

Preface:
**On the Eradication of Smallpox
and the Beginning of a Public Health Career**

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ABSTRACT

When I was a medical student, there were few lectures on public health at our university and such was true at most. The focus was on the treatment of individual patients with limited regard for the problems of the community. But as time has passed, there has been increasing concern about the population as a whole and approaches that might be appropriate for prevention of both acute and chronic diseases, for containing the spread of infection and for fostering healthy lifestyles. Many disciplines are involved but epidemiology, being the primary discipline of public health, lends itself well to serving as a common platform in joining all the disciplinary fields. Such was the case with the smallpox eradication program. The lessons learned from this experience are very relevant to current and future issues in public health.

This is undoubtedly the most exciting time in history to enter the field of public health—so much is changing and so many new opportunities are presenting as the importance of population-based public health is increasingly perceived by governments, universities, and the community as a whole. The experience of working on the eradication of smallpox was a major development in my career as it was for many colleagues who served with me. I am pleased to be able to share this experience with a new generation, which faces both enormous challenges and opportunities in disease control and health promotion.

Key Words: Smallpox, vaccinia, vaccination, surveillance, measles

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I am frequently asked how I decided on my career and how I was able to undertake the many interesting and diverse adventures that I have. My simple answer is that I embarked on a public health career. My recruitment into public health was almost by accident, but I soon found that it provided such fascinating, ever-changing, and rewarding challenges that I never contemplated another option. Even now, after repeatedly retiring, I find myself absorbed with yet another set of challenging problems of national and international concern.

Public health had no meaning for me until well after medical school. Familial expectations were that I would be a primary care physician. My mother was a nurse and a revered uncle, a general practitioner. I had no special exposure that permitted me to even understand what public health practitioners did. During medical school, there were only two lectures on public health. After a one year internship, a two year stint in the United States uniformed services was obligatory. I opted for the US Public Health Service and its Epidemic Intelligence Service (EIS). It was part of the Communicable Disease Center (CDC). The decision was an arbitrary one, based solely on the belief that it might be intellectually rewarding as I knew so little about infectious diseases.

During my two years in the EIS, I participated in a number of outbreak investigations. Each was different and each called on additional skills and knowledge. It was never dull and this is what fascinated me about public health. In 1960, after a medical residency and MPH training at Johns Hopkins, I returned to CDC where I was chief of the Surveillance Section. We focused on a number of infectious diseases of special concern. In 1961, smallpox became one of these. At that time, Europe was experiencing a number of smallpox importations from India and Pakistan. Travel was becoming more frequent and importations more likely. We needed to have a better understanding of how best to cope with an outbreak should it occur in the US. I endeavored to have one of our EIS officers participate with local public health authorities in each outbreak so as to better understand how best to handle an outbreak in the US should it occur. From these and other like experiences came a better appreciation of the importance of a diverse array of practices in different health systems. There was much we all had to learn.

The EIS was popular among physicians as an option for discharging the obligatory two-year uniformed services duty and so we were able to recruit outstanding talent. Many became interested in public health as had I, and went on to careers in the field. It was a training program which ultimately had an important beneficial impact on the public health workforce in the

US, producing many deans and department chairs in schools of public health as well as two WHO Assistant Directors General, directors of CDC, state and county health directors, and many others in academic and research aspects of public health.

During the course of preparations for dealing with a smallpox introduction into the US, the issue arose about the logistics of vaccinating large numbers of people. All countries, the US included, feared smallpox being imported and spreading rapidly in the population, few of whom had been vaccinated since birth. We believed there would be an urgent need to vaccinate large numbers in the event of an introduction. Thus, we worked on adapting for smallpox vaccination, an instrument called a jet injector. It operated by firing through the skin a small amount of vaccine at high pressure to be deposited intradermally. We perfected this in a number of studies in Latin America and the South Pacific. As many as 1,000 people an hour could be vaccinated. It was one of several initiatives that moved us into the smallpox field.

