Vision zero in disease eradication

Vision Zero in Disease Eradication

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Abstract

The eradication of smallpox – the first and so far only human disease to be eradicated – generated a tremendous amount of excitement and attention to the idea of disease eradication and elimination. In the twentieth century alone, smallpox had claimed the lives of more than 300,000,000 people (Sneed A, Scientific American, https://www.scientificamerican.com/article/who-remember-smallpox/, 2014). The last natural case occurred in 1977, almost 200 years after the smallpox vaccine was discovered, and in 1979 the World Health Organization declared that the disease had been eradicated (WHO, Smallpox, World Health Organization. World Health Organization. https://www.who.int/csr/disease/smallpox/en/, 2019c). Most importantly, it demonstrated that eradication was possible; that through the use of science, we could change our future for the better in ways that we had not even dared to think about previously. This achievement also helped to focus attention on clear definitions of disease eradication and elimination. Since then, these definitions have been continuously evolving. In 1993, the International Task Force for Disease Eradication (ITFDE I) defined disease control, elimination, and eradication. With that, they evaluated over 90 potential infectious disease candidates and concluded that six were eradicable. Subsequently in 1997, the Dahlem Workshop focused on the science of eradication and defined a range of public health approaches to infectious diseases from control, to elimination of disease, elimination of infections, eradication, and extinction. Three years later, the second International Task Force for Disease Eradication (ITFDE II) convened in 2000 to review the progress over the past decade.

Inspired by these efforts, we reviewed our own experience and interviewed leaders of several disease eradication and elimination campaigns to identify lessons learned from a variety of disease elimination campaigns including smallpox, polio, Guinea worm, and onchocerciasis. Our aim was to identify lessons that might be applied to road traffic injuries. We identified 12 lessons from these infectious disease campaigns: (1) this is a cause and effect world; (2) know the truth; (3) coalitions are absolutely essential and absolutely hard; (4) avoid certainty (the Achilles heel of science); (5) measure frequently and build in continuous improvement; (6) respect the culture and work *with* the people you are trying to help; (7) the best decisions are based on the best science, but the best results, on the best management; (8) the best solutions move us closer to global health equity; (9) do not underestimate the time, resources, or tenacity it will take succeed; (10) eradication does not always require a vaccine or a cure; (11) start in the most difficult places first; and (12) you don't begin at the end. These concepts from infectious disease campaigns have broader public health applications, and we discuss some of the implications for reducing road traffic injuries.

Keywords

Disease elimination · Disease eradication · Campaigns · Surveillance · Coalitions · Health equity · Continuous improvement · Certainty · Tenacity · Cause and effect · Smallpox lessons

Introduction

The linkage of two visions has changed the world: the eradication of smallpox and the elimination of road traffic deaths, better known as "Vision Zero." The strategy that ultimately led to the eradication of smallpox was proven effective in 1966, when Dr. William Foege was a medical missionary and faced a smallpox outbreak in Biafra, Nigeria, on the eve of civil war. The conventional response at the time was to vaccinate everyone, but this was impossible due to a vaccine shortage. He directed his team to map the spread of the disease and to vaccinate people only in villages where smallpox had already appeared and in the neighboring areas, forming a protective ring. This novel and efficient "surveillance and containment" strategy worked. Six months after the first case had appeared, no new cases were reported in eastern Nigeria. Working in relative isolation, Foege's team developed the strategy that would eventually lead to global eradication.

In 1973, Dr. Foege, the then director of the Smallpox Eradication Program at the US Centers for Disease Control and Prevention, responded to a plea from the World Health Organization to assist them in India. For years, the Indian government, with the assistance of many outside organizations, tried to control smallpox through mass immunization. But the country's size and enormous population, as well as the difficulty of reaching people in remote areas, had frustrated their efforts.

Working directly with government leaders, Dr. Foege helped develop a sense of urgency for addressing the disease and mobilized funding support from industries that had been affected by smallpox. He helped convince India leaders to shift from the unsuccessful mass vaccination approach to a containment strategy and then skillfully guided the surveillance and containment efforts. He knew success depended on motivating thousands of highly dispersed workers to map the incidence of the disease in more than 700,000 villages and to quickly contain the threat (Rosenberg et al. 2010). Putting his own life at risk, he carried millions of rupees in his briefcase to ensure that health workers received their salaries and stayed on the job and rode the trains across the country to keep morale among workers high until its clear eradication would be achieved.

Although the CDC encouraged Dr. Foege to stay until no new cases were reported, he purposely left India before the country was free of smallpox so the credit would not go to him. He felt that Indian officials and public health workers deserved the credit for the remarkable work they had done, and the recognition would motivate them to continue to work hard in the public interest. India went from 87,000 cases of smallpox in 1973 – more than any other country – to no cases at all in the spring of 1975 (Rosenberg et al. 2010).

This success led global health experts to believe they might achieve something that had never been achieved before: the actual eradication of a disease from every single country on the planet. In 1979, through the efforts of healthcare workers and experts across the world, the WHO did, in fact, declare smallpox eradicated (WHO 2019c). A disease that had killed millions of people had been driven from the face of the earth. This extraordinary success in smallpox eradication generated optimism and enthusiasm for eradication efforts for polio and Guinea worm. Both campaigns have made great strides, and these diseases are within reach of eradication today.

The success of smallpox eradication elicited inspiration beyond the infectious disease realm of public health. It inspired the Swedish Transport Administration to dare to declare that road traffic deaths could be completely eliminated. More than 30 years ago, the Swedish Transport Administration had to decide whether to aim for a 10% decrease in road traffic deaths or to do something bolder – something that would mobilize the energy, enthusiasm, and resources of the road safety sector, as well as public support and political will. The agency proposed the bold aim to eliminate all road traffic deaths in Sweden, to aim for Vision Zero (Ministry of Transport and Communications 1997). They saw that road traffic deaths are not a fact of life, nor are they the price we must pay for mobility in the modern world. Vision Zero's goal of no deaths on the road, combined with the dedicated leadership of Sweden, showed the world that this is not only a goal for which we should aim but also one that is possible through evidence-based interventions.

The Swedish Transport Administration helped to develop the Vision Zero policy, the goal of which was a road transport system free of death and serious injury resulting from road crashes. Designing safer roads was key to protecting road users from human error. One of their advances, for example, included substituting roundabouts for red lights at intersections, bringing the death rate down by 90% at these intersections (Robinson et al. 2000; WSDOT 2020). Vision Zero was subsequently presented in 1995 and adopted by the Swedish Parliament in 1997 (Ministry of Transport and Communications 1997; Larsson et al. 2010), sparking a movement of similar legislation in cities and countries around the world. In addition to the push behind the radical target of elimination rather than just a small risk reduction, Dr. Tingvall was essential in translating policy into practice, engaging stakeholders from private, public, and governmental sectors to work together.

Success in both safety and health can be represented by the idea of zero, whether that zero stands for zero deaths from disease or crashes or zero illnesses or injuries or collisions. We believe that there are important lessons to be learned from the history of infectious disease eradication and elimination efforts, lessons that might be applied to the field of road safety and beyond. With this in mind, we interviewed a number of disease eradication experts to hear what they thought were the most important lessons from the campaigns that they had worked on. We interviewed Drs. Walt Dowdle, Eric Ottesen, William Foege, and Don Hopkins. They shared with us lessons and stories of extraordinary work, extraordinary workers, and extraordinary numbers. We also added some of the most important lessons we had learned from our experience working with coalitions to address disease elimination and eradication campaigns. This chapter aims to share some of these lessons with the hope that these lessons can be applied, not only to future disease elimination campaigns but to the pursuit of reducing road traffic fatalities to zero, to making Vision Zero a reality.

