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Improving Health through Elimination and Eradication of Vaccine Preventable Diseases

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Abstract: The last two centuries have seen an extraordinary reduction in the morbidity and mortality due to infectious diseases as a result of improvements in health and hygiene-related conditions and the introduction of vaccinations. Vaccines against infectious diseases with a human reservoir can have the following beneficial effects : control, elimination, eradication and extinction of the disease. Vaccines have facilitated the eradication of smallpox in 1980 and a massive reduction in cases of poliomyelitis, of which only 1,655 were recorded worldwide in 2008. The elimination of poliomyelitis in the European region was certified by the WHO in 2002. The essential conditions for the elimination of communicable diseases are political commitment, the implementation of vaccination programmes and exhaustive disease surveillance.

Keywords: Communicable diseases, elimination diseases, eradication diseases, infectious diseases, measles, poliomyelitis, smallpox, vaccination programmes.

INTRODUCTION

One of the most important public health achievements in the last two centuries has been the extraordinary reduction in morbidity and mortality due to infectious diseases.

In most countries, this reduction began during the first half of the 19th century as a result of the increased supply and availability of food and improvements in the standard of life, and was continued in the first half of the century thanks to the adoption of environmental health measures by governments and to improvements in hygiene in general [1].

In the 20th century, vaccination played a fundamental role in reducing the impact of infectious diseases.

CONTROL, ELIMINATION AND ERADICATION OF VACCINE-PREVENTABLE DISEASES

Vaccines against infectious diseases with a human reservoir can have the following benefits: control, elimination, eradication and extinction of the disease [2, 3].

Control of a disease is defined as a locally-acceptable reduction in the incidence, prevalence, morbidity and mortality of a specific communicable disease as a result of specific policies. Sustaining the reduction achieved requires continued vaccination programmes.

Elimination of a disease is defined as a reduction to zero of the incidence of a specific infectious disease, understood as an infection accompanied by clinical manifestations [4] in a specific geographic region as a result of specific policies. Sustaining elimination likewise requires continued vaccination programmes.

Elimination is reversible, since the causal agent continues circulating outside the region in which it is eliminated and may therefore be reintroduced at any time by imported cases or small outbreaks. Therefore, surveillance is necessary to determine whether elimination is sustained in a specific region or whether new cases are occurring.

De Serres *et al*. defined elimination as a situation in which: a) endemic transmission has ceased; b) there is no sustained transmission; and c) secondary transmission from imported cases is interrupted naturally without health interventions [5].

In March 2000, an expert panel on measles and public health of the Centers for Disease Control and Prevention stated that endemic transmission of a disease should be considered as the existence of a chain of transmission that persisted for a year or more in a region in which elimination had been achieved [6].

Eradication is defined as a permanent reduction to zero in the worldwide incidence of a disease caused by a specific infectious agent as a result of specific health policies.

When eradication is achieved, unlike elimination and control, vaccination programmes are no longer necessary, as there is no risk.

Eradication of a disease requires a set of requirements: a) a defined and accessible reservoir of the infectious agent; b)

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the availability of effective control measures aimed at the agent, host or transmission mechanisms that could interrupt the transmission chain, and c) surveillance mechanisms that can monitor and, finally, certify the disappearance of the infectious agent.

Extinction occurs when the specific disease-causing infectious agent no longer exists either naturally (as occurs in eradication) or in the laboratory [3].

Although this is the terminology mostly used in public health, some participants in the Conference on Global Disease Elimination and Eradication as Public Health Strategies in Atlanta in 1998 considered that the distinction between elimination and eradication may be confusing in some languages and proposed this definition of eradication: "the absence of an infectious agent in natural conditions in a specific geographic region as a result of specific control policies. The control measures may be suspended when the risk of importing the disease is no longer present". Therefore, the terms "regional eradication" or "national eradication" may be used [7].

The possibility of eradicating a disease was suggested by Thomas Jefferson as long ago as 1800 after the discovery of the smallpox vaccine. The feasibility of eliminating and eradicating communicable diseases that cause considerable worldwide morbidity and mortality, such as malaria, tuberculosis, yellow fever, rabies and some diseases transmitted by helminths such as Guinea worm disease or lymphatic filariasis has been widely debated from the public health point of view, but diseases for which effective vaccines are available are the best candidates. After smallpox, eradication of poliomyelitis has been proposed, although still not achieved. The next candidate vaccine-preventable diseases for elimination are probably measles and rubella [8].

