Measles in Mexico, 1941–2001: Interruption of Endemic Transmission and Lessons Learned

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In Mexico, measles occurred in a cyclical endemic-epidemic pattern until the early 1970s. Beginning in 1973, routine vaccination augmented by mass vaccination campaigns led to a decrease in the incidence of measles until the 1989–1990 regional pandemic, when the measles attack rate rose to 80 cases per 100,000, resulting in 5899 deaths. Since the pandemic, measles elimination efforts in Mexico have resulted in increasing coverage to >95% among children aged 1–6 years with 2 doses of either measles or measles-mumps-rubella vaccine since 1996 and in coverage of 97.6% among children aged 6–10 since 1999. Surveillance data suggest that the transmission of indigenous measles virus was interrupted in 1997. After almost 4 years without measles cases, in April 2000, measles virus was reintroduced into Mexico and 30 laboratory-confirmed cases were reported. Detection of relatively few cases in nonprogrammatic age groups affirms the high immunization coverage and the sensitivity of measles surveillance in Mexico. We conclude that the specific strategies adopted for measles elimination have enabled Mexico to eliminate the endemic transmission of measles.

This article summarizes the epidemiology of measles and the evolution of measles control strategies used in Mexico, as well as the impact of these strategies on measles morbidity and mortality and on the elimination of endemic measles.

MEASLES IN THE PREVACCINE ERA (1941–1972)

Reporting of measles cases began in 1941. The epidemic curve of measles in the prevaccine era demonstrated a biannual epidemic pattern and an average incidence of 100 cases per 100,000 population, as shown in figure 1 [1–3]. The annual average number of measles cases reported was 38,000, and epidemic years occurred with as many as 59,000 cases.

From the onset of the measles reporting system in 1941, estimates suggest that until the 1980s, only 20% of measles cases were reported to the Ministry of Health, representing a substantial degree of underreporting [4, 5]. During this period, the reporting system was deficient, even though measles was a reportable disease. Some studies estimated that only 3% of the cases were reported and that the actual numbers of cases ranged between 500,000 and 1,000,000 per year [2, 5]. In the prevaccine era, measles was among the top 10 leading causes of infant mortality. The annual average number of deaths from measles from 1941 to 1973 was 9000. The estimated case fatality ratio ranged from 100 to 600 deaths per 1000 cases [5].

Before the initiation of the measles vaccine era, the surveillance system for transmissible diseases was the Expanded Programme on Immunization (EPI)-1-65 reporting format promoted in the region by the Pan American Health Organization (PAHO) and introduced in Mexico between 1965 and 1966. Weekly reporting was done at the local level, and the information was transmitted to the health jurisdiction and finally to the state and federal levels [2, 5].
THE EARLY MEASLES VACCINE ERA (1973–1988)

Measles vaccine was first introduced in Mexico as part of a field study in 1970 and as part of the National Immunization Program in 1973 along with bacille Calmette-Guérin, diphtheria–tetanus toxoids–pertussis, and oral poliovirus vaccine, 1 year before the World Health Organization (WHO)'s introduction of the EPI, with the same vaccine schedule. Measles vaccine has been used routinely in Mexico since 1973 (an epidemic year.) That year, >3.6 million doses of measles vaccine were administered to children aged 9 months to 5 years, ~30% of that age group [2–5]. Routine measles vaccination began nationwide, with either the Schwarz or the Edmonston-Zagreb measles vaccines, at 9 months of age (table 1). However, the immunization program was geographically limited during 1973–1985; only communities >1500 population were programmed for routine immunization activities [2, 5–8].

Because of programmatic inconsistencies, measles immunization coverage was not maintained at the initial levels, resulting in a resurgence of a measles epidemic from 1976 to 1977, with incidences of 38.1 and 37.2 cases per 100,000, respectively. Even though there was a resurgence, these rates were 3–5 times lower than the incidence reported in epidemic periods before initiation of the immunization program. This new epidemic period prompted intensive immunization campaigns, with the resultant increase in the number of vaccine doses applied between 1978 and 1980 [5, 8].

The intensive immunization campaigns were conducted over 5-day periods and were done twice in 1980 and then once a year in the ensuing years. This strategy helped maintain relatively low incidences of 4.61 and 6.88 cases per 100,000, respectively, in 1983 and 1984. However, susceptibility to measles increased during this period, and 1985 was an epidemic year. A total of 19,000 cases were reported (incidence, 25 cases/100,000 inhabitants) and 1722 attributable deaths, setting back the program almost 10 years [5, 7, 8].

