SUPPLEMENT ARTICLE

# The Americas: Paving the Road Toward Global Measles Eradication

**Carlos Castillo-Solorzano C,[1] Cuauhtémoc Ruiz Matus,[1] Brendan Flannery,[2] Christina Marsigli,[1] Gina Tambini,[1] and Jon Kim Andrus[1]**

[1]Pan American Health Organization, Washington, District of Columbia; and [2]Pan American Health Organization, Brasilia, Brazil

***Background.*** The Region of the Americas set a goal of interrupting endemic measles virus transmission by the end of 2000. This decision was primarily based on rapid decreases in measles disease burden in pioneering countries that implemented Pan American Health Organization–recommended vaccination and surveillance strategies. Review of these strategies may inform measles elimination efforts in other regions.

***Methods.*** Results from the implementation of the measles elimination strategy in the Americas were compiled and analyzed over a 30-year period, which was divided into 4 phases: the early years of the Expanded Program on Immunization (1980–1986); the start-up phase for elimination (1987–1994); the elimination phase (1995–2002); and the postelimination phase (2003–2010). Factors that contributed to elimination and the challenges confronted during the postelimination phase are discussed.

***Results.*** An analysis of vaccination strategies over time highlights the transition from monovalent measles vaccine to the incorporation of measles-mumps-rubella vaccine administered in the routine program. Regional vaccination coverage increased during the period 1987–2010, sustained at $\geq$90% since 1998. Measles elimination efforts led to the implementation of 157 national vaccination campaigns, vaccinating a total of 440 million persons. Endemic measles virus transmission was interrupted in 2002. After elimination, measles importations and associated outbreaks occurred. Measles incidence has remained at $<$1 case per 1 million population since 2002.

***Conclusions.*** The success of measles elimination strategies in the Americas suggests that global measles eradication is attainable.

Before the widespread use of measles vaccine, measles was a common illness in early childhood and was associated with substantial mortality. Although surveillance systems were still in their infancy during the 1960s, $>$600,000 measles cases were reported annually in the Region of the Americas, reaching incidence rates $>$150 cases per 100,000 population [1]. Although measles vaccine was introduced during the 1960s, it was the creation of the Expanded Program on Immunization (EPI) in 1977 that marked the beginning of sustained decreases in case numbers. During 1970–1979, Latin American countries reported ~220,000 measles cases annually, with incidence rates of 47–116 cases/100,000 population [2]. Highest mortality rates occurred among young children; from 1971 through 1980, measles-associated mortality was 14–55 measles-associated deaths per 100,000 infants and 8–54 deaths/100,000 children aged 1–4 years. By 1980, most countries in the region had established national immunization programs; however, the mean infant measles vaccine coverage in the region was only 42%.

EPI programs were progressively strengthened throughout the 1980s. During the decade, measles vaccination resulted in decreased disease incidence and lengthening of interepidemic intervals (Figure 1). By 1990, measles vaccine coverage among infants in the

Potential conflicts of interest: none reproted.

Supplement sponsorship: This article is part of a supplement entitled "Global Progress Toward Measles Eradication and Prevention of Rubella and Congenital Rubella Syndrome," which was sponsored by the Centers for Disease Control and Prevention.

Correspondence: Carlos Castillo-Solórzano, MPH, Regional Advisor, Comprehensive Family Immunization, Pan American Health Organization, Washington, DC 20037 (castilsc@paho.org).

**The Journal of Infectious Diseases 2011;204:S270–S278**



0022-1899 (print)/1537-6613 (online)/2011/204S1-0034$14.00
DOI: 10.1093/infdis/jir166

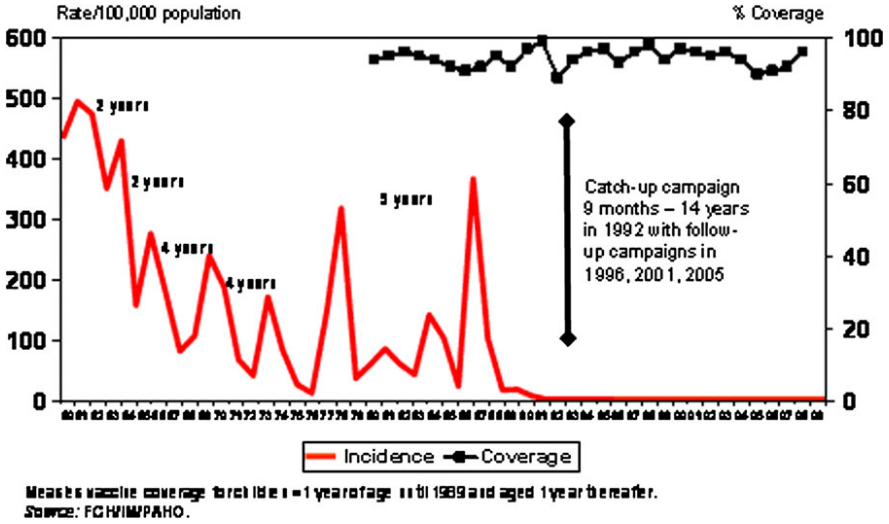


**Figure 1.** Measles incidence showing increased inter-epidemic interval following introduction of measles vaccine, Chile, 1960–2009.