Part I: Clarifying the Definitions of Disease Control, Elimination, and Eradication

The first and so far only human disease to be eradicated is smallpox (WHO 2019c). When this occurred in 1979, not a lot of attention had been given to strict definitions of disease eradication and elimination. Since then these definitions have been continuously evolving.

The International Task Force for Disease Eradication (ITFDE I) came together in 1993 to define these three previously ambiguous words: eradication, elimination, and control (Cochi and Dowdle 2011). They evaluated over ninety potential infectious diseases and six were concluded to be *eradicable*: dracunculiasis Guinea worm), poliomyelitis, lymphatic filariasis, mumps, rubella, and taeniasis/cysticercosis. Further seven conditions – including one noninfectious disease – were considered *eliminable*: hepatitis B, iodine deficiency disorders, neonatal tetanus, onchocerciasis, rabies, trachoma, and yaws (Centers for Disease Control 1993).

After much reflection and discussion, they defined eradication to be the worldwide achievement of obviating the need for further control measures. In contrast, elimination involves control of the manifestations of a disease such that the disease is no longer considered "a public health problem" within a specific region. Yet, this is a fairly vague term that may not be useful to those working on the problem.

In 1997, the Dahlem Workshop on the Eradication of Infectious Disease convened to further consider the biological and epidemiological factors of infectious diseases that are susceptible to eradication (Cochi and Dowdle 2011). The principal change to the previous set of definitions was the clearer distinction between the types of elimination and the addition of extinction. The definitions are (Cochi and Dowdle 2011):

Control – the reduction of disease incidence, prevalence, morbidity, and mortality to acceptable levels

Elimination of disease – the reduction to zero incidences of disease in a defined geographic area

Elimination of infection – the reduction to zero incidences of infection caused by a specific agent in a defined geographic area

Eradication – the permanent reduction to zero worldwide incidences of infection caused by a specific agent

Extinction – achieved once the specific agent no longer exists in nature or the laboratory

Over time, attitudes toward the feasibility and relevance of extinction of pathogens changed. Reasons for the shift in attitudes include the thought that in post-eradication, certain pathogens would inadvertently become potential bioterror agents if routine immunization and surveillance were discontinued. This is supported by the inability to account for all stocks and specimens containing pathogens, as well as the

sophistication of modern genomics and molecular biology techniques which now allow for in vitro synthesis of infective agents (e.g., poliovirus) (Cochi and Dowdle 2011).

A second International Task Force for Disease Eradication (ITFDE II) was constituted in November 2000 to assess the progress over the past decade and to review the potential eradicability of the previously selected infectious diseases (Cochi and Dowdle 2011). While the definitions remained unchanged, measles was added to the list of possible diseases for eradication. The most recent meeting evaluating the definition and disease considered to be eradicable or eliminable took place in Frankfurt in August 2010 (Cochi and Dowdle 2011).

Aside from the official set of eradication and elimination definitions, some find other renditions to be clearer. Walt Dowdle, for example, finds:

> the terms national, regional, and global eradication [to be] much more powerful and meaningful than 'elimination'. Moving from national to regional to global eradication is a logical and defensible progression. Moving from "elimination" to "eradication" means crossing a huge, but artificial, barrier. (Dowdle, W. Interview by Mark Rosenberg, 2014)

Similarly, Dr. Foege suggested the use of global eradication, national eradication, and personal eradication (Foege, W. Interview by Mark Rosenberg, 2014). Clarity is necessary, yet it remains important not to become fixated to the point of inaction.

Part II: Twelve Lessons from Infectious Disease Campaigns

These 12 lessons were gleaned from our own experience and from conversations with leaders involved in past and current eradication and elimination campaigns. The lessons are not meant to be prescriptive. In fact, many – if not most – of the lessons learned became more apparent in retrospect than they were at the time the campaigns were initiated. As Walt Dowdle pointed out, "you never know until you get there" (Dowdle, W. Interview by Mark Rosenberg, 2014).

Lesson 1: This Is a Cause and Effect World

If We Understand the Causes, We Have a Chance to Change the Effects

We can use science to understand the causes, and if we understand the causes, we can intervene to improve the outcomes. Using the scientific method means that we look at the evidence and that we assess the evidence and use it to answer four basic questions:

1. What is the problem?
2. What are the causes?
3. What works to prevent this?
4. How do we do it or implement it?

Seeing that disease eradication is even possible helped us to set new targets that we had never before dared to declare. Knowing that this is a cause and effect world also helps us appreciate the idea of agency. Diseases do not disappear by chance. Disease eradication does not happen by chance. None of these things *just* happen – they happen because someone has set an objective saying we *want* it to happen. They happened because time, energy, and lifework are dedicated to achieving the goal.

A belief in cause and effect also brings about activism and optimism. Thus, if we understand the science, it is cause for optimism because it means we *can* change things in this world and change them for the better. For the first time, eradication meant that we can aim for and hope to achieve reductions in disease levels that we rarely thought possible before.

Science – both biological science and social science – can help us understand the conditions that are necessary for a disease to be eradicable. The conditions are different for elimination but those, too, can be defined. The ITFDE identified three groups of factors that determine the conditions and possible success of a disease eradication or elimination program (Hopkins 2013):

1. **Scientific feasibility** – The factors affecting scientific feasibility include epidemiological vulnerability of the disease; availability of effective and practical interventions; the lack of an animal reservoir for the disease; and demonstrating successful elimination of the disease in a particular area. Other factors include the cost-effectiveness of eradication versus elimination or control programs; benefits of eradication in terms of reducing morbidity and mortality compared to other health interventions; the ability to coordinate with other health programs; and the potential effects of control programs on the health system.

   For smallpox this meant that there was a proven effective vaccine with an easy means of administering it. Although vaccine standards were not initially in place when the final push toward eradication was begun, they were subsequently developed; infected individuals were easily detected because of their multiple blisters, fever, and malaise; people who were immune were visibly marked by multiple scars left by the disease or a single scar at the site of their vaccination. There were also no latent infections beyond a 2-week incubation period and no animal reservoir, and the virus could not survive in the environment.
2. **Political will/popular support** – Societal and political commitment is essential, as well as the capacity for financial, managerial, and technical support. Disease eradication programs should not bypass or compromise existing health systems and attempts should be made to expand benefits to health services beyond the limited impact of eradicating the target disease. The government must commit support with a willingness to sustain the effort until the campaign has been successful.
3. **Sufficient resources** – Eradication, elimination, and disease control campaigns require resources. As such, ensuring sufficient resources lined up or a plan to get the resources necessary for the job is key. Mobilization of adequate resources may require clarifying the perceived burden of the disease, not only including the number of deaths but also the number of persons affected and how they are

affected during the acute and subsequent phases; this includes but is not limited to the long-term disabilities, stigma, and mental health impact. It is rare that the true burden of a disease is accurately perceived. This total burden of disease suggests the benefits expected to accrue from eradication. The distribution of the costs and potential benefits among the population is relevant to both rich and poor countries.

It is also valuable to quantify the expected cost of eradication, especially in relation to the perceived burden of the disease. There may also be a synergy of eradication efforts with other interventions that should be noted. And finally, the accumulation of costs and benefits over a relevant time period should be taken into account. In the case of smallpox eradication, the smallpox vaccine was inexpensive and donated free of charge to the program by the Russians (Henderson 2009; Hotez 2017). It could be administered in a single dose that seemed to produce protection from the disease.