During 1985–1988, the birth rate was relatively stable, with birth cohorts ranging from 2,665,571 to 2,622,031 live births. During this 3-year period, measles incidence dropped to 10.3 cases/100,000 inhabitants in 1986 and to 3.9 cases/100,000 inhabitants in 1987 and increased again slightly to 4.7 cases/100,000 in 1988, in large part because of the reduction in the susceptible population as a consequence of the 1985 epidemic, as well as the intensive immunization campaigns [7, 8]. An average of 5 million doses were being applied per year; however, most of the doses were applied during the intensive immunization campaigns in communities with >1500 inhabitants, favoring those communities that had permanent health facilities such as hospitals and health centers. To give an idea of the magnitude of the underserved communities, during this period there were roughly 187,282 communities with <1500 inhabitants, accounting for 24 million people, roughly 24% of Mexico’s total population [8]. There are no official figures, but we can extrapolate that the birth cohort for those communities was close to 1,000,000, ~40% of the birth cohort, a population base that presumably was not receiving the full benefits of the intensive immunization campaigns.

Overall, until 1989, immunization coverage remained <50%. Even in large urban areas, coverage was irregular, high in areas with permanent health services and poor in rural areas and
Mass immunization campaigns administered as both primary and booster dose to nearly 4 million children in the states of Aguascalientes, Nuevo León, and Coahuila. A retrospective study of children vaccinated by the aerosol route in this campaign showed a vaccine effectiveness of 92%, which was comparable to that obtained in the group vaccinated by injection [5, 9, 10].

The surveillance format, EPI-1-65, was replaced in 1985 with another format, EPI-1-85. Although these reporting systems were not systematically evaluated, there was obvious under-reporting. This situation prompted a national serosurvey to evaluate immunization coverage. The survey turned out to be a landmark project: It revealed that despite intensive campaigns, immunization coverage was well below 50% [11].


In 1989, Mexico, like the rest of the American continent, experienced the onset of a measles pandemic. Contributing factors included the increase in susceptibility to measles in rural populations as well as among people from rural areas who had migrated to suburbs. Although the pandemic affected the entire country, during the initial period, 13 states located in the central and southern regions registered the highest attack rates. On the basis of the age distribution of the reported cases, 66% of the cases occurred in either children <1 year of age (15.66%), who were presumably not yet vaccinated or in children >5 years old (50%) who were not vaccinated because they were born before the initiation of the immunization program or were missed by the intensive immunization campaigns. The cases were concentrated in rural areas and periurban slums [8].

The pandemic peaked in 1990 with 68,782 cases reported (incidence, 82.39 cases/100,000 population) (figure 1). Although most of the cases occurred among children aged 5–14 years, the highest incidence occurred in children <1 year of age [6–8, 11]. During that year, measles accounted for 5988 deaths and ranked as the second most common cause of death in children 1–14 years old and sixth cause of infant mortality [12–17].

Between 1989 and 1990, a total of 89,163 cases of measles

<table>
<thead>
<tr>
<th>Strategy</th>
<th>Year(s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Medical units (1 dose)</td>
<td>1973</td>
</tr>
<tr>
<td>Household</td>
<td>1991</td>
</tr>
<tr>
<td>Booster dose added</td>
<td>1991</td>
</tr>
<tr>
<td>MMR supplants monovalent measles vaccine</td>
<td>1998</td>
</tr>
<tr>
<td>MR added for adolescents and adults</td>
<td>2000</td>
</tr>
</tbody>
</table>

**Table 1. Measles elimination strategies in Mexico.**

<table>
<thead>
<tr>
<th>Strategy</th>
<th>Year(s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Schoolchildren 6–14 years old (2 doses)</td>
<td>1991, 1993</td>
</tr>
<tr>
<td>Children &lt;5 years old in areas with low coverage</td>
<td>1995–1996</td>
</tr>
<tr>
<td>Municipalities with coverage &lt;95%</td>
<td>1998</td>
</tr>
<tr>
<td>Introduction of MR vaccine for health care workers, school teachers</td>
<td>2000</td>
</tr>
<tr>
<td>Immunization schedule for adolescents with MR, Td, and hepatitis B virus</td>
<td>2001</td>
</tr>
</tbody>
</table>