Americas had reached 77%. Nevertheless, despite improvements in immunization coverage with a single measles vaccine dose, outbreaks continued to occur.

By the early 1990s, several countries pioneered a strategy recommended by the Pan American Health Organization (PAHO) to deliver measles vaccine to all children aged 9 months through 14 years in a catch-up campaign. The strategy appeared to be capable of interrupting endemic measles transmission. The first catch-up campaign in the region was launched in Cuba in 1986 [3]. In 1988, the ministers of health in the English-speaking Caribbean countries and territories declared their commitment to eliminate endemic measles by 1995. A catch-up campaign in 1991 achieved 90% measles vaccine coverage in the Caribbean [4, 5]. In December 1991, presidents of Central American countries announced the goal of eliminating measles within 6 years (by 1997) from their subregion. Catch-up campaigns were conducted throughout Central America in 1992 and 1993, reaching 89% of children. In South America, Brazil, Chile, and Peru catch-up campaigns were performed in 1992. In 1993, similar catch-up campaigns were completed in Argentina, Colombia, the Dominican Republic, and Mexico [6]. As a result, reported measles cases in the region reached a historic low in 1993 ($n$ = 57,400), a rate of 10 measles cases per 100,000 population. Regional coverage with the first dose of measles-containing vaccine reached 83%.

During the 24th Pan American Sanitary Conference in 1994, ministers of health passed resolution CSP24.R16, setting a goal to eliminate measles from the Region of the Americas by 2000. The approval of the resolution was based on the impressive and rapid reduction in measles burden that had been demonstrated by countries that pioneered the use of catch-up campaigns. Subsequent resolutions passed in 1995 (Resolution CD38.R6 passed in 1995 approved a Regional Plan of Action for Measles Elimination) and 1996 (Resolution CE188.R14 passed in 1996 urged all countries to assign the necessary human and financial resources to fully implement the strategies outlined in the Regional plan) provided additional elements of the measles elimination plan.

The present article describes the measles elimination experience in the Americas, which paved the way for a global eradication goal by demonstrating the feasibility of regional measles elimination.

## METHODOLOGY

Measles elimination in the Americas is defined as the interruption of endemic measles virus transmission in all countries of the Americas for a period $\geq$12 months, in the presence of high-quality surveillance.

To achieve measles elimination, PAHO recommended 3 immunization strategies: (1) 1-time mass vaccination of children and adolescents with measles-containing vaccine (ie, catch-up), (2) routine immunization of successive birth cohorts (ie, keep-up), and (3) periodic mass vaccination of young children to prevent accumulation of susceptible individuals (ie, follow-up). In 2003, after the adoption of a resolution to eliminate rubella and congenital rubella syndrome (CRS) from the Americas by 2010, a fourth strategy, referred to as "speed-up," called for a 1-time mass vaccination of older adolescents and adults with combined measles-rubella (MR) vaccines. In addition to vaccination strategies, PAHO emphasized the importance of sensitive, case-based measles surveillance with diagnostic laboratory capabilities. The vaccination and surveillance strategies were revised to include use of combined measles-mumps-rubella (MMR) vaccine or measles-mumps (MR) vaccine, fully integrate measles and rubella surveillance, and establish CRS surveillance (Table 1).

**Table 1. Alignment of Measles and Rubella Elimination Strategies**

| Vaccination | Surveillance |
|---|---|
| 1. Measles and rubella<br>• Catch-up campaign; children age 1 to 14 years.<br>• Keep-up to maintain coverage ≥ 95% in the routine program: children aged 1 year.<br>• ''Follow-up'' campaign; preschool-aged children or when the number of susceptibles to measles approaches the size of an average birth cohort.<br>• Introduction of MMR or MR in routine program; children aged 1 year.<br>• Speed-up campaign against measles and rubella in adolescents and adults. This type of campaign was conducted only once (the age group of men and women to be vaccinated depends on the year of vaccine introduction, follow-up campaigns, epidemiology, and fertility rates in the country). | 1. Integrated measles/rubella surveillance<br>• Reporting, investigation, response, and case classification of suspected measles/rubella cases.<br>2. CRS surveillance<br>• Reporting, investigation, response, and case classification of suspected and confirmed CRS cases.<br>3. Laboratory activities for measles/rubella and CRS<br>• Serological diagnosis.<br>• Viral detection/isolation and identification, and genotyping of measles and rubella virus. |

Each year, PAHO receives country reports on vaccination strategies and coverage achieved. We analyzed data from country reports for the period during 1980–2010. We divided the period into 4 phases (Table 2): (1) the early years of the EPI (1980–1986); (2) the start-up phase for elimination (1987–1994), before adoption of a regional elimination goal in September 1994; (3) the elimination phase (1995–2002); and (4) maintaining interruption of measles transmission after