At the time, I was also working with the US Agency for International Development (AID) to identify possible short-term assignments for our EIS officers. AID had decided to make available measles vaccine for nine countries in West Africa and asked for nine EIS officers to spend six months each in helping to start the programs. The initiative was a reasonable one as deaths and complications due to measles were frequent in Africa. AID planned to support mass vaccination over four years. At that point, they expected that the countries involved would continue the programs themselves. However, I was troubled by this assumption. The vaccine then cost \$1.75 USD a dose but these countries could not even afford yellow fever vaccine at ten cents per dose. To provide a needed vaccine for four years and then to stop it was a poor public health policy, as I saw it. But the question remained; how to respond to the AID request? We sought an alternate solution. We proposed instead that support be provided for an entire geographic bloc of countries to undertake country-wide smallpox vaccination programs, while at the same time giving measles vaccine. During the four-year AID program, we thought it might be possible to stop the transmission of smallpox and, with smallpox vaccine costing only one cent per dose, the countries at least could sustain smallpox control even if they could not afford to continue measles vaccination.

AID had budgeted \$5 million USD for programs that would be conducted in the French-speaking countries. The program we proposed would cover all countries in West Africa, both English- and French-speaking. It amounted to 20 countries in all and would cost around \$35

million USD. We knew AID would reject this proposal but we hoped that some sort of appropriate compromise might be reached. At that time, President Lyndon Johnson was trying to identify a program that he could announce as being a US contribution to the UN's specially designated International Cooperation Year. His staff decided that the West Africa program would be an ideal choice. This was a much more ambitious program than we were prepared for. CDC had never had responsibility for an international program and thus was without an experienced staff or administrative structure. The program would require recruiting an additional 50 people plus administrative staff, procuring vehicles, vaccine and field equipment and reaching needed agreements with each of the different countries. Dr. Alexander Langmuir, my chief as director of the epidemiology branch at CDC was angry that I had persuaded the government to fund such an unworkable project, which was so far beyond our capabilities. I tried to explain that none of us had expected the response we received.

There was no option but to forge ahead. The program was approved in November of 1965 and I began working hard with a three person staff to attain agreements with the participating countries on matters such as importation of equipment, vaccines, and plans of action, and recruiting advisory staff for the countries and training them. During this period, we crafted a detailed operational and instruction manual that called for a two-part strategy. The first was to be a vaccination program designed to reach 80 percent of the people and which would require small evaluation teams to follow the vaccination teams to validate that 80 percent were indeed being reached. This concept of quality control met with objections in practically every country, as the ministries simply could not see the value of assigning a vehicle and two people just to check on how other people were performing. They felt we should focus all efforts solely on administering vaccinations. However, this strategy proved to be critical.

The second key component of the strategy was called surveillance and containment. The concept was to have each health unit report every week about the number of cases they had seen as well as the village of residence, age and previous vaccination status of the patients. When cases were reported, a two person team was to go to the outbreak site to search for other cases and to vaccinate contacts and nearby households. At that time, no health department required weekly reports from health units, nor was it policy to send special staff to an area of an outbreak. This second component, surveillance-containment, turned out to be amazingly effective in stopping smallpox, even in poorly vaccinated areas. This proved to be one of the "magic bullets" in the program.

To staff the smallpox program, we recruited a disproportionately large number of younger people, in part because they were best able to adapt to living under rigorous field conditions and they were most receptive to exploring new approaches in disease control. But it seemed to me that all program staff needed to spend time working in the field to better understand smallpox and how best to deal with it. As director, I insisted that everyone spend at least a third of the time in the field talking to the people who were implementing the program locally and trying to understand what problems they were having and what we could do to make for a more efficient program.

In May of 1966, seven months after US approval of the West African program, the World Health Assembly convened its annual meeting. A major item on the agenda was the question of whether or not WHO should intensify its efforts in smallpox programs in order to achieve eradication within ten years. The original proposal for global eradication had been made by the Soviet Union and was endorsed by the Assembly in 1959. Few resources were provided, however, and little progress was made. Delegates from the Soviet Union were angry because they felt that more money should be apportioned to this program, which they had so enthusiastically proposed. However, a large proportion of WHO funds were then being spent on malaria eradication, and the US was heavily supporting that effort both with human and material resources.