**Table 2. Measles mortality in Mexico, 1980–1986, according to age group.**

<table>
<thead>
<tr>
<th>Age (years)</th>
<th>1980</th>
<th>1986</th>
<th>% difference</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt;1</td>
<td>20.50</td>
<td>5.89</td>
<td>−71.27</td>
</tr>
<tr>
<td>1–4</td>
<td>12.60</td>
<td>4.18</td>
<td>−66.83</td>
</tr>
<tr>
<td>5–14</td>
<td>1.72</td>
<td>0.35</td>
<td>−79.65</td>
</tr>
<tr>
<td>&gt;15</td>
<td>0.21</td>
<td>0.05</td>
<td>−76.19</td>
</tr>
<tr>
<td>Total</td>
<td>2.76</td>
<td>0.75</td>
<td>−72.83</td>
</tr>
</tbody>
</table>

**NOTE.** Rate is per 100,000 inhabitants; in children <1 year old, per 100,000 registered live births.

periurban slums. People from rural areas (many of them susceptible to measles) migrated to the marginal suburbs, increasing the overall susceptibility to measles in different age groups, including adults [3–5, 7, 8].

As shown in figure 1, the impact of coverage on morbidity was dramatic during this period, with an overall reduction in the number of cases, resulting in the widening and flattening of the epidemic peaks. Table 2 depicts measles mortality between 1980 and 1986 according to age group. As can be seen, the overall mortality rate for all age groups was reduced from 2.76 to 0.75 per 100,000 inhabitants; this was most remarkable for children <1 year old, with an overall rate reduction of 71.27%, from 20.50 to 5.89/100,000 infants.

During this period, clinical investigators in Mexico, working with Dr. Albert Sabin, also pioneered a new aerosol method of measles vaccine delivery. Between 1982 and 1990, several field studies in Mexico of an inhaled aerosolized Edmonston-Zagreb measles vaccine were conducted. By means of an electric air compressor, liquid vaccine was nebulized and delivered with disposable paper cones. This method of delivery was field-tested among children ranging from 6 months to 15 years of age and proved to be a well-accepted and effective means of measles vaccination, as evidenced by the containment of the measles epidemic. The aerosol vaccination method was also used for mass immunization campaigns administered as both primary
and 8150 deaths were registered. In 1991, the measles pandemic had waned; only 5077 cases were reported, and the mortality plummeted to 97 cases [12].

One of the important lessons learned from the pandemic was the need for a second dose of measles vaccine. In 1991, a second routine measles vaccine dose was added to the immunization schedule at age 6 years, or on elementary school entry. That same year, in efforts to harmonize the vaccine and immunization program with all of the health sectors in Mexico, the National Vaccination Council (CONAVA) was established by presidential decree, and the Universal Vaccination Program was implemented to target immunization activities to the entire population. All public and private elementary schools were visited by public health nurses, who administered the vaccine to 6-year-old children, and a total of 14,398,064 doses were applied. At the same time, coverage in 1-year-old children reached an all-time high of 79% [12–15].

In 1991, PROVAC, a computerized information system that uses regionalized operative criteria to generate monthly information on vaccination coverage and height and weight measurements according to age and sex at the local and state levels, was developed by the Ministry of Health and introduced by all institutions of the Mexican Health Sector. Manual registry of all children and pregnant women who live in a specific geographic area is done at the local level. The names, addresses, date of birth, and type and dose of vaccine that children have received, as well as height and weight at vaccination, are collected. The data are entered into a computer program at the Health Jurisdiction, forwarded electronically to the state and federal levels monthly, and analyzed quarterly at the local, health jurisdiction, state, and national levels to monitor the Universal Immunization Program and the nutritional status of children <5 years of age. CONAVA emits electronic reports quarterly, enabling health institutions of the Health Sector and all states to evaluate the national, sectorial, and state-by-state achievements as well as potential “red flags” [16].

In 1992, house-to-house vaccination for susceptible children aged 9 months to 4 years was done in the entire country; 12,159,947 doses were applied, and coverage in 1-year-olds was increased to 89.2% [14].


After the measles pandemic of 1989–1991, the Ministry of Health implemented programs to eliminate endemic measles. In 1994, the Minister of Health joined with the Ministers of Health of all countries in the Americas at the XXIV PAHO Conference in Washington, DC, to establish the PAHO goal of eliminating measles from the region by the year 2000.