The lessons learned from the eradication of smallpox (the only disease eradicated until now) and the elimination of poliomyelitis in one World Health Organization (WHO) region are a guide to further actions.

The articles of this monographic number present a broad vision to current scientific knowledge on measles, rubella and mumps. The WHO European Region has proposed the elimination of endemic measles and rubella by 2010 and the prevention (incidence < 1 case per 100000 live births) of congenital rubella [9].

Although the 1993 report of the International Task Force for Disease Eradication considered that mumps was potentially eradicable, and therefore could potentially be eliminated from a given region, data from specific elimination programmes are limited. In Finland, where two doses of the Measles, Mumps and Rubella (MMR) vaccine have been administered since 1982 and where there is exhaustive mumps surveillance, elimination of indigenous mumps was achieved in 1997 [10]. The United States has also proposed the elimination of mumps by 2010 [11].

However, the diagnostic difficulties inherent to mumps, especially in vaccinated subjects, combined with the probable lower effectiveness of the mumps component of the MMR vaccine, hinder elimination, even when vaccine coverages are high [12-16]. The studies on mumps published in this number from regions where coverages of two doses of MMR are high, highlight these difficulties. A recent report by Anderson and Seward [17] analyzes this problem in depth.

THE EXPERIENCE OF SMALLPOX

Smallpox is the only disease that has been eradicated from the world. In 1796, Edward Jenner discovered the smallpox vaccine, giving rise to the use of vaccines to combat communicable diseases [8]. It is estimated that, in the 1950s, there were 50 million annual cases of smallpox worldwide. In 1967, the WHO introduced an eradication programme on the grounds that, although smallpox had disappeared from developed countries, it was still a major public health problem in most underdeveloped countries.

The eradication programme consisted of global administration of the smallpox vaccine in all populations combined with a strategy of intensive surveillance that consisted of searching for and detecting cases and vaccinating all contacts of the cases found. The programme was an undoubted success: the last cases were detected in the Americas in Brazil in April 1971, in Asia in Bangladesh in October 1975, and in Africa in October 1977 [18]. The WHO certified the eradication of smallpox two years after the appearance of the last case [19].

After the eradication of smallpox, the main remaining problem is linked to the laboratories that still store the virus; therefore, we still cannot talk of the extinction of smallpox or any other infectious disease. Although a vaccine is no longer administered when eradication is achieved, the WHO has, as a precautionary measure, adopted measures to ensure there is always a reserve of the vaccine available in case of accident or bioterrorism.

The objective of eradicating smallpox was made possible because transmission had already been interrupted, firstly in some countries and subsequently in whole continents.

Given the enormous importance of the eradication of a disease for the health of the general population and also from the perspective of the health services and the use of economic resources, the biological and sociopolitical factors that made the eradication of smallpox possible require detailed analysis (Table **1**).

The eradication of smallpox provides other lessons, including the need for economic support, continued research, sustained quality control of vaccines and the definition of short-term objectives to be allied with the long-term goal of eradication.

Table **2** compares the factors that favour the eradication of smallpox, poliomyelitis and measles.

THE EXPERIENCE OF POLIOMYELITIS

The introduction and mass administration of the oral polio vaccine in the 1960s had a great impact in most developed countries where clinical poliomyelitis disappeared during the 1970s and 1980s.

The substantial medical costs linked to treatment of the disease and the potential economic benefits of eradication were determining factors for the declaration by the World Health Assembly in 1988 of the objective of poliomyelitis eradication before the end of 2000. The initiative was based on the use of the attenuated oral vaccine and the following strategies: a) attainment and maintenance of high vaccination coverages in children with at least three doses of vaccine; b) development of epidemiological surveillance systems that adopted very-sensitive definitions of polio (acute flaccid paralysis) with corresponding laboratory support; c) administration of additional doses of vaccine to preschool children (generally < 5 years of age) during the so-called "National Immunization Days" to interrupt transmission of the virus and d) local immunization campaigns with the administration of two doses of vaccine 4-6 weeks apart aimed at children resident in high-risk regions where the persistence of the measles virus is more likely (mopping-up campaigns) [20].

