Commentaries

When Is a Disease Eradicable? 100 Years of Lessons Learned

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ABSTRACT

Since the 1915 launch of the first international eradication initiative targeting a human pathogen, much has been learned about the determinants of eradicability of an organism. The authors outline the first 4 eradication efforts, summarizing the lessons learned in terms of the 3 types of criteria for disease eradication programs: (1) biological and technical feasibility, (2) costs and benefits, and (3) societal and political considerations. (*Am J Public Health.* 2000;90: 1515–1520)

Of the lessons learned in the past 85 years, none is more important than the recognition that societal and political considerations ultimately determine the success of a disease eradication effort. The future of eradication as a public health strategy will depend greatly on establishing mechanisms for thoroughly evaluating societal and political issues and on implementing appropriate strategies in response to these issues.

Since the launch of the first eradication initiative targeting a human pathogen in 1915, much has been learned about determinants of eradication.[1] With each effort, understanding has progressed. At 2 international conferences in 1997 and 1998, it was proposed that 3 types of criteria should be considered before launching an eradication program: (1) biological and technical feasibility, (2) costs and benefits, and (3) societal and political considerations.[2–5] There is growing recognition that cost–benefit and societal and political considerations are at least as important as biological feasibility.

Disease Eradication in the 20th Century: Lessons Learned

The 20th century closed with 6 major international eradication initiatives having been launched against human pathogens.[6,7] Of the 4 initiatives that have already been concluded, only the smallpox effort was ultimately successful, with the last case occurring in 1977 in Somalia.[8–10] Despite the fact that 3 other eradication initiatives failed, all proved important in furthering our understanding of the principal criteria necessary to interrupt transmission of an organism on a global scale to such an extent that control measures could eventually be stopped (Table 1).[5,8,11–13]

In terms of biological and technical feasibility, smallpox proved to be an ideal candidate for eradication.[14] First, humans were essential for the life cycle of the organism, there was no reservoir for the causative virus, and the virus could not amplify in the environment. Second, the vaccine used was very effective and was delivered via a proven strategy.[9,15] Finally, photograph disease recognition cards proved to be an extremely practical diagnostic tool.[9]

In contrast, the presumption that the eradication of yellow fever, malaria, and yaws was biologically feasible was eventually shown to be in error. Nonhuman primates were found to harbor yellow fever virus in 1915, and malaria mosquito vectors eventually became resistant to the insecticides.[16,17] In the case of yaws, the prevalence and importance of inapparent latent infections had been underestimated.[11,18]

Although understanding of the biological and technical determinants of eradication was rapidly advanced by these efforts, a full understanding of cost–benefit issues lagged.[4,19] The first detailed economic evaluation of yellow fever eradication was published in 1972.[20] Yaws eradication was defended not by specific cost–benefit arguments, but rather by "the general one that eradication would lead to long-term saving of recurrent expenses for control."[17(p478)] Yaws eradication did, however, introduce the concept of both "coincident" and "intangible" benefits.[4,7,18] Intangible benefits included focusing the attention of decision makers on "poor, remote, rural populations."[21]

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TABLE 1—Past Disease Eradication Initiatives and the 1997 Dahlem Criteria for Eradication

Disease	Years of Eradication Effort	Successful	Biologically and Technically Feasible	Consensus on Positive Costs and Benefits	Broad Societal and Political Support
Yellow fever	1915–1977	No	No	No	No
Yaws	1954–1967	No	No	No	No
Malaria	1955–1969	No	No	Yes	Yes
Smallpox	1958–1980[a]	Yes	Yes	Yes	Yes

[a]1958 was the year of the World Health Assembly resolution; "intensification" of smallpox eradication began in 1966.

