OCCASIONAL PAPERS

THE SAGA OF SMALLPOX ERADICATION AND BEYOND

JAMES BORDLEY III LECTURE

By
DONALD A. HENDERSON, M.D., M.P.H.
Dean
The Johns Hopkins University
School of Hygiene and Public Health
Baltimore, Maryland

September 30, 1977
THE MARY IMOGENE BASSETT HOSPITAL
COOPERSTOWN, NEW YORK
Printed in the United States of America

JAMES BORDLEY III LECTURE

You have accorded me a singular and deeply appreciated honor in inviting me here tonight to present the James Bordley III Lecture. For twenty-five years, my wife and I have been transients, shuttling between Geneva, Atlanta, Baltimore, Rochester and Cooperstown. Strangely, inexplicably, Cooperstown and The Mary Imogene Bassett Hospital have continued to represent for both of us that evasive concept of permanence and of family in a more meaningful sense than is represented by anywhere else we have lived. Something unique in character exists here.

The more experience I have had in medical and educational administration, the more deeply impressed I have become with the complexities, both tangible and intangible, of melding together an effective, harmonious group which both challenges and permits an optimum expression of inherent talent. I humbly pay special homage to Dr. Bordley, a man so versatile and able as to be able to achieve not only this, but at the same time to sustain an internationally recognized level of personal scholarship and, to the house staff, recognition as one of the finest teachers of his time. To Dr. Bordley, to the remarkable staff which he assembled at the Bassett, a family to both my wife and myself, we owe a profound debt of gratitude.

Development of the Smallpox Eradication Program

I will try to sketch for you a personal vantage point the saga of smallpox eradication as it developed over the past 11 years, to provide to you some sense of the dimensions of the problem, of why the program was undertaken, some of the difficulties we faced and, lastly, an indication of what this program might mean for the future.

A decisive point in time was May 1966, when the World Health Assembly decided to undertake a coordinated intensified program to eradicate smallpox from the face of the earth in a 10-year period.[1] The program was to commence on January 1, 1967; the hope was expressed that the last case would be discovered and isolated by December 31, 1976. The rhetoric at that

1966 Assembly was optimistic and confident. Privately, I believe it is fair to say that not more than a handful believed the project to be a practical objective, even if theoretically possible. In fact, no disease had ever before been eradicated. Moreover, and realistically, those experienced in international health work could well foresee the practical difficulties of achieving any workable degree of cooperation among the 50 or so nations which would be required to undertake special programs. Not to be dealt with lightly were the technical and logistical difficulties of executing a program which would inevitably have to be conducted in some of the most inhospitable places on earth. Better control of smallpox was envisaged but eradication was another dimension.

The 10-year time limit proposed was not grounded in an elaborate operations research process or, for that matter, in any other planning process. Quite simply, Kennedy, as you will recall, had said some years before "we will land a man on the moon in 10 years". The delegates reasoned that if one could land a man on the moon in 10 years, surely one could eradicate smallpox on earth in 10 years.

The then Director-General of WHO, Dr. Marcelino Candau, a Brazilian, expressed certainty that eradication in the Amazon basin, let alone anywhere else, was impossible. And being Brazilian, he knew the Amazon basin well. With WHO's only other eradication program—that for malaria—foundering at that time, the Director-General understandably did not want to be charged with the responsibility for yet another eradication program which he considered certain to fail. The Assembly's action, he felt, had been precipitated by the United States, and so he asked the United States to share in the expected onus of failures by making available an American to develop and direct the program. The person so designated was myself.

I had been working at the Center for Disease Control as Chief of the Surveillance Section and had been directing programs of infectious disease surveillance, vaccine evaluation and vaccination campaigns against a variety of diseases. In the early 1960's, as but one of a number of programs, we had created a smallpox unit to assess smallpox vaccine complication rates; to assess the jet injector as a possible tool for administering the vaccine; and to prepare staff to cope with smallpox cases should they be imported into the USA.

