Poliomyelitis Eradication in China: 1953–2012

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**Background.** Poliomyelitis has historically been endemic in China and has been considered an important cause of disability and death.

**Methods.** We reviewed strategies and measures of poliomyelitis control and eradication from 1953 to 2012. Data from notifiable disease and routine immunization reporting systems and acute flaccid paralysis (AFP) surveillance were analyzed.

**Results.** About 20,000 poliomyelitis cases were reported annually in the prevaccine era. During 1965–1977, live, attenuated oral poliomyelitis vaccine (OPV) was administered to children through annual mass campaigns in the winter, and the number of poliomyelitis cases started to decline. A cold chain system was established during 1982, and OPV coverage increased during the early stage of the Expanded Programme on Immunization, from 1978 to 1988. Between 1989 and 1999, routine immunization was strengthened, supplementary immunization activities (SIAs) were conducted, and the AFP surveillance system was established. China reported a last indigenous poliomyelitis case in 1994 and was certified as free of polio in 2000. To maintain its polio-free status, China kept >90% coverage of 3 doses of OPV, conducted SIAs in high-risk areas, and maintained high-quality of AFP surveillance. China succeeded in stopping the outbreak in Xinjiang in 2011.

**Conclusions.** China’s polio-free status was achieved and maintained through strengthening routine immunization and implementing SIAs and AFP surveillance.

**Keywords.** poliomyelitis; eradication; China.

When the World Health Assembly established the Global Polio Eradication Initiative in 1988, approximately 350,000 cases of paralytic poliomyelitis were reported per year in >125 polio-endemic countries and regions [1, 2]. Through an increase in Expanded Program on Immunization (EPI) vaccine coverage, national mass vaccination campaigns, and intensification of surveillance on acute flaccid paralysis (AFP), 3 regions of the World Health Organization (WHO) achieved polio-free status [3]. In 2012, only 223 poliomyelitis cases were reported, a 99.9% decline compared with before 1988, and India was removed from the list of countries with active, endemic wild poliovirus transmission, as India’s last poliomyelitis case occurred on 13 January 2011. Afghanistan, Nigeria, and Pakistan have yet to stop wild poliovirus (WPV) transmission [4].

China has the largest population in the world (1.347 million individuals in 2011) [5]. Poliomyelitis has historically been endemic in China and considered an important cause of severe disability and mortality. After the introduction of live, attenuated oral poliomyelitis vaccine (OPV) and implementation of EPI, the number of poliomyelitis cases declined dramatically. The last indigenous case of WPV infection in China was reported in 1994. In October 2000, China, along with all other countries in the Western Pacific Region of WHO, was certified to be free of polio. However, in 2011, an outbreak of imported type 1 WPV was detected in Xinjiang Uygur Autonomous Region (Xinjiang) in China. This article describes the history of endemic poliomyelitis cases; the strategies, measures, and experience of poliomyelitis eradication; and the challenges and difficulties maintaining polio-free status in China.
MATERIALS AND METHODS

Data Source of Poliomyelitis Cases in China
China’s National Notifiable Disease Reporting System was established in 1953. Numbers of poliomyelitis cases were reported from township or county hospitals to the Ministry of Health through the postal system. A real-time, web-based disease surveillance system to monitor notifiable diseases was developed by the Chinese Center for Disease Control and Prevention (CCDC) in 2004. When infectious disease cases were detected in hospitals, they could be reported to the Central Data Bank in the CCDC through a virtual private network or the Internet.

Routine Immunization Coverage Reporting System
Routine immunization coverage has been reported since the early 1980s. Township hospitals collected data on vaccination with EPI vaccines and summarized coverage rates to county, prefecture, provincial, and national centers for disease control. In 1999, the reporting system for routine immunization coverage was established. In 2005, a web-based EPI surveillance information management system was established.

AFP Surveillance
AFP cases are defined as acute flaccid paralysis, for patients <15 years of age, and as suspected poliomyelitis, for patients of any age. AFP cases must be reported by hospitals to county centers for disease control within 2 days after cases are identified. County-level centers for disease control staff are responsible for case investigation, stool specimen collection and shipment, and follow-up. Investigation forms are sent to prefectural and provincial centers for disease control for data entry, analysis, and feedback. Until 2012, each province sent an electronic database monthly to the CCDC for aggregation and analysis.

Beginning in 2012, China established a real-time AFP surveillance system based on the Chinese Information System for Disease Control and Prevention platform. All information on reported cases is transferred to the national server system in a timely manner. The CCDC and provincial centers for disease control can immediately obtain details of all cases for the first time with this system.

RESULTS

Poliomyelitis Control During the Prevaccine Era in China (1953–1964)
Poliomyelitis has historically been endemic in China and has been considered an important cause of severe disability and death. The disease has been reportable ever since the National Notifiable Disease Reporting System was established in 1953. In the early 1960s, before widespread use of OPV, about 20,000 poliomyelitis cases were reported annually; 43,156 cases were reported in 1964, the peak year of cases (Figure 1).

Introduction of OPV in China (1965–1977)
In 1960, a task force at the National Vaccine and Serum Institute developed a prototype vaccine that was tested on 4 million children in 12 cities. Seroconversion was >80%, and the vaccine was determined to be efficacious and safe. From 1960 onward, the vaccine was administered in liquid form, and in 1964, a solid sucrose-lactose based dragee was developed. Nationwide use of OPV began in 1965, and OPV was administered to eligible children through annual mass campaigns during winter. The number of poliomyelitis cases started to decline; 4500–29,000 cases were reported annually during this period.