**Table 2. Phases of Measles Elimination in the Americas, 1980–2009**

| Phase | Early EPI | Start-up phase, prior to formal elimination goal | Formal elimination phase | Maintenance phase, postelimination |
|---|---|---|---|---|
| Years | 1980–1986 | 1987–1994 | 1995–2002 | 2003–2009 |
| Routine vaccination | | | | |
| Regional average annual coverage, first dose of measles-containing vaccine | 42-59% | 61-83% | 86-92% | 92-94% |
| No. countries adding MMR1 to routine schedule | 12 | 12 | 16 | 0 |
| No. countries adding MMR2 to routine schedule | 0 | 7 | 14 | 8 |
| Vaccination campaigns | | | | |
| No. national catch-up campaigns | 0 | 37 | 1 | 0 |
| No. national follow-up campaigns | 0 | 1 | 52 | 27 |
| No. national speed-up campaigns | 0 | 0 | 20 | 19 |
| Total national campaigns | 0 | 38 | 73 | 46 |
| Surveillance | | | | |
| No. reporting sites | 130 in 1985 (a) | 16,000 in 1990 (a) | 22,000 in 1997 (b) | 49,741 in 2009 (g) |
| Total regional population | 640 million in 1983 | 720 million in 1990 | 820 million in 1999 | 930 million in 2009 |
| Average no. reported/confirmed measles cases[§] per year | 204,498 | 122,534 | 10,565 | 152 |
| Average annual measles incidence per million population | 320 | 170 | 13 | 0.2 |
| Laboratory network | | | | |
| No. laboratories in PAHO Measles/Rubella Laboratory Network | NA | NA | 12 in 1995 (d) | 148 in 2009 (e) |
| No. serum specimens from suspected measles/rubella cases[§§] | NA | NA | >41,000 in 1999 (d)<br>>46,000 in 2000 (d) | >36,000 in 2006 (e)<br>>37,000 in 2009 (g) |
| No. nasopharyngeal/urine specimens for virus detection | NA | NA | Few | 26 in 2003 (f)<br>602 in 2009 (f) |

**NOTE.** [§]Measles case confirmation began in 1994, but was not complete in the region until 1996.

[§§]Rubella case confirmation, e.g. ELISA testing from 1996 on all measles IgM negative specimens; from 1999 all specimens

(a) Health in the Americas 1994 [6] (b) Health in the Americas 1998 (d) Venzcel 2003 [7] (e) Global Lab Report WHO 2007 [8] (f) WER Oct 2008 [9] (g) Annual Immunization Summary 2009 [10]

elimination (2003–2010). The final phase includes the effects of rubella elimination activities, which contributed to maintaining measles elimination status.

Countries in the Americas annually report vaccination coverage with the first dose of measles-containing vaccine (MCV1) to PAHO. MCV1 is calculated for most countries by dividing the number of doses administered by the target population for vaccination (ie, administrative method). We calculated regional coverage estimates by multiplying reported coverage by target population estimates for each country. Coverage with a second dose of measles-containing vaccine (MCV2) is provided by some countries that include 2 doses in routine immunization schedules. Although PAHO recommends that immunization programs provide a second opportunity for measles vaccination, either through routine immunization services or through periodic follow-up campaigns, countries have chosen different strategies and age at which to provide a second opportunity.

PAHO recommends using standardized measles and/or rubella surveillance indicators to allow a transparent and uniform monitoring of surveillance data across countries. Depending on the moment or elimination phase, these indicators have been established and adapted over time. Since 2003, the indicators have included weekly reporting from 80% of surveillance sites, investigation within 48 h after notification and collection of an acute-phase serum specimen for 80% of suspected cases, report of laboratory results for 80% of samples within 4 days after receipt, receipt of 80% of samples in the laboratory within 5 days, and classification of 95% of nonmeasles cases on the basis of laboratory investigations.

## Results

### Vaccination

***Routine Delivery of Measles Vaccine.*** All countries and territories in the Americas have used measles vaccines since the inception of national immunization programs during the late 1970s. As part of EPI, measles vaccination was recommended at 9 months of age. In 1997, the PAHO Technical Advisory Group on Vaccine-Preventable Diseases (TAG) recommended increasing the age of routine measles vaccination to 12 months (to increase measles vaccine effectiveness). In addition, TAG recommended use of combined MR or MMR vaccines for routine infant immunization in countries with rubella and CRS control programs [11]. By 2002, a total of 40 countries and territories had changed to MMR vaccine for MCV1 and 21 countries and territories were providing a second routine dose of MMR vaccine. By 2009, all countries and territories used MMR or MR vaccine for the first routine dose, and 29 were providing MCV2.

In the early EPI period (1980–1986), regional MCV1 coverage was 42%–59% annually. During the early elimination phase (1987–1994), MCV1 coverage had increased to 61%–83%. Since 1998, regional MCV1 coverage has been sustained at $\geq$90%. Of 48 countries and territories in the region, 43 reported coverage in 2009 (For Canada and Haiti 2007 coverage data were substituted. The six 6 territories that did not provide coverage data were: Aruba; the French overseas departments of French Guiana, Guadeloupe, and Martinique; Puerto Rico; and the U.S. Virgin Islands). MCV1 coverage was $\geq$95% in 24 (56%), 90%–94% in 10 (23%), 80%–89% in 7 (16%), and $<$80% in 2 (5%) countries and territories. In 2009, 28 countries and territories reported MCV2 coverage: $\geq$95% (= 10 [36%]), 90%–94% (= 4 [14%]), 80%–89% (= 5 [18%]), and $<$80% (= 49 [32%] countries and territories). Coverage of $\geq$90% was reported by a larger percentage of countries and territories for MCV1 (76%), compared with MCV2 (42%).