Cost–benefit arguments played an important role in justifying the effort to eradicate malaria.[22] Only the smallpox initiative, however, was really promoted in terms of economic and coincident benefits.[7,9]

Although the importance of societal and political considerations has long been realized,[16,22–24] a comprehensive framework for evaluating these issues is still lacking. Even more evasive have been mechanisms for ensuring sustained societal and political support, in both endemic and nonendemic settings, over the lifetime of an eradication effort.[3] Broad-based political support for yellow fever eradication proved difficult to secure, particularly when the program sought to expand beyond Brazil.[16] That yaws affected mainly rural and remote populations virtually doomed that eradication effort from the outset.[11,17]

By the time the malaria eradication initiative was launched, political support was better secured through the World Health Assembly.[23] Even so, it soon became evident that many countries were not fully aware of what they had committed to.[17] The cost of narrowly based societal and political support was clear in the rapid disintegration of the malaria program once the decision was made in 1967 and 1968 to downgrade the goal from eradication to control.[17]

The late discovery of biological and technical barriers to eradicating yellow fever, malaria, and yaws proved extremely damaging to the concept of eradication.[15,25] Despite the tremendous burden of disease, the necessary political commitment for smallpox eradication, formalized in a World Health Assembly resolution, was difficult to secure.[9] Societal support was inconsistent, owing to a myriad of factors ranging from cultural traditions to religious beliefs.[9] In Ethiopia, for example, armed guards were sometimes used to enforce local acceptance of the containment strategy.

Eradication at the Dawn of the 21st Century: A Comparison of the Polio and Guinea Worm Initiatives

It was not until the 1980s that the concept of eradication was "rehabilitated" to the point of international acceptance of the new initiatives.[3,4,26] A closer examination of the ongoing poliomyelitis and guinea worm eradication efforts demonstrates the utility of the criteria proposed by the 1997 Dahlem Workshop (Table 2).

Biological and Technical Feasibility

Although the life cycles, tools for interrupting transmission, and diagnostics could hardly be more different, polio and guinea worm have both proven to be biologically and technically susceptible to eradication. Polio transmission can be rapidly interrupted by achieving high population immunity with the

TABLE 2—Comparison of Poliomyelitis and Dracunculiasis Eradication Efforts According to the 1997 Dahlem Eradication Criteria

Criteria for Targeting a Disease for Eradication	Poliomyelitis	Dracunculiasis
Biological and technical feasibility		
Etiologic agent	Virus	Parasite
Nonhuman reservoir	No	No (intermediate host)
Effective intervention tool	Oral vaccine	Education, water filter cloths, and treatment
Effective delivery strategy	National immunization days	Case containment, safe water supply
Simple/practical diagnostic	Stool culture	Clinical examination
Sensitive surveillance	Facility-based surveillance	Community-based surveillance
Field-proven strategies	Americas	Pakistan, India
Costs and benefits		
Cases averted per year	350 000	1 million
Coincident benefits	Improved immunization and surveillance	Safe water supply, health education
Intangible benefits	Culture of prevention and social equity	Social equity
Estimated annual direct global savings	US $1.5 billion	Not estimated
Estimated total external financing	US $2.0–2.5 billion	US $200 million
Societal and political considerations		
Political commitment (endemic/industrial countries)	Variable/strong	Variable/weak
Societal support (endemic/industrial countries)	Variable/strong	Strong/weak
Disease burden in politically unstable areas (% cases from war-torn countries)	10%–20% (estimated)	70% (reported)
Core partnerships and advocates	WHO, Rotary, CDC, UNICEF	Carter Center, UNICEF, WHO
Technical consensus	World Health Assembly	World Health Assembly
Donor base (number of donors of US $1 million or more in 1998–1999)	16	6

Note. WHO = World Health Organization; CDC = US Centers for Disease Control and Prevention.

oral poliovirus vaccine.[27] In contrast, dracunculiasis has an incubation period of up to 14 months, and a single person with an emerging worm can result in an outbreak 1 year later.[28] Interrupting guinea worm transmission requires mass education in endemic areas to ensure that drinking sources are not contaminated by such persons and that filtered water is used in the absence of safe drinking water.