Lesson 2: Know the Truth

Knowing the truth first requires us to understand the problem. This is the lesson of the saying sometimes – but without proof – attributed to Albert Einstein: "If I had only one hour to save the world, I would spend fifty-five minutes defining the problem, and only five minutes finding the solution" (Einstein quote). For Foege, knowing the truth means knowing "the state of things—in the real world, honestly. You need to know your enemy. In the case of smallpox, you needed to know the disease and where the virus was. You needed to be able to pinpoint its positions at any one time". Organizations have resources, cache, and networks that can be used to address many types of public health programs. For public health, this means surveillance. As Foege shared, "Surveillance is intelligence gathering and it should be complete, accurate, and honest" (Foege, W. Interview by Mark Rosenberg, 2014). Our experience with smallpox and polio eradication efforts furthered our understanding of surveillance – both as to how crucial it is and how it should be done. In turn, strengthening our surveillance systems allowed us to identify, understand, and define new strategies against diseases that not been adequately controlled in the past.

Continuous Reassessment Has Collateral Benefits

Surveillance systems, in addition to requiring continuous evaluation and improvement, also require indefinite replacement in order to detect the possibility of future disease recurrence. This requires ongoing data collection, analysis, and response. This has the additional benefit of creating a system that may have the additional ability to detect other infectious and noninfectious problems. For example, the surveillance system established by the polio program became the major source of surveillance for the Guinea worm eradication campaign (WHO 2014), and this same system was later used in efforts to control Ebola.

The Closer You Get to Elimination, the Closer You Have to Look; the Closer You Look, the More You See

The story of polio eradication also taught us that what we surveil, even for the same disease, constantly changes. For example, when the polio vaccine was first developed and deployed, public health personnel thought that since the disease produced by polio was an acute flaccid paralysis (AFP), it would be easy to count the cases of polio by looking for cases of AFP. The effectiveness of vaccination campaigns could then be monitored by looking for all cases of AFP and seeing if the number of these cases was going up or going down. While there were other causes of AFP – usually due to other types of viral infections – these were rare in comparison to the cases of AFP due to poliovirus. As such, the overall number of cases of AFP was indeed a good indicator for tracking the success of the polio vaccination programs. However, once a large number of children had been vaccinated in a particular area and the number of cases of AFP caused by the poliovirus was markedly decreased, the percentage of acute flaccid paralysis due to the other previously "rare" viruses became significant. At this point, AFP was no longer a useful indicator of infection by poliovirus. Here a new lesson became clear: *the closer you get to elimination, the closer you have to look*.

Scientists now had to look for evidence of poliovirus infection by testing each case of AFP for evidence of infection. As scientists looked more closely, they found significant numbers of persons infected with the poliovirus, but without AFP. The prevalence of asymptomatic carriers meant that surveillance now had to be looking for the virus itself. That, too, was not enough, as it also turned out that the virus is excreted in feces and could survive in sewage. Now environmental sampling of sewage was needed to know that the poliovirus was not lurking in a given area where individuals could be infected. Another lesson gave rise: *the closer you look, the more you see*.

It turned out that not only did the poliovirus live in sewage, or in contaminated fecal samples that might be stored in a laboratory, but some types of live viruses used in vaccines could actually mutate and revert to virulent viruses that could actually cause the disease – creating a new subset of now-monitored disease, vaccine-derived poliovirus cases. This ultimately led to changes in the formulation of the vaccines, with the hope that if only killed viruses were used in the vaccine, they would no longer be capable of mutating and causing disease. More experience keeps leading to new insights and improved strategies. The endgame of this eradication campaign gets more and more complicated and difficult as we get closer to eradication and learn more and more about the virus and vaccines.

Surveillance Is Useful for Tracking More Than Just the Number of Cases

In the case of vaccinating populations against smallpox or treating large populations with drugs to treat and prevent the neglected tropical diseases, it also became clear that surveillance was necessary at many different stages. Initially, surveillance was focused on searching for cases. But after that it was necessary to do surveillance to track the population that had been vaccinated or treated. Surveillance also provided

the epidemiologic data to define risk groups, to assess the effectiveness of vaccine or preventive treatments, to monitor adverse events, and to assess the effectiveness of different treatments and interventions.

Be Open and Honest with Your Data Even When That Might Be Risky

It is important to know the truth even when there is a risk that it might endanger your campaign. Information collected has also been used to undermine a public health campaign. When Dr. Foege first arrived in India to help oversee the smallpox eradication efforts, he saw that mass vaccination, the traditional smallpox strategy, was not working. Despite the best efforts of the Indian government, they could not vaccinate everyone and could therefore not achieve complete coverage of the population. There would always be susceptibles and enough of them to keep the disease going. Foege switched the strategy to one that would (1) focus on places where there were active outbreaks of smallpox and (2) vaccinate everyone in those areas. They would contain the population of towns and villages where there was active smallpox and not let anyone leave until everyone had been vaccinated. If anyone had been exposed to smallpox and then left, they would go find them, bring them back, and vaccinate that person and all of their contacts. People would be "contained" in these areas for 30 days until either they became sick and recovered or died or until they had been vaccinated and became immune. This was called the "containment strategy" (Foege 2011). Applying this containment strategy also meant that active and thorough surveillance was needed to identify every town or village with an active case of smallpox. For it was in these places that the containment strategy would have to be applied. But after only several months of applying the containment strategy, the Minister of Health (MoH) for the Indian state of Bihar went to Dr. Foege and wanted to stop the containment approach (ibid.). This would have to be stopped, the minister declared. This alarmed Foege who then asked the minister "why?" The minister replied that when Dr. Foege had arrived, when the containment program began, there were 85,000 known cases. Now, he said, the improved surveillance showed there were 125,000 cases (ibid.). "Clearly," the MoH said, "your strategy is making the problem worse and you will have to stop it" (ibid.). Fortunately, they were allowed 30 more days to turn the problem around, and in that time the containment strategy was working, and the numbers started heading down.

Establish a Very Clear Goal and a Mechanism to Certify That You Have Reached It

Surveillance is also needed to confirm that an eradication or elimination goal has been achieved. This demands precise definitions and clarification of the program goals and a degree of rigor. An important mechanism for certifying that the elimination or eradication goal has been reached is the appointment of an independent commission that is able to collect credible and accurate information and can then certify that the goal has been achieved.

To date, 156 cases of wild poliovirus were reported in 2019, 128 of which were within Pakistan and the remaining 28 within Afghanistan. Nigeria, the third and only remaining polio-endemic country – in addition to Pakistan and Afghanistan – has the

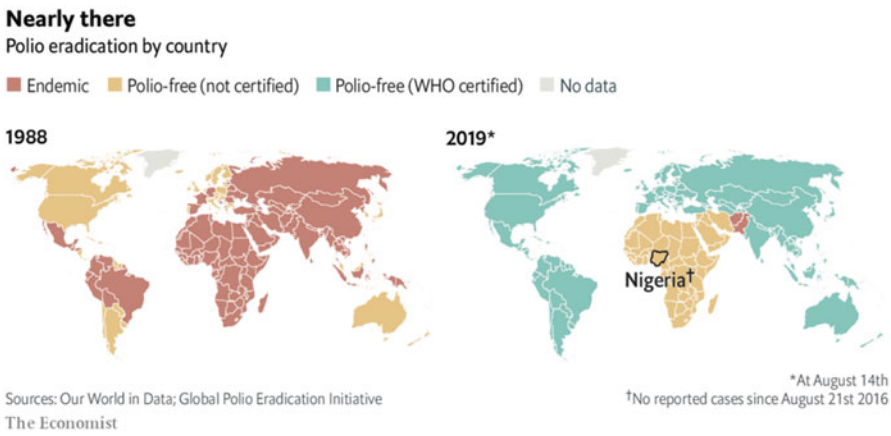

Fig. 1 Economist (updated August 21, 2019)

possibility of being certified polio-free in 2020. While circulating vaccine-derived poliovirus remains to be a challenge, with 249 cases reported in 2019, it is estimated that over 1.5 million lives have been saved and 16 million cases of paralysis averted since the onset of the polio eradication initiative in 1988 (Global Polio Eradication Initiative 2020) (Fig. 1).