Meanwhile, USAID, in the early 60's, had promoted a series

of measles vaccination programs in Francophone Western Africa which were beset with all manner of problems. In 1965, CDC was asked to help. Not wanting to refuse to assist but concerned about the basic assumptions of the program, we countered with a vastly more extensive plan for smallpox eradication throughout a bloc of 18 west and central African states with a proposal that measles vaccination be given simultaneously in countries where it was desired. Although a technically sound proposal, we felt that it was rather too ambitious to be accepted. However, to our surprise, President Johnson on November 23, 1965 announced the decision of the United States to undertake this program and I was asked to assume responsibility for its implementation.[2] This program was only in its initial phases of detailed planning, recruitment, procurement of supplies, securing of intergovernment agreements and the like when the Assembly made its historic decision to undertake global eradication. Suddenly, as such things happen, I was a recognized authority in smallpox eradication and with no direct practical experience was on my way to Geneva as the global director. I had seen precisely 12 cases of smallpox in Argentina in 1957 and one in Canada in 1962. It was understood, however, that my assignment would only be for perhaps 9 to 18 months to initiate development of the program. Accordingly, we left half of our household goods in storage and so, inauspiciously, began an incredible 10 year adventure.

I recount this to dispel any notion that this—no less than so many other memorable enterprises—developed logically and coherently within the political-planning process.

The Rationale for Smallpox Eradication

Why eradicate smallpox? Why, among all the afflictions besetting mankind, select this disease? As McNeill has so well described in his recent history, "Plagues and People," smallpox, throughout written history, has been preeminent as the most devastating disease known to mankind—the disease which more than any other has again and again altered the course of history.[3] Diseases such as plague or cholera or yellow fever have been, overall, of minor consequence. Health officials feared this diseases as no other.

Illustrative of this concern is that until 1971 in the United States, some 14 million people were vaccinated annually to pro-

tect against importation and spread of smallpox despite the fact that the last known case had occurred in 1949, more than two decades before.[4] Not only was this costly, but complications following vaccination caused between 6 and 12 deaths annually. In the United Kingdom, there were 8 smallpox hospitals maintained on a stand-by basis to admit cases should smallpox be imported. Moreover, all countries throughout the world required valid international certificates of smallpox vaccination for all travelers, the only disease for which such certificates were universally required.

Smallpox, as you know, is caused by a virus which is transmitted from person to person through minute droplets expelled from the nose and mouth. The susceptible contact inhales these and after a period of 10 to 12 days, experiences high fever and aching pains similar to the symptoms of influenza. After 2 to 4 days of fever, a rash appears on the face and rapidly spreads over the rest of the body, the lesions being most dense on the face, arms and legs. The vesicles which first appear become pustular by about the fifth day of rash. Subsequently, scabs form which separate during the third and fourth week of rash. Approximately 20% to 30% of those afflicted with variola major, the severe Asian form of smallpox, died from the disease. There is no treatment for smallpox and thus, importations into Europe were no less serious than those in Asia. Two-thirds of those who experienced the disease were left permanently scarred and some were blinded. The form of smallpox which was found throughout most of Africa was milder and resulted in death among 5% to 15% of those afflicted. The least serious form of smallpox, variola minor, was present in South America, South Africa and now in Somalia, and caused death in less than 1%.[5]

Although the disease was serious and widespread, it had certain characteristics which facilitated eradication. In contrast to such as yellow fever, man is the only known reservoir of the disease and for it to persist, it must pass from person to person in a continuing chain of transmission. Each individual, each link, in the chain of transmission experiences rash and a large proportion of those who survive bear permanent scars of the disease. In effect, the disease was visibly apparent wherever it was and left its "footprints" wherever it had been. Thus, one could readily ascertain whether or not smallpox was present or had been present in any geographic area. The disease itself was recognized by