The PAHO strategies for measles elimination served as the foundation for measles elimination programs in Mexico [18]. Three strategies (table 1) were outlined for the elimination program.

**Increasing vaccination coverage in children through 5 strategies.** The “catch-up” campaign includes a 1-time initial vaccination conducted to rapidly interrupt chains of measles transmission. PAHO recommended that all children 9 months to 14 years of age, irrespective of vaccination history or reported history of measles virus infection, be vaccinated with measles vaccine within a short period, 1 week to 1 month.

After the catch-up campaign had been conducted, some areas had suboptimal coverage. After conducting a coverage evaluation, focalized or “mop-up” vaccination was done, to increase the level of coverage in low-coverage areas.

After the catch-up and mop-up operations, the “keep-up” strategy of routine vaccination was applied in each new birth cohort to ensure coverage of those between 12 and 15 months of age with either measles or measles-mumps-rubella (MMR) vaccines.

Periodic vaccination campaigns are done among all preschool-aged children in “follow-up” efforts to decrease the population’s measles susceptibility, which occurs because of less-than-optimal vaccine coverage and because of the vaccine efficacy, which at best is 95%.

After the incidence of measles had decreased, the routine age at vaccination was increased to 12 months (“push-up”), to maximize the response to vaccination.

**Performing aggressive control measures in response to outbreaks.** Control activities with confirmed cases included vaccination of children 6–11 months of age who were at risk of exposure (blockade dose) followed by revaccination 2 months after the blockade dose (regular dose), and vaccination of adults 15–39 years of age who were at risk of exposure.

**Developing a high-quality and specific surveillance system for cases and outbreaks [18, 19].** As part of the measles elimination strategy, a specific and sensitive surveillance system for measles and other acute febrile rash illnesses was developed in 1992. Any case of febrile rash illness in a child <15 years of age is considered a suspected case of measles. If rash is of ≥3 days’ duration and the child has rhinitis, coryza, conjunctivitis, or other catarrhal signs, the case is classified as “probable” measles [18].

In 1993, CONAVA conducted a “catch-up” immunization campaign targeting children 5–14 years old nationwide, regardless of prior vaccination or measles history. The target was different from the PAHO standard, because during the previous year, high measles vaccine coverage had been achieved among children <5 years old. Campaign coverage reached ≥85% in children 5–14 years of age. During this year, 23,279,202 doses of measles vaccine were applied. That same year, the PROVAC
system registered measles coverage of >90% for children <5 years old [20].

Also in 1993, the National Immunization Days, which had been successful in helping to eliminate polio in 1990, were transformed into National Immunization Weeks. In 1994, these were further transformed into National Health Weeks to include other public health activities, such as megadoses of vitamin A, deparasitization with albendazole, and distribution of oral rehydration packets. These weeks of intensive public health actions for children and pregnant women are conducted annually in February, May, and October. The first and second weeks in February and May have immunization with oral poliovirus vaccine to all children <5 years as a priority. This strategy is in keeping with both WHO and PAHO guidelines until polio is eradicated. Measles vaccination for elementary school-aged children is the focus of the third National Health Week conducted in October, when nurses and other health care personnel visit schools to immunize 6-year-olds with their booster doses of MMR. National Health Weeks have been carried out 27 times since 1994 [14].

In 1993, a more sensitive detection and reporting system for measles was put into place, which included laboratory diagnosis of measles. A total of 172 cases and 20 related deaths were reported, the lowest in Mexico’s history to that date [16].

In 1994, there were only 128 cases of measles reported, with 6 deaths due to measles. By 1995, confirmed measles cases had decreased by 98.6% compared with 1990. In 1996, only 2 confirmed cases were reported. Since 1995, routine keep-up vaccination activities have included evaluation meetings with all state program managers, held every 4 months, to identify problems and propose solutions for areas with <95% coverage. States set immunization goals, which have been achieved >96% of the time. The most successful keep-up strategies are those designed to avoid missed opportunities for immunization in the routine program [20].

A laboratory network was established in 1994. Laboratory confirmation of measles begins with an IgM-ELISA screening test performed on serum from the suspected case patient. If the screening test yields positive results, the serum sample is sent to the National Reference Laboratory for confirmation with the Centers for Disease Control and Prevention’s measles IgM-capture ELISA (Bellini technique). Positive as well as negative results of suspected cases are immediately reported to the state epidemiologist, as well as to the Federal Epidemiological Surveillance Center and the National Immunization Council.