Malaria eradication had begun in 1955 and by 1966, it was apparent that it was far more costly and less successful than had been hoped. Some argued that it was impossible to eradicate a disease and that failure of the malaria eradication effort simply confirmed that fact—the hypothesis being that in the evolutionary process, various organisms/species had come to occupy special niches and that an organism or species could not be removed without upsetting the balance of nature.

The WHO Director General Marcelino Candau was asked by the Assembly to prepare a report for the 1966 Assembly so that it could be decided once and for all if WHO should proceed with smallpox eradication or not. Although I was in the midst of endeavoring to set in motion the US West African program, I was directed to go to Geneva to work with WHO staff in preparing the Director General's 1966 work-plan and budget. The proposed plan set forth the same two-part strategy we were designing for West Africa (i.e., both mass vaccination and a new surveillance-containment strategy). During the 1966 Assembly debate, a number of countries objected to WHO undertaking smallpox eradication. Some believed that it was impossible to achieve and if WHO were to fail with malaria eradication and

then smallpox eradication, it would jeopardize the credibility of both the organization and public health itself. Others objected to the additional costs to WHO. The US joined with the Russians in arguing for the ten-year eradication effort. After three days of debate, a vote was taken—58 votes were needed to approve the program; 60 voted in favor. The approved WHO annual budget for smallpox eradication was \$2.8 million USD. The Director-General, who had bitterly opposed the program asked that an American direct it so that when it failed, the US would be seen to bear responsibility. I was designated to be the director.

When the program began, in 1967, 43 countries were reporting cases of smallpox. More than 10 million cases and two million deaths were estimated to have occurred that year. The jet injector guns quickly came into use throughout Brazil and West Africa, but it was soon found that they were difficult to maintain and frequently needed repair. Large numbers of vaccinations could be administered but with many small, scattered villages, guns that could vaccinate 1,000 people an hour were not particularly advantageous. Vaccination was customarily performed by placing a drop of the smallpox vaccine suspension on the skin and making scratches through the drop. This would implant the virus in the superficial layers of the skin and the virus would grow and stimulate production of serum antibody. This protected the individual against infection both by *Vaccinia* virus and smallpox. There were many failures of vaccination, however, because proper vaccination technique was difficult to perform. About this time, a scientist at Wyatt Laboratories in the US invented a small instrument called a bifurcated needle. It was extremely inexpensive; it greatly simplified vaccination technique; and it required use of only one-fourth as much vaccine as was required by conventional procedures. We confirmed its efficacy in the field and introduced it throughout all programs.

The quality of vaccine was a significant problem. It was produced in many different laboratories but, as we were to discover, most of the vaccine failed to meet minimum standards. A laboratory in Canada and one in the Netherlands agreed to test samples of all vaccine. We insisted that no vaccine be used which did not meet international standards. This was the first time that WHO had taken such a position, effectively certifying a national product. Experts from five laboratories met to develop a standard operations manual and to advise the different producers. By 1972, five years into the program, more than 80 percent of the vaccine was being produced in the developing countries themselves and all met required standards.

Oversight for the global program was performed with a WHO headquarters staff of only nine people, including three secretaries. Programs were conducted in more than 50 countries, but no more than 150 international staff persons were in the field at any given time. They included both WHO full- and part-time staff as well as volunteers from the US Peace Corps, Japan, and Austria and others from CDC, OXFAM and non-governmental organizations. National staff numbered as many as 150,000 persons. Our international staff could serve as catalysts and advisers but it is evident that national staff were the ones primarily responsible for the success of the eradication effort.

We encouraged innovation and sought to learn from what was successful. This was not easy as there was no electronic mail system and no dependable intercountry telephone communication. We depended on mail service, periodic regional meetings and a great deal of personal travel by headquarters staff. Every three weeks we prepared a special report for the WHO Weekly Epidemiological Record which detailed numbers of cases reported; progress being made (or not) in specific countries; and new findings of operational importance. Those in the countries, both national and international staff, developed a sense of both pride and ownership in what they were doing and what others were doing as well.