even illiterate populations and thus it was possible through surveys in markets or by house to house survey to detect smallpox in any given area. Sometimes, cases of chicken pox were mistaken for smallpox, particularly by recently graduated physicians who, in the course of their study, often had not seen a case. However, the grandmothers in the villages generally were quite accurate in their diagnosis. Further, epidemiological studies conducted early in the program confirmed that the disease almost inevitably spread as a result of close face to face contact, usually within the confines of a house. In major part, this accounted for the occurrence of the disease in clusters of villages within a district or in sections of a town rather than being randomly dispersed over an extensive area. This feature enabled containment teams to focus their efforts in particular geographic areas. Moreover, the infected individual is able to transmit the virus for only 3 to 4 weeks, that is, from the time the rash first appears until the last scabs separate. Asymptomatic carriers thus played no role in transmission as they do in malaria. In the more remote areas, the disease continued to spread for only a finite period of time—until the susceptibles present had acquired the disease and had died or survived. Logistically, this permitted us to focus our efforts on the more densely populated, more accessible areas with expectations that the disease would spontaneously die out in many remote areas, such as mountain valleys or the further reaches of the Amazon. In fact, this is precisely what occurred. Lastly, the smallpox vaccine is an excellent one, providing a high level of protection against the disease for a decade or more and protection against death for an even longer period.

Smallpox Eradication—1958-66

When I indicate that the program started in 1967, I am slightly misstating the fact. Eight years before this, the World Health Assembly had decided that an eradication program should be undertaken on a voluntary basis.[6] It was voluntary in the sense that endemic countries were asked to undertake systematic mass vaccinations and non-endemic countries were asked to provide donations to the campaign. In fact, however, contributions to the program over this 8 year period averaged only $100,000 in cash and in kind. Strategy consisted simply of mass vaccination to create herd immunity. It had been anticipated that when 80% of the population was vaccinated that transmis-

sion would cease. However, when India, in an intensified campaign, had reached the 80% level of vaccination and found that smallpox was still spreading, a WHO Expert Committee proposed that the target be increased to 100%.[7] Practically, of course, vaccination of 100% of any population is impossible.

Underlying the events of the period was the fact that few believed eradication to be possible. However, in the 1966 resolution, a budget of $2.5 million was approved as a last gesture to the effort before abandoning it. In all, it was expected that programs would need to be conducted in some 50 countries which were either endemic for the disease or adjacent to them. Calculation thus indicates that the total budgeted was an average of $50,000 per country.

The Intensified Smallpox Eradication Program—Developmental Approach

The program commenced on 1 January, 1967—the objective was the occurrence of the last case by 31 December, 1976.

As the program commenced, we immediately faced two major problems:

1. Provision of adequate quantities of suitable vaccine and appropriate vaccination devices—the guns and bullets of the campaign, if you will; and
2. The selection of a suitable strategy—mass vaccination obviously was not the answer but what was?

Supply of Vaccine

The endemic countries, as the program began, were all conducting some sort of vaccination program to control the disease. Vaccine was being obtained from diverse sources. Two laboratories, one in Canada and one in the Netherlands, agreed to test batches of vaccine. The initial results were appalling. Not more than 10% of the vaccine in use in the endemic countries met accepted standards.[8] Some batches of vaccine, in fact, were found to contain no detectable virus whatsoever. We estimated the total need for vaccine to be approximately 250 million doses each year. At a cost of 1 cent per dose, this was equivalent to our total budget. There was no choice but to encourage the development of production in the endemic countries and, in the interim, to solicit contributions of vaccine from countries who were producing it. A group of consultants were convened and a step-by-

step manual of production procedures was developed.[9] Selected consultants traveled from laboratory to laboratory in the endemic areas to assess their potential for vaccine production, to determine what their needs were in the way of equipment and training and to participate in the training of local staff. As these laboratories commenced production, each batch was tested by one of the international testing laboratories. As the laboratories gained confidence and the quality of the vaccine improved, an ever smaller proportion of the batches of the vaccine were tested. However, throughout the program, efforts were made to test at least three batches of vaccine from each laboratory every three months.