Lesson 3: Coalitions Are Absolutely Essential and Absolutely Hard

The possibility of eradication rests on the ability to bring multiple stakeholders together; in effect, the ability to form a coalition. Indeed, solving any large-scale global health problem today requires effective coalitions. And effective coalitions require the following: (1) a clear, overriding common goal; (2) a strategy for achieving that goal; (3) a structure for the coalition; (4) defined membership; and (5) effective management of both meetings and programs. Without these, coalitions will fail. In fact, most coalitions do fail to achieve their goals. A coalition is like a marriage: it is very easy to get into it but very hard to make it work. Obstacles (and opportunities) occur at every level: global, multinational agencies, regions, countries, and communities. And these obstacles to effective collaboration abound. James Austin, Harvard Business School Professor Emeritus, characterized them as the seven C's and we have added the eighth C, conflict (Austin 2000):

Culture – All of the elimination and eradication campaigns had to deal with geographic, social, and ethnic differences in culture, including North-South differences and a multitude of different languages. In addition, in the culture of global health, there was an antibusiness bias and distrust of the private sector. Business and global health also operated on different time scales: public health traditionally used decades to measure progress, while business wanted it

measured in terms of calendar quarters. The nonprofit culture of global health also doesn't like measurements because it is doing good (rather than well). There are diverse cultures at all levels.

Conflicting goals – Inadequate attention to clarifying the overriding, shared goal at the beginning of a coalition is the most common reason for the failure of a coalition.

Confusion – The confusion that arises when coalitions fail to take time to adequately diagnose and define the problem often leads to confusion about roles, responsibility, structure, and about what the problem really is.

Control – The members of most coalitions don't want to give up control. Member organizations want control, even if individual members of the coalition are willing to give it up. For these members, they reason that even if they are not going to get resources by joining the coalition, they can at least get control.

Capabilities – Coalition members want to be seen as good at everything, often reluctant to admit that others might do it better; if you don't know your own capabilities and don't want to know your weaknesses (much less admit them), then you struggle to be seen as omnipotent, and this becomes a barrier.

Competition – Competition can become a difficult obstacle when members continue to focus on "me" rather than "us." The goal for them then becomes who is the best, who has the most, and who is the biggest. There is competition for credit, power, and funding.

Costs – In many cases, we are not realistic about what things cost, limiting our thinking to what we can do with the scarce resources we have rather than define the resources we actually need; or we focus on the costs of collaboration but not the benefits.

Conflict – Shared goals are what can help to transcend politics and even bring warring sides of a conflict together. During elimination campaigns for vaccine-preventable diseases, in several countries which had ongoing civil wars, the opposing sides agreed to a truce on days that were designated as vaccination days to allow complete coverage of the entire population by vaccination teams. Partnerships are even more vital when working in areas of conflict. Insecurity remains a substantial obstacle to current efforts on polio eradication and the control of Ebola.

The critical elements of a successful coalition are simple and clear, and we can't overstate their importance.

Clear, Overriding, and Common Goal

Getting the members of a coalition to agree upon a shared goal is the most important determinant of whether a coalition will succeed. Elimination and eradication of a problem represents a clear goal that is easy to understand and measurable. These are also goals that can inspire organizations to join the effort and become active members of a coalition. When the WHO adopted elimination goals for many of the neglected tropical diseases, this stimulated new donors and new program delivery institutions to join these efforts as active participants in these campaigns.

Strategy for Reaching the Goal

Coalitions need to have a strategy for reaching their goals. It took almost 200 years after the development of smallpox vaccination, for the delivery strategy to change from mass vaccination to containment of outbreaks and vaccination only of persons exposed to active cases.

Structure

No one would suggest that an important organization could function without a structure or organizational chart. But people sometimes fall into the trap of thinking that a coalition can function without a structure. They don't realize that a coalition made up of several different organizations is *more* complex than its member organizations. It is the sum of complicated parts. The structure need not be formal and elaborate, but it needs to assign to individuals the roles that are critical to keep it functioning. And as opposed to many corporate or bureaucratic organizations where all decision-making may be concentrated in one chief executive officer, in coalitions the most effective leadership is often shared leadership, where different leadership functions – such as strategy implementation, financial accounting, advocacy, and dispute resolution – are delegated to different coalition members. The successful leader, and especially the successful public sector leader, is one who can persuade these various people able to lead these various functions to join in harmony to support a worthy goal. This requires that the players be empowered and be given credit for their contributions. This requires, in turn, that the leader or leaders involved be more orchestra leaders, intent on the results, than themselves trumpet players. Such leadership is facilitated when the goal to be attained is easily understood, when progress is easily measurable, and when the goal itself is narrow (Henderson 1999).

Defined Membership

It is important to get the right people working together. You need people who are problem-solvers looking for problems to solve. The coalition leader, too, must have the right set of leadership skills. This includes both visionary leadership and operational leadership from the person who can make things work (Foege 2011).

For several disease eradication campaigns, people and organizations came together across governmental, private, public, civil society sectors, between countries, and between international entities. Coalitions must also include the political leaders. Don Hopkins, who, for many years, led The Carter Center's efforts to eradicate Guinea worm, noted that this was a lesson learned from smallpox eradication; however, Jim Grant, a former director of UNICEF, pushed it further in his efforts to expand childhood immunizations through the Task Force for Child Survival. Hopkins shared "we pushed as far as we possibly could in Guinea Worm eradication. We have involved not just President Carter, but General Yakobu Gown and then General AT Toure, now president of Mali" (Hopkins, D. Interview by Mark Rosenberg, 2014). In India alone, smallpox eradication required mobilization of more than 250,000 workers and staff and contributions from many different countries (Foege 2011). Eradication on a global level required the participation of more

than 150 different countries and highly skilled leadership at all levels, from the WHO down to regional, national, state, and local levels (Rosenberg et al. 2010).

Multi-sectoral collaboration can be particularly challenging. Each sector may think that this problem it is not their responsibility. For example, in trachoma elimination, clean water is needed but if the water sector thinks that this is a problem that belongs to the health sector, they may not prioritize the bringing of safe water to trachoma-affected communities. Or the education officials may not think it is important to teach children the importance of using latrines and wearing shoes to protect against soil-transmitted worms. The members of a coalition will all have their own "day jobs" and may be too busy dealing with their own set of crises to spend time working toward the coalition's goal.

Management of Meetings and Programs

Coalitions pose their own management challenges that go beyond the need for effective management of meetings and programs. Global or regional coalitions that are addressing large-scale public health problems often require that people come together, transcending politics. Most of the work on smallpox eradication took place during the cold war, and it was a global collaboration, with Russia making the offer to supply vaccine (Hotez 2017). Russia supplied the early vaccine – millions of dollars' worth – for the Global Eradication Program (Henderson 2009; Hotez 2017). Bilateral aid donations have also been very important in other disease elimination programs. The USAID has donated hundreds of millions of dollars for NTD elimination programs; the DFID and the UK have donated millions of pounds for trachoma elimination (Solomon et al. 2016). When working on an underfunded problem in an underfunded area, the problem may be that no coalition member is eager to control it or be responsible or accountable.

