage throughout the world have increased significantly.

Special-purpose programmes with intensive publicity also provide an opportunity to educate the population about selected health interventions. For example, comparatively few persons will voluntarily seek vaccination, but more than 80% can usually be reached during the course of a well-publicized, well-executed mass campaign. As Jamison (*4*) has noted, China's remarkable improvements in health over the past 30 years can be attributed in substantial measure to its special health campaigns, of which there have been four or five each year.

Improving efficiency and supervision

Special programmes involving the large-scale delivery of services permit economies to be realized and can facilitate the management of supplies and equipment. For example, the cost of a dose of vaccine in multiple-dose containers is a fraction of the cost of vaccine in single-dose containers. To realize savings, however, all or most of the contents must be used, usually during a single day, because vaccines deteriorate after a vial is opened. This is best accomplished in a campaign in which large numbers of people are vaccinated each day. Better supervision of technique and vaccine storage is also possible when a few vaccination teams administer many vaccinations than when many health centre staff participate, each performing only a few vaccinations each day.

DEFINITION OF OBJECTIVES AND STANDARDS OF PERFORMANCE

A proper definition of programme objectives and the use of these in programme management can transform a programme. A fundamental change which occurred in the smallpox eradication programme in 1967 was the decision to measure progress in terms of the programme's ultimate objective—a zero incidence of smallpox. Before 1967, progress in smallpox eradication had been measured primarily by the numbers of vaccinations performed, while the reporting of smallpox cases was considered so deficient as to be meaningless (*5*). A focus on the objective of zero cases meant that case-reporting had to be improved and surveillance systems and field epidemiology developed. New methods were devised for discovering cases and containing outbreaks; resources were allocated in order to provide more intensive efforts where the smallpox incidence was highest, at times when the transmission was most susceptible to interruption, and in regions where the risk of spread was greatest. In effect, this approach served to meld management and epidemiology.

Logic suggests that all disease control programmes should provide continuous measurements of disease incidence, and that these measurements should dictate changes in strategy and tactics. In fact, few pro-

grammes do so. Responsible authorities tend to ignore such information or dismiss efforts to obtain the data and, instead, assess progress in terms of activity, such as the numbers of vaccinations performed or patients treated.

In addition to measuring smallpox incidence with a goal of zero cases, subordinate standards of performance were established in each country and area. They closely followed Austin's principles of management in being specific, measurable, realistic and dynamic (*6*). For example, mass vaccination campaigns were expected to result in more than 80% of the population in an area having a vaccination scar. Experience showed that with a reasonably effective campaign this was realistic. Assessment teams could easily determine the proportion of the population vaccinated by examining them for vaccination scars. As programmes improved, the standards were made more rigorous and in 1974, the following were established for surveillance and containment procedures: that 75% of outbreaks should be discovered within two weeks of the onset of the first case, that containment should begin within 48 hours, and that no new cases should occur more than 17 days after containment had begun. As the incidence of smallpox decreased or ceased, other standards for the measurement of performance were developed, e.g., the extent of the population's knowledge about the reward for reporting cases and the completeness of reporting of other diseases such as chickenpox. Standards were of the greatest value when the data were promptly collected, analysed and used as guides for programme action. Knowledge, among those gathering the information, that the data were promptly being utilized facilitated the development of the system and improvement of performance.

The number of standards that could be effectively employed was limited, however. During the concluding phases of global eradication, standards proliferated in number and the volume of data accumulated, only a portion of which could be satisfactorily analysed and interpreted for use. It became apparent that a few indicators of overall performance, closely followed, were more useful than a broad spectrum of indicators measuring many aspects of programme execution.

QUALITY CONTROL

Methods to ensure that the smallpox vaccine was potent at the time of application, that vaccination coverage met the expected goals, and that progress was being made in diminishing smallpox incidence all represented forms of quality control. Before 1967, such activities were infrequent. In both industrialized and developing countries, vaccines often failed to meet the accepted international standards; few independent national testing centres monitored vaccine quality; and few health service staff examined those vaccinated to determine whether their vaccination had been successful. Many countries regularly reported large numbers of vaccinations but seldom confirmed this by surveys for vaccination scars. Reporting of smallpox cases was seriously deficient but even the available data were seldom reviewed to determine epidemiological trends or patterns in incidence.