During the first few years, the principal contributors of vaccine were the Soviet Union, which contributed some 140 million doses each year, and the United States, which provided some 40 million doses of vaccine each year for countries in western and central Africa. Smaller amounts of vaccine were donated by some 20 other countries. By 1970, essentially all vaccine met accepted standards and these standards were rigorous. The freeze-dried vaccine had to meet minimum potency requirements after incubation at 98°F for 30 days. By 1973, 80% of the vaccine being used was produced in the developing countries and certain of these countries were contributing vaccine for the use of others.

Vaccination Technique

Since Jenner's time, vaccine had been applied by some sort of scratch technique in most parts of the world. In the United States, a better method for vaccination had been developed called the multiple pressure technique. This method produced a higher proportion of successful takes. Unfortunately, it was difficult to teach this technique to vaccinators. A better approach appeared to be the jet injector which had been developed by the Army Research and Development Command and field-tested for use in smallpox vaccination by the Center for Disease Control, Atlanta.[10] With this gun, vaccine is expelled under high pressure through a very small opening into the superficial layers of the skin. Vaccination of as many as 1,000 persons per hour is possible. By 1967, field testing had been completed and the gun was ready for field use. It was introduced for use in Brazil and countries of central and western Africa. Although theoretically, as many as 1,000 persons per hour could be vaccinated with this

device, logistically, it was impossible to realize the potential of the gun. In fact, most teams in western and central Africa averaged no more than 1,000 to 2,000 vaccinations per day. With dispersed populations, difficulties of travel and problems in organization, greater numbers simply could not be vaccinated. A major drawback in use of the jet injector was the need for maintenance and repair and provision of a continuing supply of spare parts. In the developing countries, the establishment of an effective maintenance and repair scheme, let alone a satisfactory storage and distribution system for spare parts, is a formidable task.

The ultimate solution proved to be the very simple bifurcated needle, which had ben developed by Wyeth Laboratories. The needle, approximately 2 inches in length, has two small sharpened tines at one end. In 1967, it was being tested for possible application for multiple pressure vaccination. We reasoned that the needle might be equally effective if held at right angles to the skin and multiple punctures made. The design of the needle was such that only superficial penetration of the skin was possible, a desirable attribute since the vaccinia virus proliferates only in the superficial layers of the skin. Tests of multiple puncture vaccination proved most successful with a higher proportion of successful vaccinations than was obtained by scratch vaccination and equivalent to the rates obtained with multiple pressure vaccination.[11] Training of the vaccinator could be accomplished within a matter of minutes. The needle offered another important advantage in that much less vaccine was required for vaccination. When the needle was dipped into a vaccine vial, a very small amount of vaccine adhered between the two tines, an amount sufficient for vaccination. Previously, a drop of vaccine had been applied to the skin and a scratch or multiple pressures made through this drop. A vial of vaccine previously designed to vaccinate 25 people could now be used to vaccinate up to 100 persons. Wyeth Laboratories had envisaged that the needle would be disposable but with the limited budget available to us in WHO, we felt we had to have a needle which could be sterilized and reused many times. Accordingly, a harder steel alloy was utilized in fabrication. Tests showed that the needle could be used hundreds of times.

A final refinement of vaccination technique related to the use of alcohol or soap and cotton sponges to "sterilize" the skin.

Earlier studies had showed that use of a 70% alcohol solution did little more than redistribute the bacteria on the skin surface. Accordingly, studies were conducted in which complication rates were compared for children vaccinated without cleansing the skin and those vaccinated following cleansing of the skin with alcohol or soap. There was no difference in the frequency of septic complications. In some areas, the savings in alcohol, soap and cotton sponges alone paid a substantial proportion of the petrol costs.

Finally, a simple plastic container was developed which permitted one needle at a time to be dispensed and which was resistant to high temperatures. A vaccinator was issued two such plastic holders, one containing approximately 100 needles and the other empty. As each needle was used, it was placed in the originally empty container. At the end of the day, the vaccine holder containing used needles could be boiled for 20 minutes, shaken once or twice and the vaccinator was ready for the next day's work. Thus, the vaccinator's equipment consisted only of these two containers plus a few vials of vaccine. All of this could be placed in a shirt pocket. Since the dried vaccine remained potent for a period of one month at 98°F, a vaccinator could work in tropical areas over long periods far from any source of supply.