The program initially made dramatic progress. Within three and a half years, all 20 of the countries of West Africa were free of smallpox. East Africa was also progressing well and both Indonesia and Brazil became smallpox free. Six years into the program, there were only five countries that still had endemic smallpox—the Asian countries of India, Pakistan, Bangladesh, and Nepal and, in Africa, Ethiopia. However, the population of the endemic areas numbered more than 700 million persons and progress was far slower than what we had hoped.

In the spring of 1973, we discussed with the Indian government a new operational strategy—an active outreach program to mobilize health service staff to visit every village in India within ten days to find cases and immediately thereafter to contain outbreaks. As we discovered, there was a surprising amount of active movement of people throughout the country—entire families travelling by road and rail into and out of urban centers. Smallpox was spreading faster than we were able to detect and contain the outbreaks. The initial search attempts began in the autumn and involved upwards of 130,000 health workers. At first, they sought information from residents in different areas in each village. Tens of thousands of new and unreported cases were discovered and outbreaks contained. During subsequent searches, workers discovered that they could visit each house in

their areas within the ten-day period. Independent teams verified that at least 90 percent of the houses had been visited or the search in the area was repeated.

By January 1974, we were convinced that we had the answer for stopping smallpox in the most difficult of the remaining countries, but other problems intruded. A gasoline strike cut off petrol supplies, the airlines and then the railroads went on strike and then the heaviest rains in 30 years struck the most heavily populated states. Hundreds of thousands of refugees fled, carrying smallpox with them. In May of that year, India reported the trial detonation of its atomic weapon. The international press highlighted this event but also noted that India was experiencing some of the most serious epidemics of smallpox in its history. The Prime Minister was deeply concerned and redoubled support to the program. In May of 1975, the last case occurred in India and in August, the Prime Minister announced India's freedom from smallpox for the first time in its recorded history. The last case of smallpox in Asia was finally contained in Bangladesh in November 1975.

This left us only with Ethiopia, a huge country with few roads. In 1974, Emperor Haile Sellassie had been assassinated and civil war broke out. Most countries evacuated their national staff from the country. The only group that did not evacuate was the WHO smallpox staff who continued working, often under military escort. On nine occasions, teams were kidnapped and taken to Somalia. Finally, in October 1976, Ethiopia became free of smallpox only to find that the disease had been reintroduced in Somalia and another year of work was required. Finally on October 26, 1977, the last case occurred in Merca, Somalia—the last case in a continuing human chain of infection extending back at least 3,500 years.

For more than two years, countries continued their surveillance programs and searched suspect areas for possible hidden foci; a substantial reward was offered for anyone who reported a case of smallpox, but there were no others. An independent international commission monitored progress and offered suggestions as to special studies that might be undertaken that would permit them to be fully assured that eradication had been achieved. In December 1979, they announced that they were satisfied that smallpox had been eradicated and this was confirmed at a plenary meeting of the World Health Assembly on May 8, 1980. They advised that smallpox vaccination be stopped everywhere.

What was the legacy of smallpox eradication? The end of smallpox marked the end of smallpox vaccination but it had ushered in the beginning of a new era, which has been termed the Era of Vaccination. The new WHO

initiative is called the Expanded Program on Immunization and this now extends throughout the world.

From the earliest days of the programs in Africa, we were surprised by the enthusiastic response that greeted well-organized mass vaccination efforts utilizing mobile teams and intended to vaccinate large numbers of people rapidly and with high rates of coverage. The key was good team management, active participation by local staff and support by village leaders. It was readily possible for a vaccination team of four to vaccinate, on average, 2,000 persons per day, which translates into 10,000 persons per week. Coverage of 90 percent or more was usual. It seemed only logical to ask, why not administer other vaccines then in common use in the industrialized countries—DPT (diphtheria, pertussis, tetanus), measles and polio? Coverage with these vaccines seldom exceeded 10 to 15 percent in any developing country. At the time, only a few countries had ever undertaken a national program intended to vaccinate all people throughout the entire country. We convened an international meeting in 1970 and it endorsed such a program. This was approved in the WHO Assembly in 1974. UNICEF and Rotary International gave the program priority and a target was set to reach 80 percent of the world's children by 1990. Amazingly, that target was met.