In many countries, biological and pharmaceutical products were used with little assurance of their potency, purity or proper storage. Even the most elementary measurement systems, such as the enumeration of deaths by cause and the incidence of important diseases, were manifestly deficient. Where information is routinely collected, the data are more often than not relegated to statistical reports. The fact that the concept of surveillance, so simple in principle, proved so difficult to apply in the smallpox eradication programme was due to a lack of experience with measurement throughout the health field and of programme objectives that encourage such measurement.

PROGRAMME MANAGEMENT

Cooperative, multinational health programmes are inevitably difficult to manage, given the realities of national sovereignty and the nature of international organizations. The smallpox eradication programme could not operate as a monolithic structure, like a military command. Rather, it had to function as a collegial structure of many independent national programmes, each with its own administrative traditions and sociocultural patterns, utilizing resources from many different sources. It was a programme in which the coordinating organization, WHO, provided only a small proportion of the resources and had no authority over national programmes other than moral suasion. Authority and responsibility within WHO itself were highly decentralized, each of its six regional offices enjoying substantial autonomy. As such, the Organization was better suited to the implementation of local or regional programmes than to the execution of a worldwide programme requiring international mobilization and the selective allocation of resources on a global basis.

Global health programmes are confronted with similar challenges today. Thus, an effort is made here to identify the management factors that contributed to the eradication of smallpox, which might facilitate other global programmes.

The network of professional staff

Because a hierarchical structure integrating national and international staff was not possible, other mechanisms had to be found to coordinate planning and a continuing commitment to programme execution, to ensure quality control and to provide ongoing assessment and redirection of strategy. Success in achieving these objectives within WHO depended primarily on the recruitment of capable professional staff who could be given substantial latitude in making decisions, in assuring that they received needed resources and support, and in providing leadership by example and exhortation rather than by directive. The efficacy of these methods correlated with the degree to which continuing close communication could be maintained between international and national staff, their degree of mutual respect, and the level of their common understanding of problems and needs.

A unit at WHO headquarters with overall responsibility and accountability for all pertinent activities was essential. Initially, certain important activities pertaining to smallpox eradication were conducted by other units. The development of vaccine production and testing were the concern of a biologicals unit; notifications of cases were received by two other units; and the research programme was assigned to a fourth unit. The smallpox eradication unit gradually assumed responsibility for all these activities and they subsequently became more effective and responsive to the programme's needs.

More rapid progress might have been possible if, from the beginning, there had been special staff to handle two other activities—public information and the soliciting of voluntary contributions. Wide publicity was needed to encourage national programmes and to recruit support from donors, but WHO's public information office was inadequately staffed to do this. Some success was achieved through publication in the *Weekly epidemiological record*, every 2–3 weeks, of a full and candid account of progress and problems in the programme. While this served to inform the public health community, it did not stimulate coverage by the mass media for the information of a broader public. Not until 1977 was a full-time public information officer added to the smallpox eradication unit. His value was immediately apparent. As a result of his efforts, it was eventually possible to foster public confidence that eradication had been achieved so that vaccination could be stopped. The soliciting of donations represented a second problem. Voluntary contributions were expected to comprise two-thirds of all international funds for the programme. However, no WHO professional staff had full-time responsibility for seeking such support. Smallpox eradication programme staff undertook this activity but, lacking expertise, the necessary political contacts and time, their success was limited.

The smallpox eradication unit in WHO headquarters established a central point of contact for those outside the programme, whether scientists, potential donors, candidates to join the staff, or the media. Because the unit kept abreast of and widely disseminated the current technical information on smallpox, there was regular communication between the professional staff and the scientific and public health communities. This facilitated the rapid translation into practice of new developments.

A counterpart professional group of a least 2 or 3 persons in each of the four WHO regions with endemic smallpox would have been invaluable. This was strongly encouraged but was followed in only one region. Consequently headquarters staff often had to perform functions which more logically belonged in the regional offices; many national programmes were inadequately supported and monitored, and the global coordination of activities was less satisfactory than it might have been.