Strategy

Previous to the intensified eradication program, progress in any smallpox campaign had been measured in terms of the millions of vaccinations performed. Unquestionably, a program of vaccination was important but the real objective was "zero" cases of smallpox. Thus, a two-prong strategy was developed: (1) vaccination; (2) surveillance.

Vaccination

In most of the endemic countries, vaccination immunity was low. Thus systematic campaigns were developed with the objective of reaching 80% of the population. The figure of 80% was not based on epidemiological principles, but rather on a feasible operational goal. Vaccination campaigns in the different countries developed in different ways, depending on the health structure and the particular circumstances of the country. Illustrative is the program in Afghanistan. When the program there began, maps of the country which were available were obsolete and sometimes

erroneous. Over the years, new villages had been built and old ones had disappeared. Accordingly, each vaccination team was assigned an "advance man" whose responsibilities included preparation of an updated map which showed each village, school and health facility. To do this, he traveled ahead of the team to a known village and inquired there about other villages in the area. Each of these was specifically identified on the map and visited and information in regard to other villages sought. While visiting the villages, he discussed the nature of the program with the village leaders to explain what vaccination could achieve and to solicit their support and help. Later, a vaccination team progressed house by house in each village, vaccinating each person. The team kept no records but, rather, when work in a village was completed, they counted the number of needles which had been used and recorded this number. By proceeding in this manner, fewer records needed to be prepared and they were able to move more rapidly. Ten to fourteen days later, an assessment team visited a 10% to 20% sample of the villages. The villages were selected by the simple expedient of listing each village name on a piece of paper, placing the pieces of paper in a box and drawing at random the villages to be assessed. Although statistically, objections could be raised to this technique, it was a method which was readily comprehended by assessment team leaders and operationally, it proved to be workable and effective. If the assessment team found on inspection that less than 80% of individuals under the age of 5 bore marks of recent or past vaccination, the vaccination team was required to return to the area *without per diem* to revaccinate the area. This technique served admirably to increase the motivation of the vaccination teams to reach a high proportion of the villagers.

Surveillance

Regular reporting of all known cases was essential if outbreaks were to be identified and contained. However, in 1967, the reporting of smallpox cases was a shambles. At the national level, some countries reported to the World Health Organization not at all, some sporadically, and some suppressed reports of smallpox. Reporting from national

levels was actively encouraged through frequent repetitive contact with the respective governments and through persuasion that it was better to report known cases than to suppress them.

The problems at state, district and local levels were no less serious.[12] Frequently, it was found that perhaps 200 cases were known to exist at the local level but, due to casual recording practices or sometimes deliberate action, no more than perhaps 100 cases would be reported to district level. At district level, the same procedure was repeated so that perhaps 20 cases would eventually be reported at national level. Various approaches were employed to improve reporting. One of the most effective was to assign a mobile team of 2 to 4 persons for each 2 to 5 million population. The team visited each health unit on a regular basis to encourage them to report each week whether or not cases had been reported. On discovery of cases, the containment team participated with local health staff in the containment of the outbreak. By repeated visits and by working with the local health staff in containment of outbreaks, reporting steadily improved as it became clear to the local health staff that there was a real concern that cases be reported. In some countries, the fact that any higher level health staff visited a health center was itself a unique event; that anyone took action on a report which had been sent to higher levels was viewed as something of a miracle.

In 1967, 131,000 cases were officially reported but later studies revealed that not more than 1% of all cases which actually occurred that year were recorded. Thus, the total number of cases which occurred in 1967, during the first year of the program, is estimated to have been between 10 and 15 million cases.[13]

In brief, then, the strategy consisted of two components: (1) a vaccination program designed to assure that 80% of the population bore a mark of vaccination and (2) a program to improve reporting and containment measures so that those outbreaks which were present could be identified and could be contained.