***Delivery Measles Vaccine in National Campaigns.*** Most countries and territories in the region have provided measles-containing vaccines in national catch-up, follow-up, and speed-up campaigns. PAHO estimates that 440 million persons received MR-containing vaccines during these campaigns [9, 12]. From 1987 through 2009, measles elimination has led to some 157 national measles vaccination campaigns in the Americas.

During 1987–1995, there were a total of 38 national catch-up campaigns for children 9 months–14 years of age. The last of these was conducted in Paraguay in 1995. A catch-up campaign conducted in Canada during 1996–1997 was not included, because it covered only 5 provinces [13]. Coverage levels achieved in the 38 national catch-up campaigns were $\geq$95% in 18 (47%), 90%–94% in 6 (16%), 80%–89% in 8 (21%), and $<$80% in 6 (16%) countries and territories. Among the 39 catch-up campaigns, 23 (59%) used single-antigen measles vaccine, 1 (3%) used MR vaccine, and 14 (36%) used MMR vaccine.

From 1993, when the first follow-up campaign was conducted in Cuba through 2009, a total of 80 national follow-up campaigns have been performed, usually targeting children aged 1–4 years; 52 of these were conducted during 1995–2002, and 27 were conducted during 2003–2009. Among the follow-up campaigns, coverage was $\geq$95% for 48 (60%), 90%–94% for 13 (16%), 80%–89% for 14 (18%), and $<$80% for 5 (6%). For the 80 follow-up campaigns, 16 (20%) used measles vaccine, 40 (50%) used MR vaccine, and 24 (30%) used MMR vaccine.

From 1995 through 2009, there were also 39 national speed-up campaigns that delivered MR vaccine to adolescents and adults: 20 during 1995–2002 and 19 during 2003–2009. Coverage was $\geq$95% for 21 (54%), 90%–94% for 7 (18%), 80%–89% for 7 (18%), and $<$80% for 4 (10%). The 11 countries achieving $<$90% were from the English-speaking Caribbean subregion. Among the 39 national speed-up campaigns, 25 (64%) used MR vaccine, and 14 (36%) used MMR vaccine. Speed-up and follow-up campaigns conclude with rapid coverage monitoring activities as a way to guarantee the implementation of high-quality campaigns.

Bermuda and the United States did not conduct mass campaigns, because they had already achieved many years of high coverage with 2 routine doses of MMR vaccine. Several other countries have attempted to substitute MCV2 instead of follow-up campaigns. However, the PAHO TAG has advised that only in countries in which coverage of $\geq$95% with each of the 2 routine MMR vaccine doses is guaranteed for all municipalities can the follow-up campaigns be waived [14, 15].

### Surveillance

During the postelimination phase from 2003 through 2010, most regional MR surveillance indicators were greater than established targets (Figure 2). The percentage of suspected cases with adequate investigation decreased to 67% in 2007 but increased to 71% in 2010. The percentage of samples reaching the laboratory in $\leq$5 days has been consistently problematic, in the range of 55%–63% during 2004–2007; however, 83% compliance with this indicator was achieved in 2010. The indicator for classification of a minimum of 95% of nonmeasles cases based on laboratory criteria has been achieved in almost every year (Data reported until epidemiological week 42/ in 2010.)

Although an expected baseline for the incidence of suspected measles and/or rubella cases is used as an indicator of the intensity of measles and/or rubella surveillance, it has proven to be difficult to develop a population-based indicator for measles [16] in the last 3 years (regional reporting rate for suspected measles and/or rubella cases per 100,000 population during 2007–2009 was 6.4, 4.6, and 2.2, respectively).

### Measles Epidemiology in the Americas

The impact of all the vaccination activities can be viewed broadly in the number of measles cases reported during 1980–2010 (Figure 3). During the early days of the EPI (1980–1986), the regional annual mean number of reported measles cases was 204,498 (Table 2). As regional measles vaccine coverage levels increased during 1987–1994, the regional annual mean number of measles cases decreased by some 40%, to 122,534. During 1989–1991, the countries of Central America reported persistent measles outbreaks, with disease incidence peaking in 1990 at 136 measles cases per 100,000 population. After investigations linked these outbreaks to low coverage with measles vaccine, there was a renewed effort to increase routine vaccine coverage in this subregion, and catch-up campaigns were also implemented during 1992–1993 in Central America [17].

During 1995–2002, there was strong evidence of the impact of high levels of routine coverage and national vaccination campaigns, with a regional mean number of measles cases of 10,565 per year. The regional annual mean during 1995–2002 represents an 86% decrease, compared with the period 1987–1994, and 95% decrease, compared with the period 1980–1986. Regional data demonstrate another dramatic decrease during 2003–2010, when an annual mean of 155 confirmed cases was reported for the region. The regional annual mean for the period 2003–2010 represents a 99.9% decrease, compared with the period 1987–1994 or 1980–1986.

Decreases in annual measles incidence in the region demonstrate the impact of elimination strategies. Incidence was 320 cases per 1 million population during 1980–1986, 170 cases per 1 million population during 1987–1994, 13 cases per 1 million population during 1995–2002, and .2 cases per 1 million population during 2003–2010 (Table 2). In the postelimination phase, incidence remained at $<$1 case per 1 million population every year, despite large numbers of cases in an outbreak in Venezuela and in North America during 2008.