Lesson 4: Avoid Certainty (the Achilles Heel of Science)

A Great Many Things Are Subject to Change as We Learn More About Them

The CDC published a guideline for disease elimination and eradication campaigns that required that potential eradication campaigns be almost certain that eradication is possible before committing to the campaign. While it is important to highlight the feasibility and overall benefit of a campaign, Dr. Foege counters that "if we had waited until we knew that we could eradicate smallpox, we never would have been able to do it" (Foege, W. Interview by Mark Rosenberg, 2014). Even if we know what to do, there is so much uncertainty, so much we do not know. The physicist Richard Feynman said that certainty is the Achilles heel of science (Foege 2013). It is quite clear now that we did not know how to eradicate polio when the WHO first committed to doing it. Now we are not certain it can be done. But it is better to try and then learn that it cannot be done, than to prematurely think that something cannot be done and create the self-fulfilling prophecy that it will not be done. As Don Hopkins asserts, "there is no getting around it. The only proof that you *can* eradicate

something is that you *have* eradicated it. . .CDC is right to want to reduce the risks that you can, but eradication is always risky business" (Hopkins, D. Interview by Mark Rosenberg, 2014).

Stay open to revisiting and revising your goal. Participation in a successful eradication campaign can also be effective in improving the morale and performance of workers in public health, although this potential benefit can also sometimes be derived from a control program. An eradication campaign requires complete surveillance, rigorous administration, and operational research to a degree that may not be necessary in a control program because the standard of success in an eradication program is unambiguous and uncompromising. Another requirement of an eradication campaign may be funding to support measures to eliminate a minor focus of disease from a country where the disease has limited impact and does not constitute a national priority. But don't be afraid to change your goal if you learn new information or it appears that for reasons you had not foreseen, eradication or elimination would not be possible.

The potential negative effects of an eradication campaign, especially an unsuccessful one, must also be weighed. It is important to take into account the economic burden and consequences as well as the potential negative impact on broader public health programs. The possible effects of competition for scarce resources and the political implications of a campaign that fails are among the factors that should also be considered (Henderson 1999). Campaigns that succeed may also have unexpected consequences. After the successful conclusion of the smallpox campaign, "support for any new eradication effort seemed especially unlikely since the smallpox eradication programme was then being critically maligned by traditional international health planners. To them, the smallpox campaign epitomized the worst of what they characterized as anachronistic, authoritarian, 'topdown' programmes which they saw as anathema to the new 'health for all' primary health care initiative" (Henderson 2009).

Lesson 5: Measure Frequently and Build in Continuous Improvement

Don Hopkins designed and oversaw the campaign to eradicate Guinea worm and believes that it is important to "pick a handful of indices for the most important outcomes and processes that people implementing the programs can use to track their own progress or lack thereof (Hopkins, D. Interview by Mark Rosenberg, 2014). This handful of indices can focus attention on the interventions that are most important, and they can foster friendly competition. Besides showing progress, these data are useful for motivating people and for advocacy" (ibid.).

During the course of the campaign, the overarching goal – eradication of Guinea worm disease – remained constant, but the strategy and tactics would change based on what they learned. When the campaign to eradicate Guinea worm began in 1986, an estimated 3.5 million human cases were occurring each year spanning across 21 countries (CDC 2011; The Carter Center 2019). By 2019, only 49 human cases were reported, 43 of which were within Chad, 4 in South Sudan, and the remaining

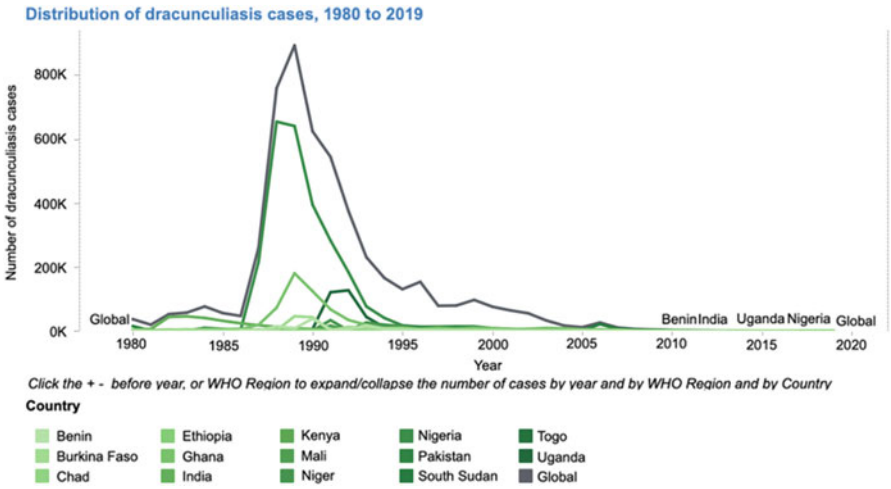

Fig. 2 (WHO 2019a)

1 in Angola (The Carter Center 2019). This was a remarkable 99.9% reduction in human cases since The Carter Center began their Guinea worm eradication campaign in 1986 (ibid.) (Fig. 2).

But after 30 years of campaigns to control Guinea worm, and just when it appeared that eradication was in sight, it was discovered that dogs could also be hosts for the Guinea worm. Dogs had previously been overlooked as reservoirs for the parasite, and it was clear that a major change in strategy and tactics would be required. The strategy for eradicating smallpox also changed as the program progressed.

Lymphatic filariasis (LF) is another one of the neglected tropical diseases, a group of deforming and debilitating diseases collectively known as the NTDs. These are diseases that for a long time were neglected because they infected "neglected people" living in poor tropical and subtropical countries. The NTDs include onchocerciasis, trachoma, intestinal parasites of children, schistosomiasis, and lymphatic filariasis. For LF, also known as elephantiasis, changes in the strategy for eliminating it also occurred as new treatments, and new diagnostic tests were developed. The main strategy for eliminating LF is treatment of those infected by mass drug administration with the goal of preventing further transmission. Using this approach, the Global Program to Eliminate LF has mobilized treatment numbers that have never been seen before [Ottesen]; since the start of the program in 2000, 7.7 billion treatments have been delivered throughout 68 countries with a target population of 910 million people (WHO 2019b). But an even broader and more effective strategy became feasible when new diagnostic tests and new treatments became available.

As we look at the history of efforts to control NTDs, we noticed a larger pattern, a meta-cycle, that we think is worth pointing out. These are very roughly stages in the evolution of the battle against these diseases. Different stages required different strategies that needed to be modified, extended, and continuously improved as more

players and resources joined the battle. Our short and greatly oversimplified history of the battle against NTDs has 8 phases:

1. **Creation** – The modern history of global health institutions began in 1945 when the WHO was born, along with UNICEF and the World Bank. It was thought that the WHO would be *the* organization to deal with global health, the World Bank would deal with poverty, and UNICEF would take care of the health of children. It was thought that these organizations would each have a clear and well-defined role, but that was not to be. Overlapping mandates often resulted in fierce competition. Defining a role for each organization and getting them to collaborate effectively in the disease elimination programs was not automatic and not easy. As noted above (Lesson 3) coalitions would be needed to facilitate effective partnerships.
2. **Donation** – Another NTD, onchocerciasis, *or river blindness*, was endemic to 31 countries within Africa and several in Latin America. Then Merck developed and tested a human version of the drug, avermectin, and they were faced with an interesting dilemma. They had a drug so good it could inhibit the microfilaria of onchocerciasis for an entire year with a single dose. But the population in need included some of the poorest people in the world. This was not a promising commercial endeavor. In October 1987, Roy Vagelos, the Merck CEO, decided to donate the drug, all that was needed for as long as it was needed. Thirty-three years later, more than 1 billion avermectin treatments have been provided free by Merck. Millions have been spared the loss of sight and even more spared the burden of itching. A coalition of partners has now made huge advancements in the reduction of onchocerciasis worldwide through mass drug administration. The disease is diminishing to the point where it has been possible to contemplate a new strategy aimed not just at control, but at elimination, first in Latin America and eventually even in the most infected regions of Africa. The Mectizan Donation Program brought Merck a very high return on this investment in terms of disease and disability prevention, employee morale, and positive company name recognition. This, in turn, has inspired other pharmaceutical companies to follow suit. And now it is not just Merck but GSK donating albendazole for control of soil-transmitted helminths (STH) and LF; J&J donating mebendazole for STH; Merck Serono donating praziquantel for schistosomiasis; Eisai donating DEC; Pfizer donating Zithromax for trachoma; Novartis for malaria and leprosy; and more. And funds are being donated for implementation by the USAID and DFID and Geneva Global and more. And for operational research, by the Bill and Melinda Gates Foundation (BMGF) and more. These donations, are rewriting history.
3. **Multiplication** – Increased donations of money and drugs led to more participation by private sector, nongovernmental (NGOs), governmental, and multilateral organizations working to eliminate NTDs.
4. **Fragmentation** – As more organizations from civil society and the private sector entered the battle against NTDs, they created a changed landscape with no focal point. Competition – for countries to work in, for resources to work with, and for credit – rather than collaboration characterized this stage. Countries were faced