While the eradication of polio may appear simpler than eradication of guinea worm in terms of interrupting transmission, the ease of diagnosing dracunculiasis clinically simplifies the logistics of identifying and containing infected communities.[29] In contrast, thousands of poliovirus infections can occur before an infection results in paralysis. Although the clinical case definition (acute flaccid paralysis) for polio eradication has high sensitivity, its low specificity requires a complex system for transferring stool specimens to an accredited World Health Organization laboratory for analysis.[30,31]

The technical feasibility of both initiatives is best seen in the tremendous progress that has been made. The annual incidence of polio has fallen by more than 90% worldwide, from an estimated 350 000 cases when the initiative was launched in 1988 to slightly more than 7000 reported in 1999 (Figure 1).[32] Polio has now been eradicated from 3 of the 6 regions of the World Health Organization, and it remained endemic in only 30 countries at the start of 2000. In 1999, a marked acceleration of activities was undertaken to meet the goal of global certification by 2005, with particular emphasis on countries in which polio is highly endemic and those affected by conflict.[32]

In 1999, a total of 96 293 cases of guinea worm were reported, representing a 97% reduction from the 3.3 million cases estimated worldwide in 1986.[33] Seventy percent of the cases in 1999 were reported from southern Sudan, where civil unrest hampers full implementation of eradication strategies. Transmission has been confined to 13 African countries, 7 of which reported fewer than 500 cases in 1999 (Figure 2).[34,35]

Costs and Benefits

The cost–benefit arguments for eradication of polio and eradication of guinea worm are distinctly different. In addition to preventing the crippling effects of polio forever, eradication will eliminate the need to immunize against the disease, resulting in an estimated global savings of US $1.5 billion per year.[36] In terms of coincident and intangible benefits, polio eradication will leave behind stronger immunization and surveillance systems, a global laboratory network, thousands of trained health care workers, and a strong advocacy movement.[37,38]

Guinea worm is a painful disease resulting in temporary and sometimes permanent disability.[39] The economic impact of dracunculiasis on affected communities is significant