At national level, WHO considered it essential that an accountable and responsible professional person, preferably dealing exclusively with smallpox eradication, should act as a locus of contact in planning and implementing national programmes. Each country was therefore requested to designate a specific person to be responsible for smallpox eradication rather than an office or a section of the health ministry. This approach generally proved to be effective. However, three functions were customarily the responsibility of other units or divisions of the ministry and often presented special problems—case reporting, quality control of vaccine, and public education.

The national notification of cases was often the responsibility of a statistical unit which was not much concerned with the completeness of notifications and with feedback to the programme. The situation improved only when the smallpox eradication programme officers assumed responsibility and began to employ the data for monitoring the programme and in allocating resources, but this did not occur until months or years after the programmes began.

Quality control of smallpox vaccine production was a problem in most countries. National control laboratories were unknown and thus the production laboratories themselves were usually the ultimate arbiters of quality. Although WHO policy required a WHO collaborating centre to test all vaccines used in the programme, the laboratory directors often opposed this and sometimes refused to submit samples. Compliance was seldom easily achieved, and in a few countries some substandard vaccines continued to be used throughout the programme.

Responsibility for health education was usually assigned to a special unit in the ministry of health,

but such units were seldom adequately staffed or especially able or imaginative; few contributed significantly to smallpox eradication campaigns. Most educational efforts were mounted by regional and local smallpox programme personnel who pragmatically developed materials as required.

The basically collegial management of the programme functioned well overall, its principal handicap being the lack of sufficient senior staff at WHO headquarters and in the regional offices, in national programme offices and in states or provinces. For example, in one very large country the national programme directorate until 1972 consisted of only one professional person, and in one of WHO's regional offices smallpox eradication was a part-time duty of a medical officer who was assigned many other responsibilities.

Personnel recruitment and training

The competence, motivation and experience of professional staff ultimately govern the success of all programmes and this was unquestionably the case in smallpox eradication. Considerable time was required to assemble such a staff within WHO. Staff recruitment, except for headquarters personnel, was a regional office responsibility, and headquarters was at first seldom consulted. Selection did not always give due weight to professional competence and motivation; performance was not always closely monitored; and contracts were sometimes renewed irrespective of performance. Not infrequently, unsatisfactory personnel were transferred to posts no less critical to the programme than those they initially occupied. However, increasing numbers of competent staff were recruited as the headquarters unit made special efforts to identify qualified candidates through personal contacts with epidemiologists, and applications were encouraged from staff who had performed well in national programmes.

The quality of national programme leadership was initially no less irregular but, as the programme progressed and eradication appeared more attainable, national officials increasingly assigned more able staff, often those with field experience. Contrary to widely held perceptions, staff who were competent to assume leadership positions were more than adequate in number in most countries; many, however, lacked practical management experience.

A common understanding by all senior staff of the programme's basic strategy and tactics and of important measurements of progress was also critical. With such an understanding, programme directors were better equipped to innovate and to adapt the programmes to existing circumstances. WHO's *Handbook for smallpox eradication programmes in endemic areas*,[a] surveillance reports, national and intercountry meetings and personal visits all helped to accomplish this. Special training programmes of 2–4 weeks' duration for all newly assigned international and senior national staff could have been especially effective, as was demonstrated in the USA-supported programme in western and central Africa. However, the failure of the WHO regional offices to appreciate the need for such courses and the lack of senior personnel to conduct them precluded the development of WHO-sponsored training programmes until 1974.

National smallpox eradication programmes in most countries were usually staffed by persons already engaged in smallpox control and others who were reassigned from other programmes. Most countries had many more health staff than programmes with sufficient resources to support them and their work. Given 1–2 weeks of practical field training for smallpox eradication, a continuing flow of supplies and equipment and good field supervision, most performed competently and with dedication. The quality and nature of supervision were of vital importance. The best results were obtained where WHO, national, and state or provincial supervisory staff travelled frequently into the field to review activities and to work with field staff in resolving problems. Monthly or bimonthly meetings in which field staff and supervisors from different areas met to discuss progress and problems and to compare differences in results were also of value.

It was also found that village residents, if properly approached, cooperated effectively in organizing vaccination programmes and in detecting cases. From 1973, when programmes were greatly intensified, many villagers were recruited and trained for part-time work in these activities. Their performance was directly proportional to the clarity of direction provided and the quality of supervision; when these were adequate they made substantial contributions.