In the Americas, this program proceeded especially well and in 1985, the countries of WHO's Pan American Health Organization decided to eradicate polio using oral polio vaccine (OPV). A five year goal was set and achieved. Subsequently, this methodology was adopted for a global polio eradication effort. Meanwhile, the countries of the Americas succeeded in interrupting both measles and rubella transmission. Other vaccines are now in widespread use. The smallpox program demonstrated how much could be done with vaccination and how inexpensively even where the overall health services were limited. It demonstrated, as well, that skills in surveillance and management and in social mobilization were important.

A substantial proportion of the US and WHO international staff who served in the program were under 40 years of age. Subsequently, many of them, invigorated by the program, altered career plans and, as I did, embarked on a public health path. A motivation was the recognition of how much could be done and how satisfying it was to deal with public health challenges. Contrary to what some believe, public health involves a great deal more than paper shuffling. Last year, I published a book entitled *Smallpox - Death of a Disease*, with the intention of providing an illustrative case history of the joys, as well as the vicissitudes, of the smallpox eradication adventure.

The conquest of smallpox has been lauded as one of the greatest achievements in the history of medicine. It was a victory achieved by a great many dedicated, imaginative people who did not know that smallpox eradication had been deemed by many professionals to be an impossible goal.

Acronyms list:

AID = US Agency for International Development

CDC = Communicable Disease Center

EIS = Epidemic Intelligence Service

Conflict of Interests: None declared.

About the Author: DA Henderson is a legendary person in public health who led the WHO team in smallpox eradication using a « Search and Containment » strategy to the eradication of smallpox. Their accomplishments showed, to an initially skeptical world health community, that control and even eradication of important plagues of the world could be achieved through political commitment and professional leadership. His story is one to inspire a new generation of public health workers. He is currently Professor of Medicine and Public Health at the University of Pittsburgh and a distinguished scholar at a center for disaster preparedness in Baltimore MD, USA.

Addendum: Editor's Note:

Smallpox is an acute contagious disease caused by the Variola virus. Having originated more than 3,000 years ago in India or Egypt, smallpox is one of the most devastating diseases known to mankind. For centuries, repeated epidemics swept across continents and decimated populations. The disease, for which there was no effective treatment, killed as many as 30 percent of those infected and left survivors blind, disfigured and marginalized. For centuries, protection was sought by variolation which meant infecting people deliberately with smallpox to prevent epidemics and sometimes providing a lucrative practice for fashionable physicians. In 1796, a rural general practitioner, Edward Jenner, noting that milkmaids did not get smallpox, used cowpox pus from the finger of dairymaid Sarah Nelmes to infect a young boy, James Phipps, who then became immune to smallpox. This became known as vaccination and was adopted widely to prevent epidemics, but the disease continued to rampage in many parts of the world well into the second half of the twentieth century.

In 1967, when the disease still threatened 60 percent of the world's population, WHO launched an intensified plan to eradicate smallpox. Through the success of the global eradication campaign, smallpox was finally pushed back to the horn of Africa with the last recorded case in Somalia in 1977. The World Health Assembly in 1980 declared smallpox eradicated from the face of the earth.

In May 2010, a statue to commemorate the 30th anniversary of smallpox eradication was erected in the gardens of WHO. At the unveiling ceremony, WHO's Director General Dr Margaret Chan applauded health workers from around the world whose dedicated work over 14 years made this possible.

The boldness of undertaking such a mission, and the creative management and adaptation to shifting circumstances place this as one of the great dramas in human historic public health achievement as related modestly by Dr Henderson in this preface to the Public Health Reviews issue on Public Health Education. The application of lessons learned from this experience should inspire faculty and students of public health for generations to come, and help in defining goals and strategies to the many population health issues that exist now and lie ahead in developed and developing countries.

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