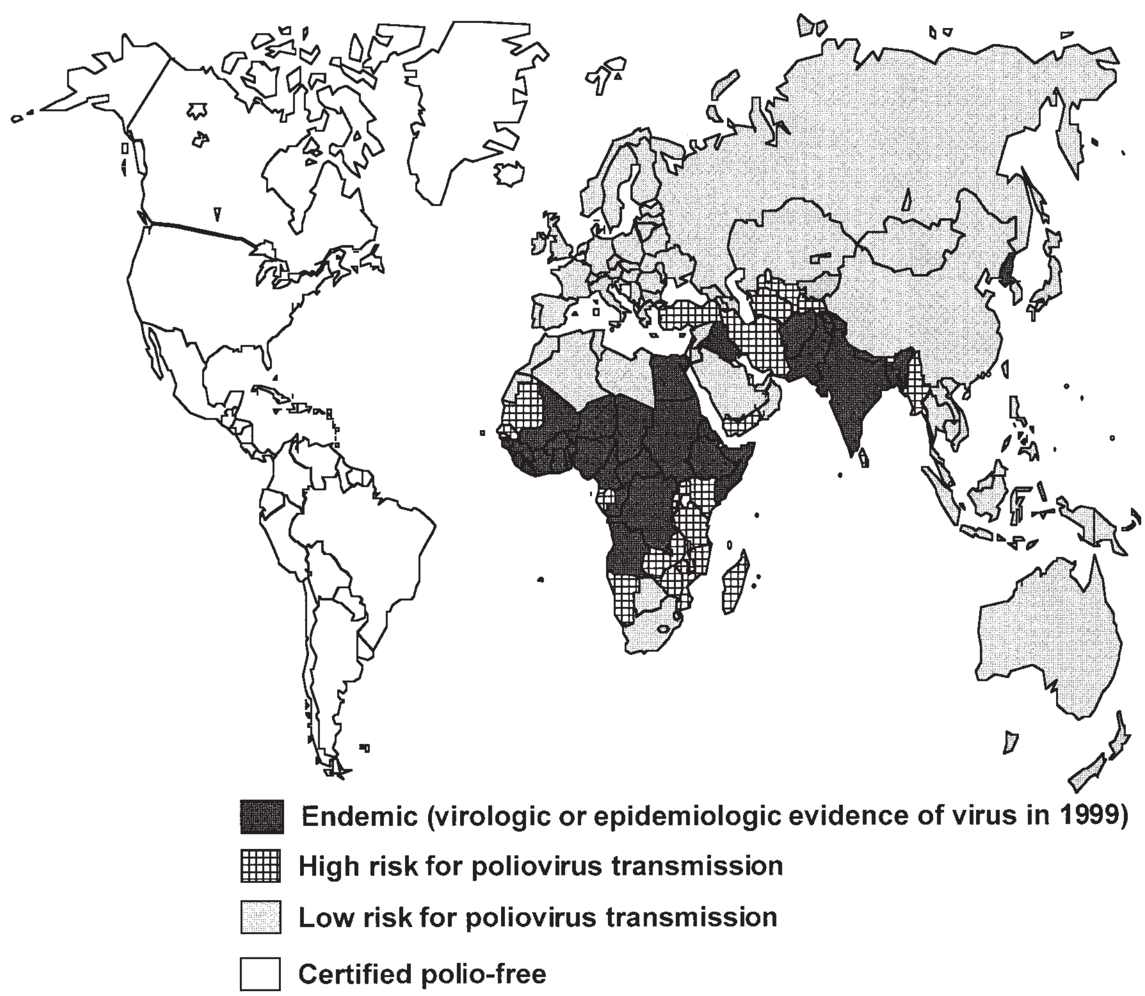

FIGURE 1—Status of poliomyelitis eradication in 1999 (based on World Health Organization data available as of August 7, 2000).