Table 1. Main Biological and Sociopolitical Factors that Favoured the Eradication of Smallpox

Biological factors
Lack of reservoir animal
No recurrences
Only one serotype
Laboratory confirmation
Availability of an effective vaccine
Sociopolitical factors
Elimination achieved in many countries before eradication campaign began
Few social or religious barriers to the search for cases
Quarantine costs stimulated the participation of the richest countries
Clearly defined objectives that seemed attainable

Indigenous transmission of the wild virus was interrupted in the Americas in August 1991 and in the Western Pacific including China in 2000 [8,21,22]. The objective of elimination by 2000 was not achieved, but substantial advances were made in many regions. The worldwide incidence of polio fell from 350,000 cases in 1988 to 1,655 in 2008 (Fig. **1**) [23]. On 21 June 2002, the WHO certified the elimination of polio in the European region [24].

THE IMPORTANCE OF VACCINATION PROGRAMMES FOR THE ELIMINATION OF MEASLES

In 1988, McLean and Anderson, based on the experience with the measles vaccine, proposed the term "posthoneymoon outbreak" to describe the resurgence of the disease after a period in which immunization reduced the transmission but allowed the number of susceptible people to increase until it exceeded the threshold necessary for outbreaks to occur [25]. For this reason, it is accepted that a second vaccine dose is necessary to give a second opportunity for children who were not vaccinated with a first dose and to correct primary vaccination failures.

Strategies for achieving high vaccination coverages by the administration of this extra vaccine dose include the so-called "Scandinavian strategy" [26] and the mass vaccination campaigns included in the so-called "Pan-American Health Organization strategy" [27].

The Scandinavian strategy consists of the administration of two doses of MMR at 12-15 months and 4-6 or 11-12 years. Although the results were not apparent until some years after the programme had been introduced, this strategy has been adopted by many developed countries. Finland eliminated measles in 1994 using this strategy and similar results have been observed in Canada, Sweden and Spain. The same strategy has enabled the interruption, at different times, of measles transmission in the United States since 1993. Fig. (**2**) shows vaccination coverage and reported cases of measles between 2000 and 2008 in the European region [28].

Table 2. Main Factors Favouring the Eradication of Smallpox, Poliomyelitis and Measles

	Smallpox	Poliomyelitis	Measles
Biological factors			
Severity, sequelae	Yes	Yes	Yes
Animal reservoir	No	No	No
Subclinical cases	No	Yes	No
Recurrences	No	No	No
Serotypes	1	3	1
Laboratory diagnosis	Easy	Easy	Easy
Sociopolitical factors			
Countries in which disease eliminated	Many	Quite a lot	Few
Barrier for the search of cases	No	No	No
Economic incentive for rich countries	Strong	Moderate	Moderate

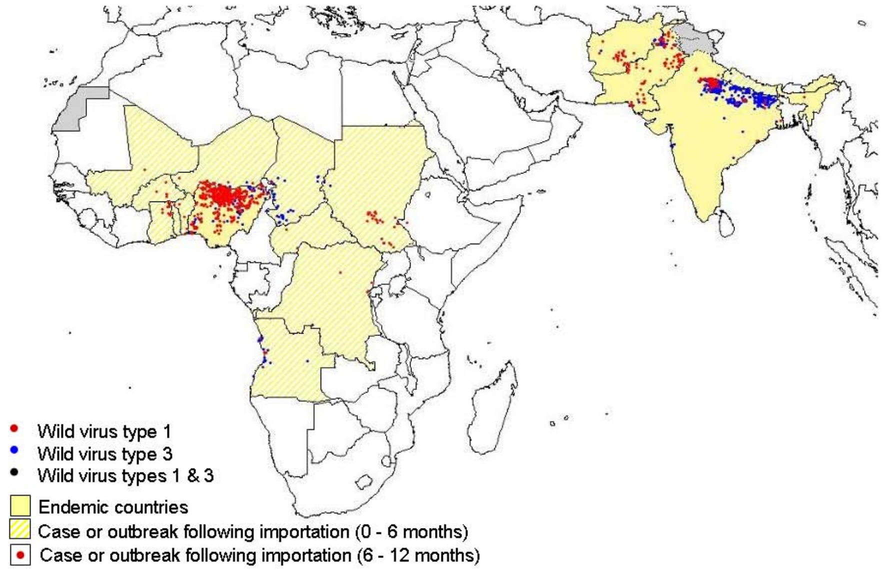

Fig. (1). Number of wild poliovirus (WPV) cases* - worldwide, 2008†.
*Data reported for 2008 to the World Health Organization as of March 3, 2009 (N=1,655).
†Excludes polioviruses detected by environmental surveillance and vaccine-derived polioviruses.