The implementation of the measles elimination strategies modified the pattern of measles in the country. By 1992, the epidemic had ended and only 846 cases were reported. By 1996, only 2 laboratory-confirmed cases of measles were reported, and no cases were registered for the ensuing 4 years until April 2000.

In May 1998, National Immunization Council replaced the measles vaccine with the MMR vaccine. The first dose was moved from 9 months to 12 months, in accordance with PAHO push-up strategy, to maximize the response rate. The second or booster dose of MMR was maintained at 6 years. Coverage for both doses has been high (>97%) since 1997 [21].

Also in 1998, CONAVA conducted a national follow-up campaign, targeting all children <5 years old, irrespective of previous immunization history, and mop-up activities in counties with vaccination coverage of <95% for children 1 year of age (table 2). Even though some states had measles coverage of >95%, the averages tend to mask counties in which coverage may be lower. The areas of low coverage were identified though the PROVAC registry system.

In 1999, a mop-up campaign was also conducted in the 3 southern states bordering Guatemala and Belize, Quintana Roo, Tabasco, and Chiapas, and the isthmus state, Oaxaca. The campaign targeted all children aged 1–4 years, regardless of their vaccination status. Even though coverage was high in these states, this campaign, named “Frontera Sur” (Southern Border), was conducted because these states represent points of entry and high immigration flux from Central America, where immunization coverage at the time was uncertain. In 2000, the mop-up was extended to the 3 adjoining states. The resultant coverage in these municipalities was raised to 94%.

Finally, in keeping with the recommendations of the PAHO Technical Advisory Group meeting held in Hull, Canada, in April 1999, regarding measles elimination and control of congenital rubella syndrome, in 2000 CONAVA integrated rubella control into the measles elimination campaign. Health care personnel were immunized with the measles-rubella (MR) vaccine during the second National Health Week, in May, and junior high and high school students, school teachers, and tourist industry workers in selected vacation spots were immunized with MR during the third National Health Week in October [21–24].

In 1999, the surveillance system was expanded to included all cases of febrile rash illness, regardless of patient’s age. This system relies on the same negative weekly reporting network of health units used for acute flaccid paralysis. Each year since 1994, >10,000 cases of febrile rash illness have been reported and screened for measles by laboratory testing. During 1994–1999, only 2–12 cases tested positive each year. Thorough epidemiological investigation of these cases did not reveal secondary cases or case sources, suggesting that surveillance is sensitive [20]. Since 1994, >80% of febrile rash illnesses reported have been investigated within 48 h of report, with a serum and urine sample collected between days 6 and 20 of rash. However, clinical and epidemiological information is <60% complete for the period between 1993 and 1996. Since that time, epidemi-
Laboratory specimens have been sent in a timely fashion for these cases in Southern California prior to this case, but no link to the probable index case in Mexico City was established. The cases that followed were in Mexico City and the state of Mexico. The presumed index case occurred in and presumably the index case was in a Canadian adolescent girl who visited Mazatlán with her family on a religious mission. The diagnosis was made in Alberta, Canada, 2 weeks after her return from Mazatlán. She and her family spent >6 h in Mazatlán International Airport and then traveled to Los Angeles International, where they spent several hours, and then on to Alberta. In retrospect, she was the first case and the only case in which the virus was isolated; the virus was not of genotype D6. There was only 1 secondary case in Mazatlán, in an airport security worker. The cases that followed were in Mexico City and the state of Mexico. The presumed index case occurred during the Mexican Holy Week holidays, when there is significant national tourism to beach resorts, although no link could be made with this case and the cases in and around Mexico City. The case in Mexicali was isolated but occurred in a previously immunized 11-year-old child who attended school in Imperial Valley, California. There were reported imported measles cases in Southern California prior to this case, but no link was established.

In response to the reported cases in Mexico City and the other 3 states, active case investigation was conducted, with >70,000 households visited around the reported cases and >500,000 persons interviewed. Those susceptible were immunized with MMR. Additionally, 3.5 million health center and hospital charts were reviewed for diagnoses, to detect any unreported measles cases.