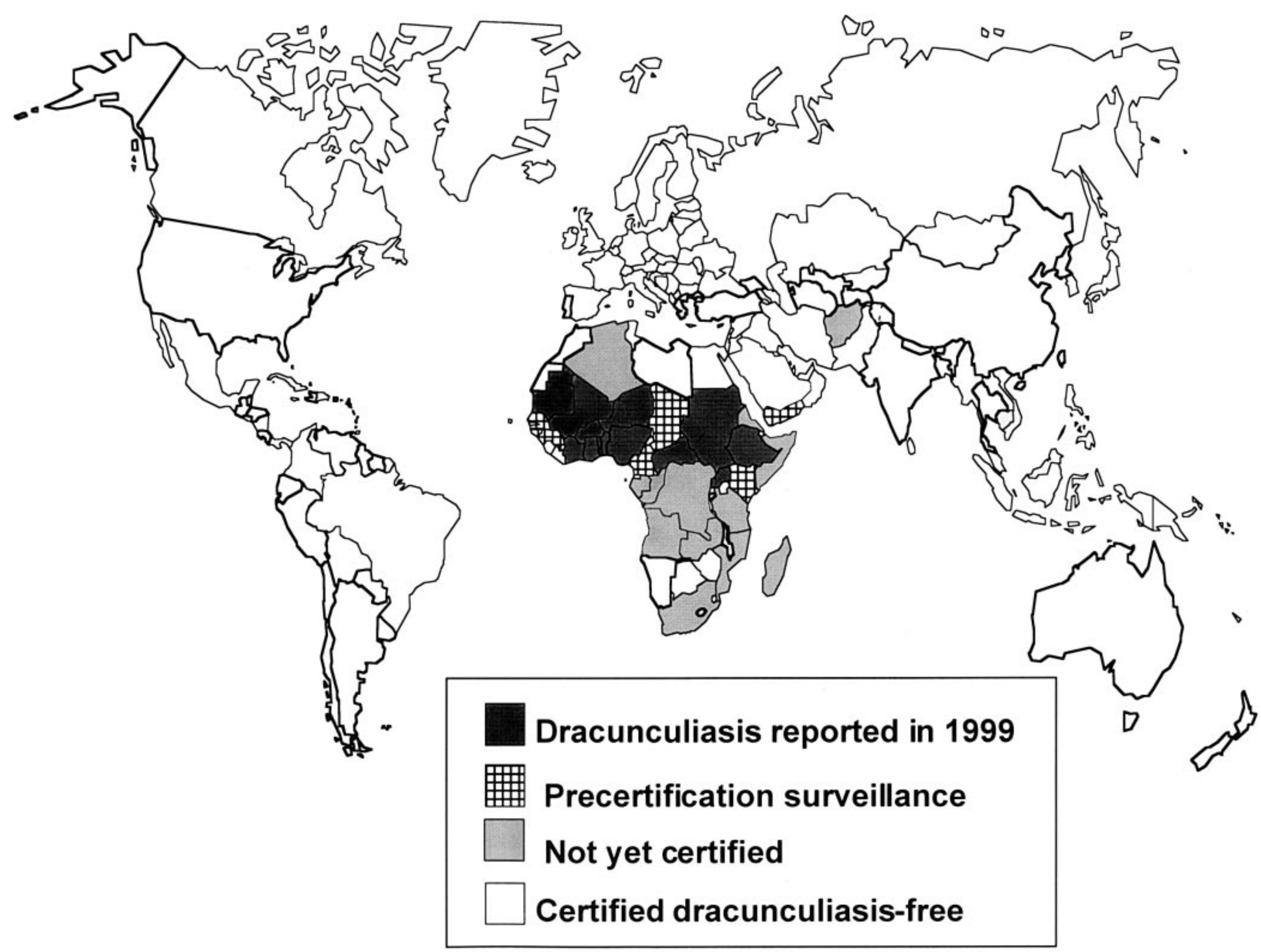

FIGURE 2—Status of dracunculiasis eradication in 1999 (based on World Health Organization data available as of February 25, 2000).

and well documented.[40–42] The benefits of dracunculiasis eradication, in stark contrast to polio eradication, will accrue almost exclusively to countries in which the disease is endemic. Much of this benefit will be in the form of coincident effects for some of the world's most underprivileged populations, including clean drinking water and the existence of community-based health volunteers who are capable of delivering other basic health services.[18,21]

Societal and Political Support

Both polio and guinea worm eradication were launched with the high-level political and technical consensus inherent in a World Health Assembly resolution.[43,44] Polio eradication had from the outset the advantage of far-reaching societal and political support because of the high awareness of the disease in industrialized countries as well as countries in which the disease was endemic. For example, Rotary International, a private humanitarian organization, has played a key role by providing financing and a global network of volunteers. The importance of a strong civil society partner is also evident in the unprecedented political support for polio eradication that has been developed largely through the advocacy efforts of Rotary.[36] Heads of state, such as Chinese President Zemin, South African President Mandela, and US President Clinton, have heightened the program's visibility. The guinea worm initiative has also relied heavily on political advocacy, benefiting tremendously from the support of former heads of state such as US President Carter and General Touré of Mali.

Despite high-level consensus and ongoing advocacy, both programs face inconsistent societal support at national or subnational levels in the final phase of eradication.[6] The challenge to guinea worm eradication is to maintain the commitment of central-level authorities for a campaign that targets a very small proportion of the national morbidity burden in the poorest communities. Sustaining societal-level support has been complicated by the logistic difficulties of routinely supplying, supervising, and ensuring surveillance in remote rural areas. Similarly, some of the remaining countries in which polio is endemic have had difficulty in sustaining societal support owing to competing priorities and the fatigue of multiple years of national immunization days.

Societal and political support has a special meaning in areas affected by war as well as by endemic disease. Support has to be mobilized simultaneously through the official government and rebel movements. Nongovernmental organizations, international humanitarian agencies, and consortiums, such as Operational Lifeline Sudan, play an essential role in reaching these populations. Both the polio and guinea worm initiatives have benefited hugely from the access and expertise of these organizations. Combining eradication activities with the delivery of other essential health care services has achieved excellent synergy in these

TABLE 3—1997 Dahlem Disease Eradication Criteria for Candidate Eradicable Diseases

Disease	Biological and Technical Feasibility	Consensus on Positive Costs and Benefits	Broad Societal and Political Support
Measles	Yes	Yes	No
Rubella	Yes	No[a]	No
Hepatitis B	Yes	Yes	No
Hepatitis A	Yes	No	No

[a]Yes, if part of a measles eradication effort.

areas. In addition, collaboration between polio and guinea worm eradication efforts in areas such as southern Sudan has improved polio immunization coverage and helped the guinea worm program detect more than 500 new villages in which dracunculiasis is endemic.