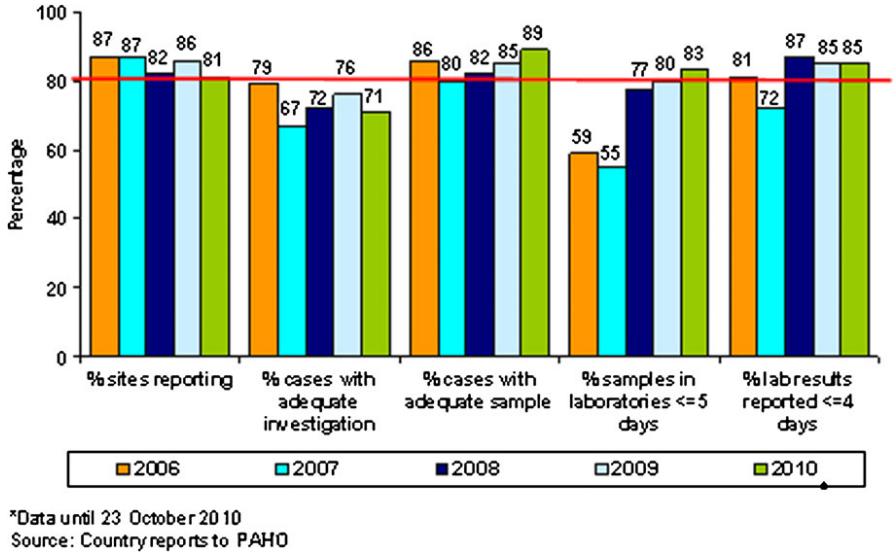


**Figure 2.** Integrated measles-rubella surveillance indicators, region of the Americas, 2006–2010. Data until 23 October 2010. Source: Country reports to PAHO.

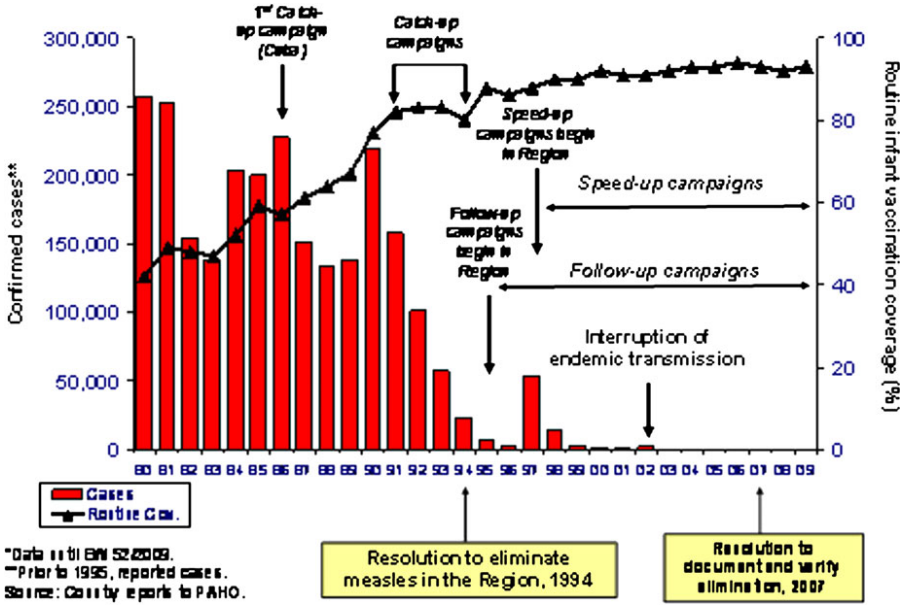


**Figure 3.** Measles elimination campaigns, the Americas, 1980–2009.

Annual reports on measles-associated deaths are available for Latin America and the Caribbean during 1990–2010. The number of measles-related deaths decreased sharply from a peak of 16,514 deaths in 1990 to 0–3 deaths per year after 1999. The last 2 deaths were reported in 2004 from Brazil; both were due to subacute sclerosing panencephalitis.

***Measles Outbreaks During the Pre-Elimination Era, 1996–2002.*** Among 45 countries and territories that provided data during 1996–2002, 22 (49%) countries and territories reported no laboratory-confirmed measles cases, whereas 7 (16%) countries and territories reported >1000 cases. Details of larger measles outbreaks during this period are summarized in Table 3.

Molecular epidemiology provides information linking epidemiologic case investigations with measles virus genotypes. Genotype D6 was considered to be endemic in the Americas, associated with 1997 outbreaks in Brazil and subsequent outbreaks in Argentina, Bolivia, Haiti, and the Dominican Republic [18]. Absence of D6 virus despite identification of genotypes from other regions supports elimination of the D6 genotype from the Americas [19]. During 2001–2002, an outbreak of a previously unknown genotype, D9, was first identified in Venezuela and, later, in Colombia. Subsequent investigations identified D9 genotype measles in Indonesia, suggesting that D9 viruses may have been imported into Venezuela from an unidentified index case [20]. Figure 4 provides a genotype map for the Americas during 2001–2009.