with a shortage of healthcare workers, generally lacking critical skills, especially in the areas of management and finance. While this may have been a more democratic approach to global health, it also led to a change in the authority and perception of the WHO. There was a dispersion of strategy and governance and a culture of diplomacy with little accountability. This lack of coordination imposed a huge burden on the minister of health who had to deal with many multilateral, philanthropic, bilateral, nonprofit, and corporate organizations. A multiplicity of donors acting on their own contributed to the burden.

5. **Aspiration** – To make the challenge even tougher, the donations and multiplication of interested players raised hope and led the WHO to set some aspirational goals: to eliminate some of the NTDs and control others.
6. **Collaboration/integration/convergence –** It became clear that things had gotten out of control. Bringing people together from different organizations and different cultures with different needs and expectations is challenging and takes strong, but sensitive, leadership. Collaboration takes time and attention, and these are scarce resources that are often not well-managed. Participants will not commit these resources unless they see that the collaboration is worth it. Because people believe collaboration should be easy and natural, they are naïve about what it takes to collaborate successfully, and they often don't put in the time and attention needed. In the beginning of the worldwide effort to control NTDs, many donors and implementers set up parallel programs for NTD control that were not centered in country governments. That was a mistake (Fig. 3).

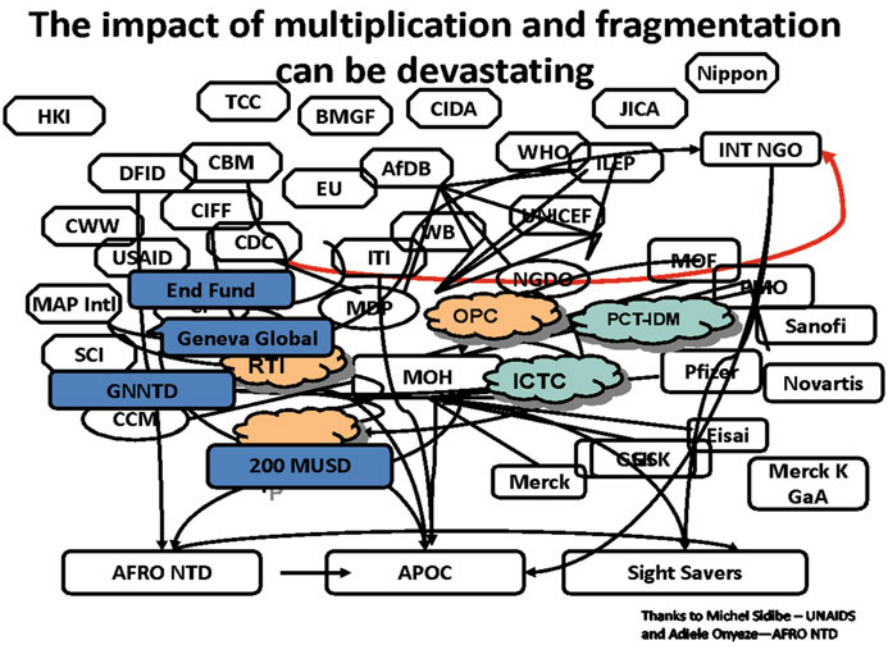

Fig. 3 Based on personal communication from Michel Sidebe and Adiele Onyeze

7. **Capacitation** – Later, each country developed their own NTD master plan, and it became clear that the capacity to control NTDs must reside within country health systems. NGO and donor implementers can work alongside – not in the place of – country programs. Countries coming together will strengthen the countries' voice and role.
8. **Elimination** – Having built the capacity to achieve elimination, states, countries, regions, and continents can certify that they reached their goal. But post-elimination plans need to be put in place. These plans should be open to continuously assessing your strategy and your progress because your world will keep on changing.

Lesson 6: Respect the Culture and Work with the People You Are Trying to Help

"If we are to succeed," Foege noted, "it will be because in everything we do, behind every decision we make, we see the faces" (Foege, W. Interview by Mark Rosenberg, 2014). Seeing the faces means we need to remember exactly who are the people we are trying to help. We need to understand both the individuals and communities that we work with. This means respecting diversity and including those who are different from ourselves. It also means we need to understand what the theologian Dietrich Bonhoeffer called "the view from below," the view of those who suffer from the problem and those who suffer most. Bonhoeffer said:

> There remains an experience of incomparable value. We have for once learned to see the great events of world history from below, from the perspective of the outcasts, the suspects, the maltreated — in short, from the perspective of those who suffer. Mere waiting and looking on is not Christian behavior. Christians are called to compassion and to action. (Bonhoeffer 2015, p. 16)

Global health, by definition, crosses boundaries and involves the participation of citizens of multiple countries, multiple cultures, multiple languages, and many diverse people. We, coming from one culture, need to work together with partners whose knowledge and cultures complement our own. We must be respectful and collaborative if we want to be successful. When global health began in the nineteenth century, it was very much a missionary-fueled movement, where people largely from the Global North traveled to the Global South to improve the health of the people there. The missionaries did things to improve their health, and they also tried to convert people to their own religion. They did things TO the people. In the next phase of global health, it was fueled by philanthropy, and people from the Global North did things FOR the people. Today it is clear that we need to do things WITH the people we want to help. And this means we need to understand and appreciate the local culture. It is also important to recognize lingering effects of colonialism.

That said, while "respecting the culture" is important, we must go beyond to empower: realizing that every elimination intervention is, in fact, a concomitant and

essential opportunity to strengthen health systems, bring and create parity, and build cross-cultural exchanges with bidirectional (and equal) shared learning and receiving. Middle- and high-income countries stand to learn a tremendous amount from low-income countries because poverty often drives innovation and discovery (Hiatt et al. 2016).

Lesson 7: The Best Decisions Are Based on the Best Science, but the Best Results Are Based on the Best Management

The importance of good management is often undervalued, but it is absolutely essential to the success of any elimination or eradication program. The ability to actually reach your goal, to get to the "last mile," and to deliver the results you are aiming for depends on good management. The importance of strong management with meticulous supervision cannot be overemphasized. It is not enough to just train people and send them forth to do good. It is imperative to encourage them and to ensure that they get supplies, constructive mentoring, and constructive supervision in order to keep them on target. It is also important to supplement what they have learned with training and re-training sessions (Hopkins, D. Interview by Mark Rosenberg, 2014).