In brief, it was demonstrated that a comparatively few motivated and knowledgeable professional staff could organize and effectively mobilize large numbers of persons, and that in most countries there was an eager response by health staff and the general population alike. The limiting factor was the inadequate number of motivated and knowledgeable leaders, largely because too few were recruited, trained and assigned to responsible positions.

Financial and other resources

A deficiency of resources was a continuing problem and one that seriously jeopardized the international effort. Support for the programme was

[a] *Handbook for smallpox eradication programmes in endemic areas*. Unpublished WHO document, SE/67.5. Rev. 1, 1967.

barely adequate to sustain it, even during the concluding months. In the early years, this was due to scepticism about the feasibility of disease eradication, owing to the failing global malaria eradication programme which had required substantial resources from both bilateral donors and United Nations agencies. Gradually they withdrew their support and many declined to provide more than token help for yet another eradication campaign.

Only limited voluntary contributions were provided to WHO until 1974, when a well-publicized intensified campaign had begun to stop transmission in the 5 remaining endemic countries. At that time, WHO provided additional funds, large contributions were received from Sweden and, later, support was received from other donors. These helped the successful large-scale programmes in Asia but until 1976 they were insufficient to adequately strengthen the programmes in Ethiopia and Somalia. With the occurrence of the last case in 1977, but before eradication could be certified, support again waned and resources became a constraint.

Obtaining sufficient national resources in the endemic countries was no less a problem. Although few countries had to provide significantly larger sums for smallpox eradication than they had for smallpox control, health budgets were small and competing needs were many. When a zero incidence was reached, support diminished rapidly and resources sufficient to permit certification were seldom more than barely adequate.

Voluntary contributions in cash and in kind constituted a major component of support. Most of the donations of cash, however, were restricted to use in specified countries and donations in kind were primarily of vaccine. In order to conduct the programme, it was essential to have an allocation of funds that could be used for any necessary purpose and in any country. Fortunately, the WHO regular budget met this need. Illustrative of the importance of these funds was the need in western and central Africa. The USA could provide all the necessary resources except "local costs" (costs of petrol, vehicle repair and per diem expenses of teams) which, as a matter of policy, it could not meet. The required amounts of money were small but critical if the programmes were to operate at all. Similarly, contributions in kind fully met the needs for vaccine but funds were needed, such as for the purchase of vaccination instruments and for the printing of package inserts.

Logistics

The availability of vaccines, vaccination instruments, vehicles and other supplies ultimately determined whether the programmes were able to function. Ensuring continuing availability, however, was difficult owing to fluctuating demands for resources as a result of natural and man-made disasters, unexpected epidemics and other problems. To meet this need, the WHO smallpox eradication unit took an active operational role rather than serving in the more common advisory technical capacity. Being in frequent contact with national and WHO programme staff, the unit could anticipate problems, evaluate requests and respond quickly. An emergency reserve of vaccine and vaccination instruments was created, permitting these to be distributed within 48 hours after receipt of a request; deliveries of supplies and equipment were occasionally able to be diverted from one country to another; and special funds could be provided for emergency procurement of equipment or to pay special consultants.

The major constraint in beginning or intensifying a programme proved to be the availability of vehicles, a problem that was never fully resolved. Most health ministries had a dearth of roadworthy transport and were seldom able to provide for emergency requirements. Vehicles of foreign-manufacture usually required 12–18 months between submission of a purchase order and delivery, but needs could often be anticipated no more than 3–6 months in advance. Purchase of locally manufactured or assembled vehicles solved the problems in some countries; local purchase of already-imported vehicles was possible in other countries; and, in some instances, special motor repair workshops were established. Better results would have been obtained if it had been possible to procure a reserve fleet of new vehicles to be dispatched quickly when needed, and if more efforts and resources had been directed to the development or improvement of national vehicle maintenance and repair facilities.

Administrative constraints in dispensing and accounting for funds and in the use to which they could be put was a constant, often formidable problem. In many endemic countries, small per diem allowances and long delays in payment all but precluded travel by national field staff; allowances for petrol often permitted vehicles to operate for only a few days each month; budgets for vehicle maintenance and repair were small and facilities were often inadequate; and there were no provisions to dispense funds for exceptional needs such as patient isolation facilities or rewards for reporting cases. Many of these problems were expeditiously resolved by providing to WHO advisers and senior national staff an advance of funds, called an imprest account. The account was regularly replenished on receipt of the itemized expenditures which had been made. Implementation of the system was not without problems. Proper accounting through

receipts proved difficult in many areas because of illiteracy and there were, in all programmes, numerous questions as to what were proper expenditures. Without the sympathetic and flexible administrative support provided by WHO, satisfactory solutions would seldom have been found.