***Experience With Measles Importations During the Post-Elimination Era: 2003–2010.*** Since 2003, historically low numbers of measles cases have been reported in the Americas: cases reported for each year from 2003 through 2010 were 119, 108, 85, 237, 176, 207, 89, and 228, respectively. During this 8-year period, 34 (76%) of 45 countries and territories reported no measles cases, and 5 (11%) countries and territories reported <10 confirmed measles cases. A total of 1239 (99%) of 1249 confirmed measles cases were reported from 6 countries: United States ($n$ = 514), Canada ($n$ = 314), Mexico ($n$ = 137), Venezuela ($n$ = 131), Brazil ($n$ = 122), and Argentina ($n$ = 21) (Figure 5).

Of 524 confirmed measles cases reported during 2008–2010, 222 were measles importations and 302 were import-related cases. Origins of imported cases were only reported for 124 (56%) of 222 imported cases, and 35% of these were importations from the World Health Organization European Region. Large international events, namely the 2010 Winter Games in Vancouver and the 2010 FIFA World Cup in South Africa, were associated with large numbers of measles cases reported by Canada, Argentina, and Brazil in 2010.

## DISCUSSION

Eight years passed from the time Resolution CSP24.R16 was adopted, calling for measles elimination, to the declaration that endemic measles virus transmission was interrupted in the Region of the Americas. Elimination was ultimately achieved through the commitment of an entire region to reach a common goal, the subsequent and full implementation of the PAHO-recommended vaccination and surveillance strategies by the countries, and the dedication of the health care workers in the Americas.

It is estimated that the full cost of a measles mass campaign id US $0.50–0.75 per child. When using the MR vaccine, the cost per child is estimated at US $1.00–1.20. The vaccination strategy

**Table 3. The Last Large-Scale Measles Outbreaks in the Americas (1996–2002)**

| Year | Country | # of confirmed cases | Genotype/origin | Groups most affected | Comments |
|---|---|---|---|---|---|
| 1997 | Brazil | 52,284 cases | … | Infants, young adults (20–29 years), and children (1–4 years) | More than 50 deaths reported, mostly children aged <1 year |
| 1997 | Guadeloupe | 116 cases | France | … | … |
| 1998 | Argentina | 10,229 cases | Sao Paulo, Brazil | 65% of cases occurred in children aged <5 years. | … |
| 1998-2000 | Bolivia | 2,567 cases | Suspected origin from Argentina since outbreak initiated in border area | Highest incidence in children aged 6–11 months, followed by those aged 1–4 years and young adults aged 20–24 years | 4 deaths reported |
| 1999-2001 | Dominican Republic | 641 cases | … | Highest incidence among infants aged <9 months, children aged 9 months–4 years, and adults aged 20–29 years | 274 cases in 1999, 254 cases in 2000, and 113 in 2001 |
| 2000-01 | Haiti | 1,149 cases | Probably due to importation from the Dominican Republic | Most measles cases occurred among unvaccinated children <5 years. | 990 cases in 2000 and 159 cases in 2001 |
| 2000 | Canada | 165 cases | … | Mainly affected members of groups opposing vaccination for philosophical reasons and/or religious reasons | … |
| 2001-02 | Venezuela | 2,507 cases | … | Age group most affected was children aged <1 year, followed by children aged 1–4 years, and young adults aged 20–29 years | 115 cases in 2001 and 2392 cases in 2002; spread to 16 of the country's 24 states |
| 2002 | Colombia | 139 cases | Venezuela | Age group most affected was children aged <15 years. | … |

toward achieving measles elimination in Latin American and Caribbean countries cost an estimated US$ 244 million over the entire period, incremental to the cost of vaccination before the elimination program. From 2000 through 2020, the current program will have prevented the occurrence of 3.2 million cases of measles and 16,000 deaths. Thus, the vaccination strategy prevents a single case of measles at the cost of US$71.75 and prevents a death due to measles at the cost of US$15,000 [21]. The case-fatality rate depends on a well-functioning treatment program for measles cases. The vaccination strategy saves a total of US$208 million in treatments costs resulting from reduced incidence of measles.

Several factors created the environment necessary for a measles elimination goal. Political commitment at all levels was cultivated, and proactive support was provided for the elimination initiative. The countries of the region prepared plans of action that outlined resource allocation and human resource support. Designs of effective campaigns were clearly defined, and most of the countries that had conducted mass vaccination campaigns had also established surveillance systems with laboratory support. Finally, several national and multinational initiatives to eliminate measles were underway that were having a major impact on the incidence of the disease.

Measles elimination was achieved and maintained by the countries of the Americas by building on lessons learned from >30 years of experience in implementing disease elimination strategies. These included: (1) monitoring coverage at the district or municipal level, (2) building consensus among various stakeholders, (3) resource mobilization, (4) alliances with scientific associations, (5) relationships with the private sector, (6) social mobilization around the regional elimination goal, (7) effective communication strategies, (8) integrated measles and rubella surveillance, and (9) mass vaccination with combined MR vaccines. To build consensus, PAHO provided evidence of the technical feasibility of elimination. Alliances with scientific associations created advocacy for measles elimination goals and provided positive media exposure for partner organizations. PAHO encouraged private sector involvement to improve completion of immunization schedules and detection of suspected cases by surveillance systems. PAHO successfully engaged ministries of health and local health care workers in social mobilization around the elimination goal. Local participation in communication strategies for immunization campaigns fostered a sense of ownership. When countries achieved elimination, there was a collective feeling of success.