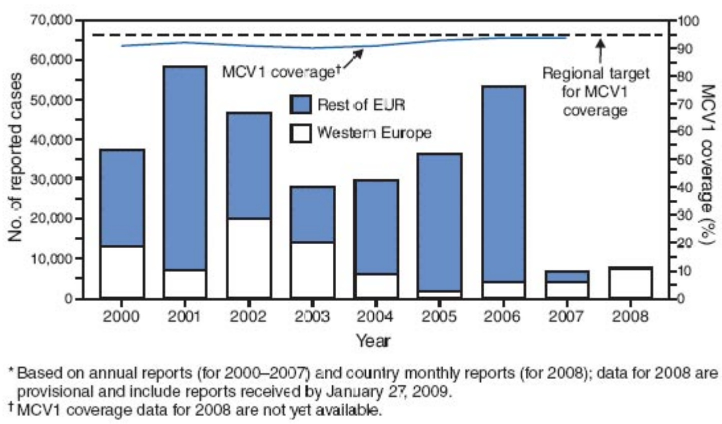

Fig. (2). Regional coverage with 1 dose of measles-containing vaccine (MCV1) among children age 12-23 months and number of reported measles cases – European Region (EUR), World Health Organization, 2000-2008*.
*Based on annual reports (for 2000-2007) and country monthly reports (for 2008); data for 2008 are provisional and include reports received by January 27, 2009.
†MCV1 coverage data for 2008 are not yet available.
MCV: measles vaccine coverage.

POLITICAL COMMITMENT, AN ESSENTIAL ELEMENT

One of the greatest obstacles to the elimination and eradication of measles is the lack of political commitment. The objectives and commitments to the elimination of measles vary depending on the WHO region. In some developed countries, measles was not perceived as a priority and some countries with very low vaccination coverages have suffered outbreaks with a varying number of cases, hospitalizations and deaths [29]. It is essential that developed countries with this profile apply extraordinary measures to eliminate indigenous transmission while, at the same time, helping to finance activities in developing countries. This demands firm political commitment that may be easier to make if it can be shown in detail that the costs derived from cases of measles may be very high, even when disease incidence is low [6, 27].

The eradication of measles also requires international consensus such as the declarations of the World Health Assembly in 1967 on smallpox and in 1988 on poliomyelitis. The greater the economic benefits derived from eradication, the greater the probability of a consensus. The cost of a case of measles in the United States in 1994 was estimated at 1000 dollars [30] and in a recent outbreak in 2008 in Indiana, where coverages with two doses of vaccine were 98% before the outbreak, the estimated cost was 4932 dollars per case [31].

Although available resources are limited, political commitment to controlling measles is high in Sub-Saharan Africa and southwest Asia, where measles is a major cause of infant mortality. The severity and case-fatality rate of the disease and the perceived risk of reintroduction in countries that have eliminated the disease are important factors that favour attaining a consensus and obtaining the necessary resources.

In Europe, the WHO decision to eliminate measles by 2007 (postponed until 2010 in 2003) has increased the commitment of European countries to eliminating the disease. Fig. (**3**) shows worldwide cases of measles and vaccination coverages [32].

THE ROLE OF EPIDEMIOLOGICAL SURVEILLANCE AND THE LABORATORY

Disease surveillance is essential for measuring the impact of vaccination programmes on the reduction in vaccine-preventable diseases. It played a crucial role in the eradication of smallpox [33] and continues to be vital to attaining the objective of eradicating poliomyelitis [34] and more-local measles elimination objectives [35].

The fundamental mission of surveillance in the context of elimination programmes is to detect the circulation of the virus in the population. This requires the establishment of reporting systems that facilitate the urgent detection and investigation of suspected cases, with subsequent laboratory confirmation of each individual case. All outbreaks should be studied and urgent control measures implemented.