Progress in the Program

In 1967, 34 countries were considered to be endemic and 11 others experienced importations. By 1970, the number of en-

demic countries had decreased to 17 and by 1973, to 6. However, these 6 included India, Pakistan, Bangladesh and Nepal which together had a total population of 700 million persons. In these countries, traditional vaccination programs had been in progress for many years. However, reporting of cases was poor; the containment of outbreaks was all but ignored; and throughout the subcontinent, there prevailed a sense of profound pessimism.

Beginning in the summer of 1973, this began to change. In June of that year we developed a plan in India which was later extended to the other countries, to utilize for one week each month all health workers in a village by village, later house by house, search for cases.[14] Special containment teams (called fire-fighting units) were constituted who would move in promptly to stop the outbreaks. As was done with the vaccination program, special assessment teams were formed which visited a sample of the villages to determine whether, in fact, the search had been properly performed. To facilitate the discovery of cases, a reward was offered to anyone who reported a case. The reward initially was very small, but as the number of cases declined, the reward was steadily increased. The result of these measures was a veritable explosion in recorded cases. The experience in one Indian state, Uttar Pradesh, illustrates this. Considerable work directed toward the improvement of reporting had been in progress for almost two years, but the state was large and had a population of 100 million persons. During September 1973, between 100 and 300 cases had been reported weekly. During the first search week, some 7,000 cases were discovered. Later we were to learn that during that first search, only 50% of the villages had, in fact, been searched and thus the true number of cases at that time was even greater. Once cases were discovered, however, they could be contained. The system of search and containment was steadily improved as time passed and, eventually, assessments showed that in every state of India more than 90% knew that there was a reward for reporting a case of smallpox and knew where to report a case. In fact, the knowledge of the reward and the interest thereby generated resulted in literally hundreds of thousands of cases of rash of all types being reported to health authorities. Each of these had to be individually screened and assessed. However, as the smallpox incidence fell and smallpox cases disappeared, the fact that so many possible cases were be-

ing reported provided increasing confidence that if a case were present, it would be discovered. The experience in Bangladesh, Nepal and Pakistan paralleled that in India.

To appreciate the magnitude of the undertaking of the search operation in India, some data are useful. In all, some 120,000 health staff searched the estimated 120 million households in India on repeated occasions. For each search, more than 8 tons of forms were required. Assessment of the search was performed at three levels—district, state and national—the separate assessments serving to cross-check each other.

In October 1974, the last known case of smallpox occurred in Pakistan; in April 1975, in Nepal; in May 1975, in India. The last known case of smallpox in Asia and the last known case of the severe form of smallpox, variola major, occurred in a three-year old girl, Rahima Banu, on Bhola Island, Bangladesh. The date was 16 October, 1975, two years ago.

The Final Phases

The last battleground of the smallpox eradication campaign proved to be Ethiopia where the least severe form of smallpox, variola minor, was prevalent. Death rates due to this form of smallpox were less than 1%. Several factors account for the persistence of smallpox in Ethiopia after it has dissappeared from all other countries. The program there, for various political reasons, started three years later than in any other country. Political stability was a real problem; the road system was very limited; the terrain was perhaps the most difficult of any country in which the program was conducted. Local rebel groups sometimes shot at the teams and, on more than one occasion, WHO advisors as well as national staff were kidnapped and held hostage for varying periods of time by rebel groups. Every conceivable approach had to be used to overcome the problems. Because of the size of the country, the all but impossible road conditions, and the limited number of supervisory staff available, helicopters were employed in this program. Despite these problems, good progress was made and in August 1976, the last known case occurred. More than 2,000 Ethiopian local staff and WHO advisors searched the country. For seven weeks, no cases could be found anywhere. We thought that the last case had been discovered and contained.

However, in late September, cases were discovered in Mogadishu, the capital of Somalia, which lies adjacent to Ethiopia.