Several challenges for reaching elimination were confronted by the countries of the Americas. Campaigns, although effective, are complex. Adequate organization and close supervision are required to ensure that groups of the target population are not missed, in which virus transmission could be maintained. The purpose of PAHO's recommendation for countries to conduct high-quality follow-up campaigns was to prevent the

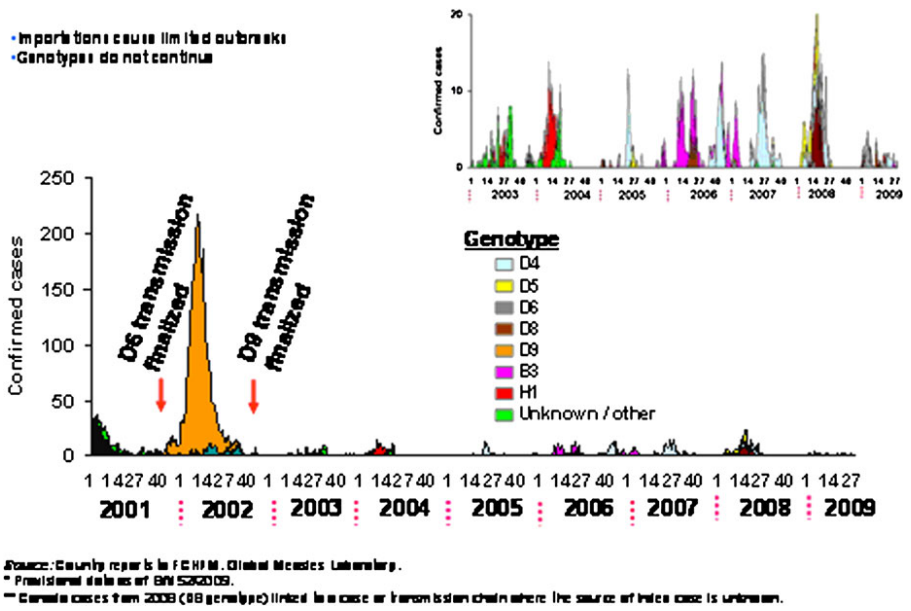


**Figure 4.** Measles genotypes identified from case investigations in the Americas, 2001–2009.

accumulation of susceptible cohorts. In the last countries to successfully interrupt endemic measles virus transmission, measles outbreaks demonstrated the dangers of failing to maintain high routine vaccination coverage. Finally, successful catch-up campaigns can rapidly decrease viral transmission but may lead to a shift of susceptibility to older age groups.

Outbreaks are just one of the many challenges confronted during the postelimination era and are reminders that, until global measles eradication is achieved, countries in the Americas are at risk of importations of measles virus. Countries must therefore maintain high-quality elimination strategies, strengthen sensitive surveillance to rapidly detect and respond to importations and isolated cases, improve coordination with the private sector, and strengthen coordination with dengue surveillance. Ongoing surveillance challenges include the need to obtain appropriate specimens from case patients and contacts and to rapidly transport these to the laboratory. When the incidence of disease has been dramatically reduced, sporadic cases pose a diagnostic challenge because of the potential for false-positive or false-negative laboratory results. With virus elimination as a target, laboratories must establish proper virus containment procedures.

The decision by the countries of the Americas to eliminate rubella and CRS served as a catalyst to strengthen measles elimination efforts. Mass vaccination of adults and adolescents with combined MR vaccines for rubella elimination boosted

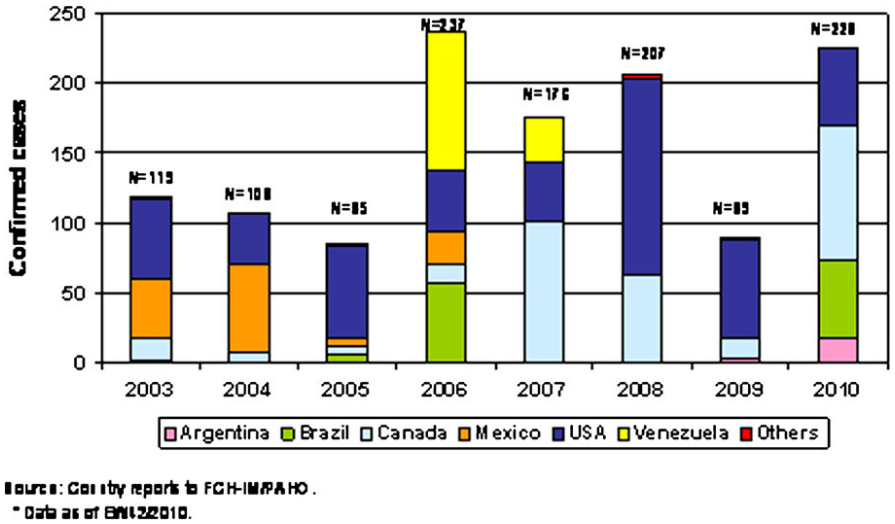


**Figure 5.** Distribution of confirmed measles cases following the interruption of endemic transmission, the Americas, 2003–2010.

measles immunity in the population to prevent the reestablishment of endemic measles virus transmission. In addition, rubella elimination has encouraged countries to switch from single antigen measles vaccine to routine vaccination of infants with MMR vaccine and to maintain very high coverage levels. Integrating measles and rubella surveillance capitalized on existing surveillance infrastructure to improve case detection and classification without increasing costs. Network laboratories conduct measles and rubella serologic examination on all serum samples from suspected case patients. Urine or pharyngeal specimens collected from suspected case patients provide a specimen bank for virus identification and sequencing. Finally, introducing rubella elimination and its integration with measles elimination led to renewed enthusiasm of health care workers at all levels and greater support from PAHO strategic partners.