Operational tactics and strategy

An important principle underlying the operation of the smallpox eradication programme was the recognition that each national programme must have an administrative structure and pattern of operations compatible with its own health structure and sociocultural environment. Operational objectives rather than a specified methodology were defined: (1) a vaccination campaign to ensure a high level of vaccinial immunity to substantially reduce the smallpox incidence; and (2) a surveillance programme to ensure prompt reporting of cases from all health facilities, to permit the investigation and containment of outbreaks, and to analyse patterns of occurrence so that corrective measures could be taken.

Programmes were expected to be designed as a collaborative effort of national and WHO staff and to evolve with time in the light of experience. Consequently, programmes differed greatly between countries and over a period of time. The role of nationally-assigned WHO staff also differed from country to country. Most effective were those who took an active role in field operations. Those who assumed a passive role of detached technical adviser were encouraged to leave the programme. As working counterparts, WHO staff frequently provided continuity and sustained the momentum in programmes when national leadership changed, and they were sometimes better able than their national counterparts to approach senior health officials when additional support or changes in policy were required.

The first priority of the smallpox eradication staff in WHO headquarters was to anticipate, respond to and support national programme needs. An immediate response to requests for resources or advice and frequent contact through visits and meetings were essential elements. Global strategy and priorities were regularly discussed in meetings of regional and national advisers and national programme staff. These meetings were important because it was in the execution of national programmes that important observations were continually being made, as a result of which changes in strategy and tactics were introduced. Because of these contacts, those who served with the smallpox eradication programme identified as much with international as national goals; they related closely to each other; and they sustained a remarkably high level of morale despite arduous working conditions.

A definite end-point—the zero incidence of smallpox—undoubtedly was important in motivating staff and sustaining interest. Though few health programmes have such an end-point, comparable levels of achievement, interest and morale should be possible where specific goals are identified, where progress is monitored, and where programme staff are fully supported in their efforts.

RESEARCH

The importance of problem-oriented research that was conducted throughout the course of the smallpox eradication programme cannot be too emphatically stated. The nature and extent of the research agenda could not initially be foreseen. The most explicit question at the outset of the programme was whether there was a natural reservoir of variola virus which could thwart the objective of eradication. Beyond this, it was believed that studies conducted during the execution of programmes would reveal a great deal about the epidemiology of the disease and about programme implementation, and that the available tools and methods could be improved to permit the task to be achieved more efficiently.

The extent of the changes that occurred in programme strategy and tactics and in the understanding of the epidemiology and virology of smallpox and other poxviruses was not anticipated. Contributions were made by a range of disciplines, from basic molecular biology to applied technology to the social sciences. Most research was undertaken in the context of ongoing field programmes to answer practical problems or to resolve apparent paradoxes of observation. This provided unusual impetus to the research effort and permitted many of the findings to be translated promptly into practical application.

While the lesson for other disease control programmes would appear to be evident, research on problems of the greatest importance to the developing countries receive little support. Research is still considered by some to be an academic luxury and, in consequence, the potential of modern science has barely begun to be realized.

CERTIFICATION OF ERADICATION

Certification of smallpox eradication was a valuable and necessary exercise in providing confidence to the global community. In order to permit cessation of vaccination, both the general public and health officials throughout the world had to be convinced

that the disease had been eradicated everywhere. This required a special programme of assessment conducted under WHO auspices, utilizing respected scientists of diverse nationalities who were requested to be critical in providing a written judgement of their observations and conclusions.

Fostering the necessary confidence was a difficult problem at many levels. National authorities recognized that the reporting of infectious diseases was deficient, and that in certain circumstances governments suppressed information about known cases. Smallpox vaccination was well established and was not lightly discarded by health officials. Efforts to publicize widely and in detail what was being accomplished, and how, convinced many that the programme had been well conducted and that WHO and national officials spoke with justified confidence of the achievement, but more than this was required.