Good management also means that we understand how decisions will be made. Graham Allison, a professor of political science at Harvard's Kennedy School of Government, gave us a powerful way to understand the issues by saying we have to look at three models or levels of thinking to understand how decisions will be made (Allison 1969). The **rational model** views actions as the rational deliberation of a single solitary and strategic actor who chooses actions that are most likely to achieve a goal. This model leads us to ask what are the costs and benefits of an elimination or eradication campaign? What are the most cost-effective strategies for achieving our goal? The **organizational model** sees output as a function of "routine" rather than of "choice" and leads us to ask: How do the organizations operate that make the policy and lead the implementation? The WHO passed a resolution to eradicate polio in 1988, but essentially nothing happened for 10 years. To understand why nothing happened, a good manager has to understand the organizational dynamics. In 1988 when they passed the WHO polio resolution, the program was going so well in Latin America that they almost shamed the WHO into doing something about it. Haftan Mahler, the WHO Director General at the time, really pushed this. But the WHO staff fought it because they did not know where the money would come from, and without that it would not be possible. In addition, the WHO had signed onto the Declaration of Alma Ata, which had a goal of "healthcare for all," and many staff said "no more vertical programs." These staff felt that to provide primary care for all, the WHO would have to emphasize programs that addressed *all* of the most basic healthcare needs, i.e., horizontal programs. When polio came up, they had already agreed there would be no more programs that focused on a single disease like smallpox, no more vertical programs. All of these organizational factors contributed to the WHO missing their 2000 polio eradication target by more than 20 years. The

individual model sees policy as the outcome of individuals in positions who can pull strings depending on who they know. It leads us to ask: Who are the key players, how are they connected, and what strings can they pull and what levers can they push? At the WHO, the Director General, Dr. Mahler, had signed on to the Alma Ata agreement but he personally strongly supported the polio eradication campaign. And that made a very important difference.

Lesson 8: The Best Solutions Move Us Closer to Global Health Equity

Eradication is a step toward global health equity and social justice. Smallpox eradication did this. Before smallpox was eradicated, the rich countries were already rid of the disease, but the disease still percolated along among the world's poorest and most vulnerable citizens. Millions living in poverty remained vulnerable. For other global health problems as well, frequently those who continue to suffer from the diseases or public health issues that we can eradicate and eliminate are those with the fewest resources and those who are the least well-off. This is global health delivery in the pursuit of social justice, a noble calling.

The campaigns to eliminate the "neglected tropical diseases" are another good example. NTDs are widespread, disabling, and devastating diseases, and elimination means people like us will be able to see, learn, walk, and support our families. We are concerned with the suffering of others. But they are diseases of poverty, so the developed world does not see the people, bear witness to their lives, and understand their problems. Advocacy and resource mobilization for HIV/AIDS was extremely effective because the advocates were highly influential individuals affected with HIV/AIDS who lived in the USA. NTDs are diseases of neglected people who live out of our sight. As long as the high-income countries only track diseases that represent threats to their own health (like MDRTB, SARS, and influenza), they will not focus on the NTDs because they do not spread in rich countries with cooler climates and good sanitation. Therefore, we need to work even harder together to make our case, mobilize the resources we need to implement our master plans, and reach our ambitious elimination goals.

Finally, in designing and implementing disease elimination and eradication programs, it is important to achieve clarity about our values and what our goal really is. Is it to protect the most poor and vulnerable or is it to protect ourselves? The philosopher Martin Buber described two types of relationships, which can be the drivers for disease elimination and eradication campaigns. We can be concerned with others primarily as they affect us and our own security and well-being, seeing ourselves as "I" and others as "It" (Buber 1958). Or, we can view others as important in their own right and recognize that their well-being affects us because we are interconnected, and their suffering diminishes us. This latter view leads to what Buber called "I and Thou" relationships (ibid.). Our current global health security priorities are driven by "I-It" considerations: we need to protect ourselves here by controlling this disease over there. The WHO's International Health Regulations primarily require reporting of diseases that represent cross-border threats, for

example, Ebola virus or multidrug-resistant tuberculosis. While "I-It" surveillance serves an important public health function, "I-Thou" campaigns are needed if we are to reduce health disparities, monitor progress toward global health equity, or address the complex social determinants of health in the twenty-first century. Indeed, if we value consequential compassion, I and Thou values must play a role in designing our elimination and eradication campaigns.

Lesson 9: Do Not Underestimate the Time, Resources, Tenacity, and Focus It Will Take to Succeed

Elimination and eradication campaigns always take longer than people initially thought. Looking at the extended time it has taken to eradicate Guinea worm, Don Hopkins emphasized that it is important to focus and stay focused. With respect to Guinea worm, Hopkins said he never imagined it would take this long, as he shared:

> To me it was such a logical thing with just obvious benefits and an obvious no-brainier, and I didn't anticipate how much work it would take to mobilize the countries and the international agencies. That to me is the biggest surprise of all... It took wearing them down, working with those groups willing to work. There were a lot of people willing to work, but results came not from standing there and butting your head against the wall of those unwilling to move but going with those who were willing to move. I thought that the results would convince the others to come along. That also took longer than I would have liked. (Hopkins, D. Interview by Mark Rosenberg, 2014)

Costs as well have been much greater than anyone had dreamed in regard to the polio campaign. Simply because the personnel needs have been quite high in the countries that require assistance for adequate surveillance and immunization coverage, also the costs for supplies – including new types of vaccine and antiviral agents that came to be required – have been greater than anticipated.

There is always a decline in coverage and interest when any country has reached its initial elimination target. When coverage is reduced in countries that have become polio-free, they are at a great risk of becoming reinfected, and that contributes to the high cost. The lack of participation in the campaign of Nigeria for several years led to virtually all of the susceptibles becoming reinfected, in very large numbers. They had not had any polio in that area for 10 years, so they kept doing the same thing, surveillance, for years, and then slowly stopped paying attention. But there were groups that were difficult to reach, and they had gone un-immunized. In other neighboring countries, endemic transmission has been cleared only to find that the virus from Nigeria has entered the country (Dowdle, W. Interview by Mark Rosenberg, 2014).

The deliberate spread of disinformation about polio case workers has generated violence against them. This slowed the polio campaigns in Nigeria and has led to the murder of some case workers in Pakistan.

Measles is a prime example of how important the social will and public trust are and what happens when that trust is lost and resistance to the elimination campaigns

gets crystallized and spread. Biomedical science only gets you so far; effective implementation in the face of human complexity can continue to be a tremendous challenge. Today, *measles* remains a leading cause of death for children worldwide. The WHO has made significant improvements to decrease that number by vaccinating over one billion children in high-risk countries since 2000, hoping to achieve measles elimination in at least five of the WHO regions by 2020. But in recent years, low vaccination rates in many areas of the USA and Europe have led to a resurgence of cases. Resistance to vaccination by groups opposed to vaccinations – given the name of "the anti-vaxxers" – has resulted in large outbreaks in several cities in North America (Benecke and DeYoung 2019).

Sometimes a variety of factors have contributed to the undermining of public trust. 1986 saw one of the biggest bovine spongiform encephalopathy (BSE) (i.e., mad cow disease) outbreaks in the UK (WHO 2010). The rise in cattle deaths led to the speculation of a circulating disease. It took time for scientists to identify the pathway of infection and etiological agent, which was later discovered to be a prion. In the meantime, lack of certainty led officials, the very people on whom the public depended, to deny any risk to human beings. In fact, in 1990, John Gummer, the presiding Minister of Agriculture, not only stated the threat BSE posed to humans was "so remote as for all practical purposes to be ignored," he also tried to publicly feed his daughter a hamburger to assuage public concerns (*The Guardian* 2000). Sir Donald Acheson, Chief Medical Officer at the time, followed, stating on TV that there was "no risk associated with eating British beef" (ibid.). It would be another 5 years until a ban was placed on "mechanically recovered meat" (ibid.). Between 1986 and 2004, it is thought that Creutzfeldt-Jakob disease, the human BSE variant, contributed to 152 deaths in the UK (WHO 2010).

Soon after, in 1998, Andrew Wakefield published a paper in the Lancet, claiming a link between vaccine and autism (Rao and Andrade 2011). The wavering credibility and authority of science and health officials from the preceding years of BSE in the UK created the perfect storm for Wakefield's claim to prevail even though his work was quickly discredited.