Specific control activities with confirmed cases included, for children 6–11 months of age at risk of exposure, vaccination with monovalent vaccine or MMR (blockade dose), followed by vaccination with monovalent vaccine or MMR 2 months after the blockade dose (regular dose), and, for adults 15–39 years of age at risk of exposure, vaccination with monovalent vaccine or MR. It is noteworthy that of the 30 case patients, 9 were <12 months old, 4 were >6 years of age, and 14 were ≥15 years old. Only 3 cases were in children between 1 and 5 years of age; these cases were deemed to reflect program failure, but 2 patients had false contraindications to vaccination and 1 had been vaccinated, attesting to high national immunization coverage and the nonprogression to an epidemic.

Research on aerosol vaccination was continued during this period with follow-up studies, using both MR and MMR vaccines. Preliminary results show that both MR and MMR vaccines applied by aerosol have seroconversion efficacy equivalent to vaccination by injection [25–27]. A clinical trial in Mexican school-aged children compared the antibody booster response of injected versus aerosol-administered measles, rubella, and MR vaccines. In this study, the aerosolized measles and MR vaccines induced a better booster response than did injected vaccines [25]. In contrast, when we investigated measles immunity in 12-month-old previously unimmunized infants who were immunized by either aerosol or subcutaneous delivery of measles vaccine, aerosol delivery of measles vaccine was as effective as subcutaneous delivery for inducing cellular immunity. However, geometric mean titers were lower in children immunized via the aerosol route, indicating that eliciting humoral immunity in young unimmunized children requires a higher aerosol measles vaccine dose than is required for priming measles-specific T cells [26].

Unpublished results from a clinical trial evaluating MMR vaccine given by either the subcutaneous or the aerosolized route in healthy adult volunteers found MMR aerosolized vaccine to yield significantly higher titers when baseline titers were controlled for in multivariate analysis. Moreover, aerosolized vaccine produced significantly more seroconversions for mumps in both univariate and multivariate analysis [27].

The ongoing strategy to ensure the sustainability of the current vaccination coverage rates is based on active surveillance of fever with rash illness, especially in states bordering Guatemala and Belize; ongoing immunization with MMR for 12-month-olds with coverage, and booster immunization for 6-year-olds on school entry; and finally, an intensive program of immunization of adolescents and women of childbearing age with MR vaccine.

Despite major advances in the control of measles in the continent, measles continues to be a major cause of morbidity and mortality in other regions of the developing world, and ironically, several European and Asian countries are now the major exporters of measles to the Western Hemisphere. There are major challenges to overcome, including maintaining high immunization coverage rates and active surveillance. To this end, perhaps the most important challenge has to do with the sustainability of public financing of immunization programs for countries in the region and worldwide. Operational self-
sufficiency is a key element in immunization sustainability, which is achieved if a country purchases or produces all the routine vaccines it requires and invests in the immunization programs. Mexico’s investment in health and in the purchase of vaccines, initially through the PAHO Revolving Fund and currently through consolidated national purchases, is depicted in table 3, and the investment in the primary immunization schedule, including administrative costs, is listed in table 4.

The introduction of new vaccines, including MMR, *Haemophilus influenzae* type b, and hepatitis B, took us from the basic 6 vaccines in the EPI to 10 immunogens; this represented an increase in the immunization budget from 0.04% of the 1996 health budget to only 0.09% of the overall health budget by the year 2000 but an increase in the per capita investment from $0.10 to $0.60. The factors that significantly contributed to making it possible to achieve these goals included the leadership of the PAHO Technical Advisory Group, the PAHO Revolving Fund for the purchasing of vaccines, and the political will of our health authorities. There is no question that this public health strategy continues to be among the most cost-effective, as evidenced by its impact on polio, measles, and other vaccine-preventable diseases.

**DISCUSSION**

Measles is no longer endemic in Mexico. The few imported cases with limited local spread that occur serve to highlight the sensitivity of the rash illness surveillance system. The success in interrupting the transmission of measles in Mexico has resulted from 10 years of concerted effort in ensuring that enough vaccine is available to immunize all children with 2 doses.

All evidence from the surveillance supports the absence of endemic measles in Mexico. During 1997–1999, all cases that tested positive for measles in the laboratory were thoroughly investigated, and no evidence of local transmission was found. Moreover, other measures of surveillance quality have been monitored, including the following: the number of cases of febrile rash illnesses with timely epidemiological study (48 h after notification); the number of cases with serum samples taken between days 6 and 20 of exanthem; the number of cases with complete clinical and epidemiological information; and the percentage of health units in the negative weekly reporting network that in fact report.