Subsequent investigation revealed that cases had been imported into Somalia as early as April or May of 1976 and, although discovered by lower level government health officials, reports of these cases had been suppressed. Parenthetically, it should be noted that smallpox transmission in Somalia had been interrupted in 1963, but in 1968 a WHO-sponsored program had been inaugurated because of the high risk of importation of cases into Somalia from Ethiopia. The objective of the program was to strengthen surveillance and to conduct systematic vaccinations. Almost 700,000 of 3 million persons were vaccinated annually. Until 1976, importations had been rapidly identified and contained.

Unfortunately, cooperation on the part of the government had gradually deterioriated. When the cases were discovered in Mogadishu, the necessary containment measures were greatly delayed and poorly conducted. Not until late in the year were satisfactory measures able to be applied. In mid-January 1977, transmission appeared to have been stopped in Mogadishu. Limited search conducted among nomads in the vast Ogaden desert area surrounding the capital revealed no cases. Again, we thought that perhaps the last case had been detected. However, as later information revealed, at least 3 to 4 infected nomadic camps remained in the desert. Again, some of these were known to lower level government health authorities but were not reported. In March and April, as the rainy season began, the nomadic groups began moving actively across the desert, concentrating in agricultural development areas. With this movement, the disease spread rapidly. Increasing Somali staff were deputed to the program, the government declared a state of national emergency and additional WHO veteran smallpox eradication workers were brought into the country. By June, a major effort was underway. In all, somewhat more than 3,000 cases occurred, but the incidence is declining rapidly and it is anticipated that no later than the end of this year, the last case of smallpox in Somalia will have been found and isolated. Meanwhile, in adjacent areas of Kenya, search operations have been in progress. Although an importation occurred early in the year, it was rapidly contained. No cases have been found since. In adjacent areas of Ethiopia, civil disturbances since August this year have prevented an adequate program of surveillance. However, prior to that time, an extensive vaccination and case search program had been conducted

throughout the entire area bordering Somalia. No cases had been discovered since August 1976.

Our 10 year time target expired on 31 December, 1976. Thus, regrettably, eradication has not been achieved within the allotted 10-year period. However, I believe it will not have been missed by more than 12 months.

Confirmation of Eradication

To confirm that eradication has been achieved, two full years of intensive search will have to be conducted to be certain that transmission of smallpox is not still occurring. Only then can a WHO International Commission be convened to determine through inspection of records and field visits that they are satisfied that smallpox is no longer present. So far, WHO Commissions have certified smallpox eradication in South America and in all of western and central Africa. By the end of the year, all of the Asian subcontinent as well as Indonesia will also have been certified. Hopefully, the last areas will be able to be certified in December 1979.

Meanwhile, intensive research studies have been conducted to determine if naturally-occurring smallpox transmission could be detected in nature. None has been found. The fact that during the past 10 years, every focus of smallpox in non-endemic areas has been able to be traced to known endemic regions is the most persuasive evidence that indeed no natural reservoir of smallpox does exist.

With the cessation of smallpox transmission, variola virus will be confined to research laboratories. Since 1975, WHO has been engaged in a special program to identify and register all laboratories retaining stocks of variola virus. All governments have been officially queried; all laboratories registered as being able to conduct variola virus diagnosis have been contacted; and all laboratories which since 1950 have reported in the literature having done research with variola virus have been questioned. At present, only 17 laboratories in 10 countries are registered as retaining stocks of variola virus; more than 60 have destroyed their stocks. By 1979, it is expected that no more than 4 laboratories will retain variola virus under high security precautions.

Cost

We have endeavored to tabulate all international assistance made available to this program in whatever form. Through 1979, when we believe that final certification of eradication will be possible, approximately 100 million dollars will have been spent—approximately 8 million dollars per year or about one-half the annual revenue of this one hospital. The developing countries themselves will have spent perhaps twice this amount but few will have spent much more than what they were spending in smallpox control programs. With final confirmation of eradication, vaccination everywhere will be able to be stopped. The savings worldwide are estimated to be in excess of $1,000 million dollars annually.