The role of the laboratory is determinant in confirming each case using appropriate techniques in the context of elimination and eradication programmes. The poliomyelitis eradication programme involved a Global Laboratory Network consisting of 84 national laboratories, 40 subnational laboratories in large countries, 16 regional reference laboratories and seven global specialized laboratories capable of detecting wild-type and vaccine-related poliovirus [36]. Building on the success of this network, a similar global network has been established for the laboratory diagnosis of measles and other exanthematic diseases, including rubella [37]. IgM antibody determination is normally very useful, since these antibodies are the first to be detected and may be detected shortly after the appearance of the rash by a single serum specimen.

However, the presence or absence of these antibodies does not have the same significance for all diseases that are candidates for elimination. In mumps, for example, the results in vaccinated subjects are difficult to interpret, as negativity does not exclude the disease [19]. PCR techniques for detecting the virus, which have advanced greatly in recent years, are also very useful.

CONCLUSION

Vaccine-preventable diseases with an exclusively human reservoir and appropriate diagnostic techniques are potentially eradicable. If the efforts of one or more generations are able to eradicate a disease, the benefits will be seen in subsequent generations, who will not only not suffer the disease, but will not need to be vaccinated for protection, with the consequent economic savings and lack of possible vaccination complications and adverse effects. Socially, the benefits of eradication are unquestionable, as they affect the entire human population. Therefore, immunization against potentially-eradicable diseases should be considered as one of the most desirable medical interventions [38].

As Foege [38] stated "When eradication is achieved, all children - the rich, poor, educated, illiterate, rural, urban, black, brown, yellow, white, male, female, illegal immigrant, political elite, nomad, slum dweller, refugee, animist, Buddhist, Christian, Hindu, and Muslim - will be protected from polio: protected without vaccination."

LIST OF ABBREVIATIONS

WHO = World Health Organization.

MMR = Measles, mumps and rubella.

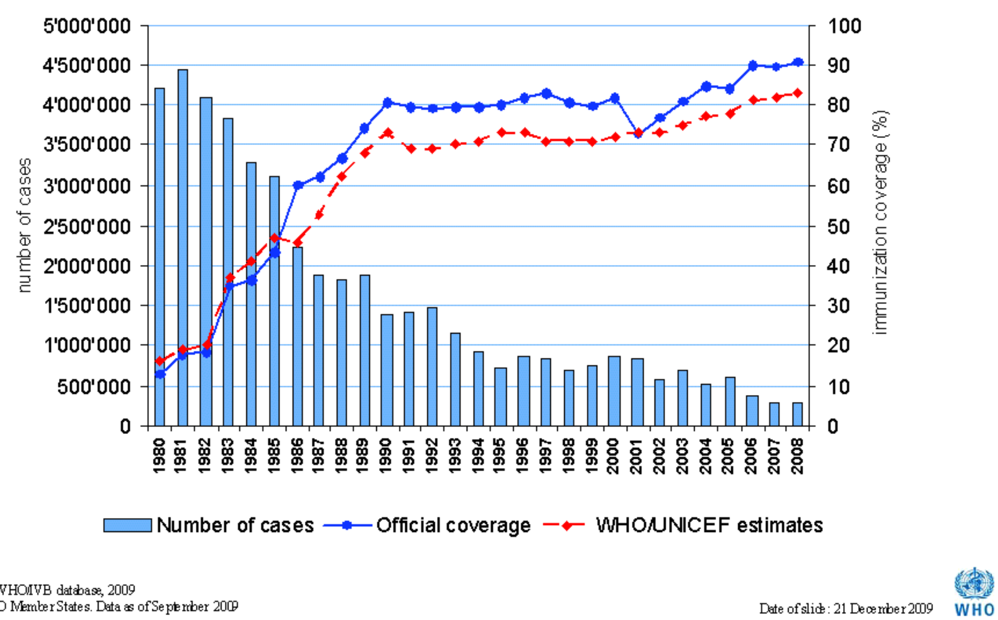

Fig. (3). Measles global annual reported cases and MCV* coverage, 1980-2008.
*MCV: measles vaccine coverage.

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