The achievement of measles elimination in the Region of the Americas effectively harnessed the trust of the population in immunization and lead to sustained demand for vaccination services for the child and family. The success of the initiative also exerted a pull effect, which has catalyzed the addition of new vaccines into routine programs and has strengthened primary health care in the Americas by basing strategies on the principal of equity and striving to deliver vaccination services to all communities, including high-risk areas where vulnerable populations are found.

Considering that a safe and affordable vaccine is available, along with the knowledge and experience on how to use it to achieve elimination, it is imperative that determined measles eradication efforts are made.

## Funding

Funds for the measles and rubella elimination initiatives were provided by the ministries of health of the countries of the Americas, strategic partners, and the Pan American Health Organization.

## References

1. Olive JM, de Quadros C, Castillo-Solorzano C. Sarampión en las Américas: revisión de las situación ce los últimos 30 años. Document EPI/TAG8/90-0. In: VIII Reunión del Grupo Técnico Asesor de P.A.I., México, 19–22 Marzo **1990**.
2. Borgoño JM. Current impact of measles in Latin America. Rev Infect Dis **1983**; 5:417–421.
3. Galindo MA, Santin M, Resik S, et al. La eliminación del sarampión en Cuba. Rev Panam Salud Publica **1998**; 4:171–177.
4. Irons B, Smith HC, Carrasco PA, de Quadros CA. The immunisation programme in the Caribbean. Caribb Health **1999**; 2:9–11.
5. Irons B, Carrasco P, Morris-Glasgow V, Castillo-Solorzano C, de Quadros CA. Integrating measles and rubella surveillance: the experience in the Caribbean. J Infect Dis **2003**; 187(Suppl. 1):S153–S157.
6. Pan American Health Organization. Health conditions in the Americas, 1994 ed. Vol 1. Scientific Publication No. 549. Washington, DC: PAHO, **1994**.
7. Venczel L, Rota J, Dietz V, et al. The Measles Laboratory Network in the region of the Americas. J Infect Dis **2003**; 187(Suppl. 1): S140–S145.
8. Fifth WHO Global Measles and Rubella Laboratory Network Meeting, 26-28 September 2007, WHO, Geneva. Final summary and recommendations. Geneva, Switzerland: World Health Organization, **2007**.
9. Progress towards eliminating rubella and congenital rubella syndrome in the western hemisphere, 2003-2008. Wkly Epidemiol Rec **2008**; 83:395–400.
10. Pan American Health Organization. Immunization in the Americas: 2009 summary. Washington, DC: PAHO, **2009**.
11. Pan American Health Organization. Report of the XII Meeting of the PAHO Technical Advisory Group on Vaccine-preventable Diseases, XII Meeting, Guatemala, 8–12 September 1997. Washington, DC: PAHO, **1997**.
12. Pan American Health Organization. Immunization in the Americas: 2008 summary. Washington, DC: PAHO, **2008**.
13. Castillo-Solorzano C, Ruiz-Matus C eds: Compendium of measles articles. Washington, DC: Pan American Health Organization, **2009**; 59– pp.
14. Pan American Health Organization. Final Report of the XVII Meeting of the Technical Advisory Group on Vaccine-preventable Diseases, Guatemala City, Guatemala, 25-27 July **2006**.
15. Pan American Health Organization. Final Report of the XVIII Meeting of the Technical Advisory Group on Vaccine-preventable Diseases, San Jose, Costa Rica, 24–26 August **2009**.
16. Izurieta H, Venczel L, Dietz V, et al. Monitoring measles eradication in the Region of the Americas: critical tools and activities. J Infect Dis **2003**; 187(Suppl. 1):S133–S139.
17. Castillo-Solorzano C, Ruiz-Matus C eds: Compendium of measles articles. Washington, DC: Pan American Health Organization, **2009**. p 40,42,56.
18. Rota PA, Featherstone DA, Bellini WJ. Molecular epidemiology of measles virus. Chapter 7. In Griffin DE, Oldstone MBA eds: Measles—pathogenesis and control. Berlin, Germany: Springer-Verlag, **2009**.
19. Hersh BS, Tambini G, Nogueira AC, Carrasco P, de Quadros CA. Review of regional measles surveillance data in the Americas, 1996–99. Lancet **2000**; 355:1943–1948.
20. Anon. Absence of transmission of the D9 measles virus—region of the Americas, November 2002–March 2003. MMWR Morb Mortal Wkly Rep 52:228–229.
21. Acharya A, Diaz-Ortega JL, Tambini G, de Quadros C, Arita I. Cost-effectiveness of measles elimination in Latin America and the Caribbean: a prospective analysis. Vaccine **2002**; 20:3332–3341.