Future Prospects for Eradication Initiatives

Candidate organisms for future eradication programs will undergo tremendous scrutiny in determining whether launching an eradication effort is warranted.[36] Participants at the 1998 Atlanta conference on eradication considered a large number of candidate diseases in terms of the 3 major types of criteria that had been proposed in 1997 (Table 3).[5] Only measles, rubella, hepatitis B, and hepatitis A were determined to be biologically and technically feasible candidates for eradication.[45] No bacterial or parasitic diseases were judged to be eradicable by existing tools. However, organisms such as *Haemophilus influenzae* type B and one of the lymphatic filariae were considered potentially eradicable in the longer term, given the rapid development of technological tools.[46,47]

Measles led the list of candidate diseases considered for eradication.[45] There is no nonhuman reservoir for the virus, the vaccine is very effective, and available diagnostic tools are of sufficient sensitivity and specificity. However, experience in the Americas, which are approaching hemisphere-wide interruption of measles transmission, suggests that a coordinated global effort would be needed over a relatively short period of time.[48] Rubella also met the biological and technical determinants of eradicability.

Viral hepatitis A and B were considered theoretically eradicable on biological and technical grounds, although the persistence of the hepatitis B virus in chronically infected persons raises critical operational questions. High population immunity would have to be maintained for several generations, stretching the time frame for eradication well beyond the 15 years that has been suggested as the upper limit for such a focused effort.[49]

From a cost–benefit perspective, strong arguments exist for embarking on measles eradication. The vaccine is inexpensive, and the disease is one of the top 5 causes of death among children younger than 5 years.[50] In contrast, the global disease burden due to congenital rubella syndrome has not been well defined in developing countries.[45] That said, the addition of rubella vaccine to measles vaccine as part of a combined eradication strategy could markedly improve the cost–benefit equation in favor of eradication.

There is much less consensus on the benefits of hepatitis A eradication, because the vaccine is expensive and the disease burden is relatively low. Hepatitis B is a leading cause of death among adults in developing countries, making it a primary eradication candidate in terms of cost–benefit arguments.[45]

The Dahlem Workshop gave special attention to the political and societal factors that should be considered in evaluating a potential eradication initiative (Table 2). An examination of these issues in the context of a measles eradication initiative is particularly helpful.

Despite strong biological, technical, and cost–benefit arguments for eradication, securing societal and political commitment is now recognized as a substantial challenge. The high burden of measles and the public awareness of the disease in developing countries would greatly facilitate the sustained commitment needed in that setting. Ironically, many question whether such commitment could ever be achieved in industrialized countries, where concern about the disease is very low. The implications of this are already evident in the western hemisphere, where most of the relatively few measles viruses that are now detected are genetically linked to countries such as Japan and Germany.[51] Societal and political support in industrialized countries is also essential for mobilizing external resources for eradication in developing countries.

Given that it would be difficult to ensure sustained support for such a well-recognized global concern as measles, the societal and political challenges are much greater for rubella, hepatitis A, and hepatitis B eradication, for which there are less compelling cost–benefit arguments and lingering questions about technical feasibility.

Conclusions

Over the past 85 years, understanding of the determinants of disease eradication has been tremendously advanced through the 6 large international eradication initiatives that have been undertaken. The lessons learned about assessing biological and technical feasibility have been more carefully applied with each successive effort, and there is now a thorough appreciation of the complexity of evaluating the costs and benefits of these massive public health undertakings.

In contrast, the importance of achieving and sustaining societal and political commitment for the lifetime of an eradication effort has yet to be translated into practice. Explicit efforts to identify countries with weak societal or political commitment must be central to evaluating the overall feasibility of any future eradication effort. A genuine appreciation of societal and political considerations will be critical in transforming future eradication programs from technically feasible efforts into operationally successful initiatives. □

Contributors

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