The Future

Is this then the end of a program or the beginning of some greater effort?

Many of the same individuals who were scathing of the prospects of eradication only 10 years ago now insist that its achievement was some sort of fluke, an aberration in the health system, that no disease could be dealt with in the same manner, that such "prodigious" sums of money could not possibly be mobilized for other health problems, and so on. In brief, many have effectively made a plea to return to business as usual.

But can it ever be the same again? In many of the developing countries, where health ministries have traditionally been held in low esteem, there is a perceptible new sense of confidence in their own ability to deal with the overwhelming health problems. Moreover, there is respect within their own governments that given modest support, well-conceived plans, involvement of the community and an element of management that the impossible is within reach.

More than 700 international staff from 52 countries served WHO in this campaign and, in the process, acquired an expertise, a point of view and a sense of the possible. The majority were under 40 years of age, far younger than the average WHO consultant. Many were not physicians. Several are now already serving in directorate general positions in their own governments; one is Assistant Director-General of WHO; and two of the U. S. Public Health Service's six agencies are headed by former smallpox staff.

More than this, one senses that there is an increased perception that in this one world, better health *per se* is important and important to all countries. It is my hope, and I know the hope of the thousands with whom I have worked in this program that we have helped to do much more than eradicate smallpox—that this achievement, unique though it may be, represents but a very small beginning in a very much greater and more complex effort to prevent disease at the source rather than to treat sickness after it occurs. It is this hope which brought me to the country's oldest and the world's largest School of Public Health—at Johns Hopkins—in hopes that I might participate even more actively in this process. My highest aspiration is to serve as director of an institution which bears the mark of excellence which I knew so well at Cooperstown.

REFERENCES

1. World Health Organization, 1966. *Official Records No. 152 of the World Health Assembly* (pp. 258-296), Geneva.
2. Foege, W. H., Millar, J. D., and Henderson, D. A., 1975. "Smallpox Eradication in West and Central Africa." *Bull. Wld. Hlth. Org.* 52: 209-222.
3. McNeill, W. H., 1976. *Plagues and People.* Garden City, New York: Anchor Press/Doubleday.
4. Neff, J. M., Lane, J. M., Pert, J. H., Moore, R., Millar, J. D., and Henderson, D. A., 1967. "Complications of Smallpox Vaccination." *New England J. Med.* 276: 125-132.
5. Henderson, D. A., 1973. *Smallpox.* Maxcy-Rosenau Preventive Medicine and Public Health, 10th Edition. Edited by P. E. Sartwell. (pp. 104-116) Appleton-Century-Crofts, 1973.
6. World Health Organization, 1971. *Handbook of Resolutions and Decisions of the World Health Assembly and the Executive Board* (pp. 47-48), Geneva.
7. World Health Organization, 1964. *Expert Committee on Smallpox.* Technical Report Series, No. 283, Geneva.
8. Arita, I., 1972. "The Control of Vaccine Quality in the Smallpox Eradication Program." *Series Immunobiol Standard.* 19: 79-87.
9. World Health Organization, 1968. *Methodology of Freeze-Dried Smallpox Vaccine Production,* Geneva.
10. Millar, J. D., Morris, L., Macedo, A., Mack, T. M., Dyal, W., and

Madieros, A. A., 1971. "The Introduction of Jet Injection Mass Vaccination into the National Smallpox Eradication Program of Brazil." *Trop. Geogr. Med.* 23:89-101.

11. Henderson, D. A., Arita, I., and Shafa, E., 1972. "Studies of the Bifurcated Needle and Recommendations for Its Use." Field document. World Health Organization, Geneva.
12. Henderson, D. A., 1976. "Surveillance of Smallpox." *Intl. J. Epidemiology* 5: 19-28.
13. Henderson, D. A., 1976. "Smallpox—The Final Battle." *Scientific American* 235: 25-33.
14. Sharma, M. I. D. and Grasset, N. C., 1975. "History of Achievement of Smallpox 'Target Zero' in India." *J. of Communicable Diseases* 7: 171-175.