In 1971, the decision was made to appoint independent international commissions of recognized scientists to visit each country in the endemic areas two or more years after the occurrence of the last known case. They were to ascertain whether the national surveillance programme would have detected smallpox if this was present. If they were not satisfied, they were asked to recommend additional measures. Such visits were arranged only after WHO and national smallpox eradication staff were themselves confident of the status of the programme and its documentation. The first of 21 international commissions visiting 60 different countries was convened in 1973.

Several features of this approach deserve mention. Firstly, each country was required to prepare a report detailing those activities which documented the absence of smallpox. This stimulated national officials to support smallpox surveillance programmes after the occurrence of the last case, when the inclination was strong to divert resources to other needs. Secondly, the involvement of scientists of many different nationalities, including those who were most sceptical, led to wider knowledge of the nature of the programme and confidence in its success. Thirdly, a Commission's decision that eradication had been achieved presented important opportunities for national and international publicity.

A Global Commission, composed of 21 scientists from 19 countries and assisted by 11 advisers from 8 countries, surveyed the status of the programme worldwide and recommended other activities that were needed. Although some activities involved special studies in areas and countries to which access by international staff had been limited, all were able to be completed and global eradication was certified.

CONCLUSION

Extraordinary achievements are possible when countries throughout the world pursue common goals within the structure provided by an international organization. WHO played this role in the eradication of smallpox. It now offers a unique although only partially realized potential in promoting other efforts in disease prevention and health promotion. It is an organization which can demonstrably catalyse achievements far out of proportion to the resources it commands. The extent to which it is successful will depend upon the confidence of Member States in WHO, on the effectiveness of its leadership in enunciating clear and measurable objectives and in mobilizing support for their realization, on the number and competence of its professional staff, and on its ability to set aside extraneous political questions. Its ability to respond appropriately to old and new challenges will be decisive in the much larger task of providing improved health and a better quality of life for all the world's people.

RÉSUMÉ

LE PROGRAMME D'ÉRADICATION DE LA VARIOLE: PRINCIPES ET ENSEIGNEMENTS

L'éradication de la variole a exigé un effort international unique de totale collaboration de la part de l'OMS et des Etats Membres. Nous en avons tiré de nombreux enseignements relatifs à l'organisation, à l'exécution et à l'évaluation, qui peuvent être appliqués à d'autres activités internationales. Nous retiendrons notamment qu'il importe de fixer des objectifs mesurables et d'évaluer les progrès et les résultats par rapport à ces objectifs, de mettre en place des mécanismes de contrôle de la qualité, aussi bien en ce qui concerne les vaccins que l'exécution des tâches, de recruter le personnel le plus qualifié possible et de le soutenir, et de mener en même temps un programme continu de recherches orientées sur les problèmes, visant à faciliter les activités et à résoudre des questions apparemment paradoxales. Les capacités dont ont fait preuve les services de santé nationaux pour exécuter leurs propres programmes d'éradication de la variole ont été étonnantes et autorisent à penser que d'autres actions de santé plus complexes pourraient être entreprises. Pour cela, il faudrait recruter un nombre suffisant de cadres compétents, à qui l'on déléguerait des responsabilités; ces

cadres existent mais manquent souvent d'expérience. L'OMS a joué, dans l'orchestration de cette vaste entreprise, un rôle de catalyseur essentiel. Bien que ses possibilités soient encore partiellement inexploitées, elle est en mesure de promouvoir d'autres efforts de prévention de la maladie et de promotion de la santé.

Les pays qui poursuivent des objectifs communs dans le cadre structurel offert par une organisaton internationale peuvent réaliser des prouesses. L'OMS a joué ce rôle de promoteur dans l'éradication de la variole. Elle a en effet montré qu'elle pouvait obtenir des résultats sans commune mesure avec les ressources engagées. Mais le succès dépend de la confiance que placent en elle les Etats Membres, de l'efficacité de la direction (qui devra fixer des objectifs clairs et mesurables et mobiliser l'appui qui permettra de les réaliser), du nombre et des compétences de ses cadres et de son aptitude à s'abstraire de toute considération politique. Son attitude sera décisive dans la tâche beaucoup plus ambitieuse qui consiste à assurer une meilleure santé et une meilleure qualité de vie à tous les peuples du monde.

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