Today there are similar problems where the truth is not welcomed. Climate change, tobacco, and gun violence, all reinforce the importance of human factors in campaigns directed at disease elimination and eradication.

Lesson 10: Eradication Does Not Always Require a Vaccine or a Cure

If successful, Guinea worm (dracunculiasis) would be the first parasitic disease to be eradicated, and the first disease to be eradicated without a vaccine or even without a curative treatment. Guinea worm disease is spread when an individual drinks water that is contaminated by tiny water fleas that carry the Guinea worm larvae. By treating unsafe drinking water with a chemical that kills the water fleas and always filtering drinking water from possibly unsafe sources, the disease can be prevented. When an individual is infected with the larvae, they mature after about 1 year in the subcutaneous tissues of the legs or arms, reaching a length of 70–80 cm. After the

worms emerge, if that person enters a lake, pond, or well, the emergent worm can liberate larvae into the water which can then contaminate additional water fleas.

Before the recent development of an effective Ebola vaccine, some Ebola outbreaks were also eliminated without a vaccine or cure. But the idea of eradication extends well beyond infectious diseases; it is applicable to general public health eradication or elimination campaigns, such as women who die in childbirth, or deaths due to smoking, or medical errors. In this case, environmental, educational, and engineering interventions are powerful tools. It is usually not the discovery of a single magic bullet that turns the tide, but successful elimination usually depends on incremental improvements over time, as new parts of the problem are understood and new solutions are discovered. This requires a sustained commitment to research and continuous improvement.

Lesson 11: Start in the Most Difficult Places First

Don Hopkins, the architect and long-time manager of the Guinea worm eradication program, told us that:

> The most difficult places will take the longest and will be the hardest, and that time cannot be bought back. It might seem better to go after the low hanging fruit first, but it's just the reverse: it's better to face the harder problems and solve them and then pick up the low hanging fruit later. Ideally, it would be done simultaneously—but that is usually not how the world works. (Hopkins, D. Interview by Mark Rosenberg, 2014)

Eliminating the problem in the most difficult places will often require the development, testing, and delivery of new and innovative approaches. These will take time, so better to get this work started earlier. In addition, there is often a limited amount of time during which the public will pay attention to an elimination or eradication campaign, but it may be possible to sustain that interest for a longer time if you can show that you are making progress even in the most difficult to reach places. If you start on only the low-hanging fruit initially, then it may be more difficult to sustain interest – of the public, of your funders, and of your staff – when you are trying to push through to the end.

Sometimes the most difficult place is not a particular geographic locale, but it is the most difficult part of the strategy, made difficult because of intense disagreement. Sometimes the decision is made to defer working out an agreement because two sides may seem just too far apart, and a discussion could threaten the survival of the coalition. But that is usually a mistake. We have found it is better to try to resolve these basic differences directly. The conversations needed to resolve these differences can be very difficult, but they are important. Frances Kissling has given very helpful advice:

> Have the courage to be vulnerable in front of those we passionately disagree with. Ask what is it in your own position that gives you trouble? What is it in the position of the other that you are attracted to?. . .When people who disagree with each other come together with a goal

> of gaining a better understanding of why the other believes what they do, good things come of that. . ..It is very hard for all of us in these situations to acknowledge, for example, that we just don't have the answers to this problem. (Kissling 2011)

Lesson 12: You Don't Begin at the End

Be wary, Walt Dowdle said, of prematurely closing our minds thinking that we know what eradication is when we have only seen it done once (Dowdle, W. Interview by Mark Rosenberg, 2014). Smallpox has been seen as an example of eradication, but the problem is that it has been seen as the *only* example.

Smallpox was not the first disease eradication program. The Rockefeller Foundation began campaigns to eradicate hookworm in 1907 and yellow fever in 1915. Both these campaigns against diseases of humans failed: the hookworm campaign because mass treatment of affected populations with anthelmintic therapy reduced the severity of individual infections but rarely eliminated them and thus did not prevent rapid reinfection (Nuwer 2016) and the campaign against yellow fever because of the previously unknown, inaccessible cycle of disease among nonhuman primates living in forests (Soper 1963). Acceptance of the concept of eradication declined during the late 1920s and early 1930s, after the futility of the eradication of hookworm and yellow fever was recognized.

Humility and an open mind are needed because when you begin, and at almost every stage before the last mile, you can't be sure what will work and when you will succeed. The CDC's guideline requires that potential eradication campaigns must be almost certain that eradication is possible before committing to the campaign. But as Don Hopkins noted earlier, "The only proof that you *can* eradicate something is that you *have* eradicated it" (Hopkins, D. Interview by Mark Rosenberg, 2014). And there is no way to know that at the beginning. You will not know it until the end.

The Lessons from Disease Eradication and Elimination Apply to Road Traffic Safety

We believe that all of these lessons are relevant to the elimination of road traffic injuries and can be useful in the development and the application of Vision Zero.

1. This is a cause and effect world
2. Know the truth
3. Coalitions are absolutely essential and absolutely hard
4. Avoid certainty, the Achilles heel of science
5. Measure frequently and build in continuous improvement
6. Respect the culture and work *with* the people you are trying to help
7. The best decisions are based on the best science, but the best results on the best management
8. The best solutions move us closer to global health equity

9. Do not underestimate the time, resources, or tenacity it will take to succeed
10. Eradication does not always require a vaccine or a cure
11. Start in the most difficult places first
12. You don't begin at the end

These lessons are not as much about the behavior of infectious agents as they are about how to understand problems, develop strategies, and successfully apply those strategies to solve those problems.

Claes Tingvall has been a pioneer in applying the idea of elimination to road traffic injuries and in spearheading the development of a standard for the management of road traffic safety systems; he has focused our attention on the importance of good management (ISO 2012). He has pointed out that there are interventions – such as traffic circles – that have been so effective that they have been called "vaccines for roads" (Rosenberg 2007). The biggest changes have been in road design, infrastructure designed to reduce the number of crashes by widening and straightening roads. Recent efforts to reduce road traffic injuries have aimed not just to decrease the number of crashes but to decrease the number of fatalities and serious injuries. The body has crash tolerance limits; they should not be exceeded. As soon as the driver loses control, the infrastructure should take over to mitigate the seriousness of the crash, for example, by clearing trees and boulders from the sides of roads and installing side barriers; it is kinetic energy control.

As Vision Zero is adopted by more and more governmental and non-governmental organizations, the value of applying elimination to road traffic injuries is proving its worth. Barriers and roundabouts and design for pedestrians have become increasingly important in improving road safety. The idea of a "shared space" between pedestrians and vehicles was trialed successfully in Gothenburg and other cities, as long as the environment is redesigned for slow traffic. Two-lane roads – the real killers – were also adapted into roads with two lanes in one direction and one lane in the opposite direction, the 2+1 system. But the real trick was to install a crash barrier between the lanes, saving approximately 50 to 60 fatalities per year.

Conclusion

The lessons above highlight the importance of partnership, leadership, strategic planning, as well as compassion, focus, determination, and, above all, perseverance. The thoughts shared from these disease eradication and elimination experts go beyond disease. Compassion moves us to seek to eliminate suffering as much as is humanly possible. We understand the perspective of those "down below," in the words of Dietrich Bonhoeffer, and we know that those who continue to suffer from the diseases or public health issues that we can eradicate and eliminate are

those with the fewest resources and those who are the least well-off. This is global health delivery in the pursuit of social justice, a noble calling.

Every eradication or elimination campaign, however, will learn much more as it progresses. It is important to capitalize on this opportunity for continuous improvement by creating, from the beginning, a strong research component, including a research agenda, and strong links between the research community and the operational challenges facing the implementers.

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