Although these indicators for measles surveillance have improved, the number of cases investigated suggests that the system does not detect all febrile rash illnesses. However, the system is better and more sensitive than in the past, and the combination of the number of febrile rash illnesses investigated and the lack of confirmed measles cases among the investigated cases indicates the absence of endemic measles. Even considering a high underreporting of febrile rash illness cases, the extremely rare laboratory-confirmed cases suggest that the strategies have been successful thus far in eliminating endemic measles from Mexico. It is not necessary to detect all febrile rash illnesses to demonstrate the absence of endemic measles. If measles were endemic in Mexico, many of the febrile rash illnesses would yield results positive for measles on laboratory testing.

**Table 3. Expenditure on health and vaccines, Mexico, 1992–2002.**

<table>
<thead>
<tr>
<th>Expenditure</th>
<th>%, by year</th>
<th>Annual expenditure per capita (US$)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Portion of GNP</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Health expenditure (public and private)</td>
<td>4.2 6.5</td>
<td>128 300</td>
</tr>
<tr>
<td>Health expenditure (public)</td>
<td>2.0 2.6</td>
<td>72 122</td>
</tr>
<tr>
<td>Portion of public health expenditure</td>
<td>0.4 0.9</td>
<td>0.50 1.00</td>
</tr>
<tr>
<td>Vaccine expenditure</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cost of complete vaccine schedule (2002 only)</td>
<td>... ...</td>
<td>13.58</td>
</tr>
</tbody>
</table>

**NOTE.** GNP, gross national product.

**Table 4. Cost of vaccine schedule, Mexico, 2002.**

<table>
<thead>
<tr>
<th>Vaccine</th>
<th>Cost/dose (US$)</th>
<th>No. of doses</th>
<th>Cost (US$)</th>
</tr>
</thead>
<tbody>
<tr>
<td>HBV, Hib, DTP</td>
<td>3.5</td>
<td>3</td>
<td>10.50</td>
</tr>
<tr>
<td>MMR</td>
<td>1.20</td>
<td>2</td>
<td>2.40</td>
</tr>
<tr>
<td>BCG</td>
<td>0.15</td>
<td>1</td>
<td>0.15</td>
</tr>
<tr>
<td>DPT</td>
<td>0.11</td>
<td>2</td>
<td>0.22</td>
</tr>
<tr>
<td>Td</td>
<td>0.07</td>
<td>1</td>
<td>0.07</td>
</tr>
<tr>
<td>OPV</td>
<td>0.06</td>
<td>4</td>
<td>0.24</td>
</tr>
</tbody>
</table>

**Total vaccine cost** | 13.58
**Cost of distribution (15%)** | 2.04
**Administrative costs** | 13.50
**Total cost** | 29.12

**NOTE.** BCG, bacille Calmette-Guérin; DPT, diphtheria-pertussis-tetanus; DTP, diphtheria—tetanus toxoids—pertussis; HBV, hepatitis B virus; Hib, *Haemophilus influenzae* type b; MMR, measles-mumps-rubella; OPV, oral polio-virus vaccine; Td, tetanus and diphtheria toxoids, adult type.
Many lessons learned from the poliomyelitis eradication program have been useful for measles elimination, not only for control measures but also for epidemiological surveillance. The lessons learned from the poliomyelitis eradication campaign, such as National Immunization Days, are applicable for measles elimination in children. National Immunization Days have evolved into National Health Weeks, and in each October National Health Week, nurses immunize all children entering elementary school with MMR vaccine.

The high immunization coverage with MMR vaccine, the introduction of MR vaccine for at-risk adolescents and adults, the analysis of febrile rash illness surveillance indicators, and the fact that from 1996 until the year 2000 no indigenous cases of measles were reported allow us to conclude that the specific strategies adopted for measles elimination have enabled Mexico to eliminate the endemic transmission of measles [20, 22].

Finally, in addition to the development and implementation of novel strategies for vaccine delivery, including aerosolized vaccine, collective efforts toward guaranteeing the timely purchase of quality vaccines, sustained high immunization coverage, and field and laboratory surveillance by countries in the region are the key elements for measles elimination in the Americas.

References