Early Stage of EPI (1978–1988)
Since 1978, OPV has been one of 4 routine vaccines (BCG vaccine, OPV, diphtheria–pertussis–tetanus vaccine, and measles vaccine) given to all children in China. The routine vaccination schedule in China included doses of trivalent OPV at 2 months, 3 months, 4 months, and 4 years of age. Cold chain systems were established in southern China in 1982 and covered the whole country at the end of 1980s. By 1982, expansion of the cold chain enabled immunization sessions to be conducted monthly or every 2 months instead of once or twice in the winter.

China achieved childhood immunization goals of >85% coverage with the above 4 vaccines at the provincial level in 1988. The immunization coverage of OPV increased continuously and then reached >90% in 1988, as shown in Figure 1.

With the implementation of EPI, the reported number of poliomyelitis cases decreased dramatically. The number of poliomyelitis cases reported during 1979–1988 was 71% less than that reported pre-EPI era.

In 1988, global polio eradication was initiated. Leaders of the Chinese government made a political commitment to polio eradication in China in 1989. China reached childhood immunization goals of >85% coverage with the above 4 vaccines at county and township levels in 1990 and 1995, respectively.

In 1988, with increasing coverage, the number of reported cases declined to 667, the lowest number reported up to that time. To stop the transmission of WPV, provinces began conducting supplementary immunization with OPV to further raise levels of population immunity above the basis provided by high routine immunization coverage. In 1990, 6 provinces conducted supplementary immunization activities (SIAs). SIAs were conducted by 18 provinces in 1991 and by 29 provinces in 1992. These activities were coordinated by the provinces, which decided the age group, target areas, and timing of the activities.

National immunization days (NIDs) were conducted on 5–6 December and 5–6 January during 1993–1995, with highly publicized participation by government leaders. About 70 million children younger than 4 years were immunized during each round. The NIDs were highly successfully in interrupting
transmission of WPV; the last laboratory-confirmed case of indigenous poliomyelitis was identified in September 1994. During 1996–1999, sub-NIDs were conducted in China, with 40 million vaccinations in each round. Approximately 800 million doses of OPV have been administered to children <4 years of age during 14 rounds of NIDs or sub-NIDs (Figure 2).

In 1991, a poliomyelitis-specific surveillance system based on identification and investigation of AFP cases was established in China. By 1993, all provinces except the Tibet Autonomous Region were implementing standardized national surveillance guidelines, including active surveillance, case investigation, and collection and culture of stool specimens. AFP surveillance in Tibet began in 1998. The number of reported AFP cases increased from 2488 in 1992 to 5079 in 1999. Performance indicators improved significantly over the years and met the WHO requirements from 1997 onward.

In 1992, a poliomyelitis laboratory network was established consisting of a National Poliomyelitis Laboratory (NPL) at the Chinese Academy of Preventive Medicine (later, the CCDC) and laboratories in 31 provinces. In 1995, the NPL was designated as a WHO regional reference laboratory. The NPL and all provincial laboratories were accredited.

Between November 1995 and April 1996, 4 cases of imported poliomyelitis were detected and reported by the Dehong
In October 2000, China, with all other countries in the Western Pacific Region of WHO, was certified as free of polio. Since then, China has been adopting strategies and measures to maintain its polio-free status, which includes strengthening routine immunization and conducting SIAs in high-risk areas and among children, maintaining high-quality AFP surveillance, responding to circulation of vaccine-derived poliovirus (VDPV) and imported WPV, and laboratory containment of WPV infectious or potentially infectious materials.

In 2002 the National Immunization Program was established in the CCDC. In 2007, EPI service increased to 11 vaccines (BCG vaccine, hepatitis B vaccine, OPV, diphtheria–tetanus–acellular pertussis vaccine, diphtheria–tetanus vaccine, measles–rubella vaccine, measles–rubella–mumps vaccine, live Japanese encephalitis virus vaccine, group A meningococcal vaccine, group A + C meningococcal vaccine, and hepatitis A vaccine). During this period, the reported coverage of OPV remained >95%. Risk assessment was conducted at the province level to determine high-risk areas and target children. Two rounds of SIAs were implemented for children <4 years old, and about 30 million doses of OPV were administered to the target children every year.

Every province has continuously maintained high-quality AFP surveillance. The reported incidence rates of nonpoliovirus AFP cases has remained >1/100,000 persons <15 years of age, reaching 2.5/100,000 persons <15 years of age in 2011 and 2012 (Figure 3). Except for the requirement of sending virus isolates from provincial centers for disease control to the CCDC ≤14 days of the positive test result, other indicators of the timeliness of AFP surveillance have continuously met the requirements of WHO. All indicator requirements have been met since 2010 (Table 1).

During May–July 2004, type 1 VDPV was isolated from 2 AFP cases and 4 contacts individual in Guizhou Province. Isolates differed from the Sabin type 1 by 9–11 VPI nucleotides (1.0%–1.2%). A coverage survey conducted among 619 children of the affected areas and found that coverage with ≥3 doses of OPV ranged from 24% to 67%. A province-wide immunization response targeting all children <5 years old was initiated in August, with 8 million doses of OPV given, and the strain has not been isolated since.

Type 2 VDPVs (which differed from one another by 6–12 nucleotides) were isolated from 4 AFP cases and 1 contact between 20 August 2011 and 8 February 2012 in Aba County, Sichuan Province. The estimated coverage rates of OPV3 were about 70% in the affected areas. Rigorous control measures were taken in Sichuan Province to interrupt circulation of VDPVs. Local health departments strengthened AFP surveillance, including zero-case weekly reports, and routine surveillance in the public and private hospitals at the county level. Three rounds of SIAs were conducted during March–May 2012, and 6.5 million doses OPV were given to children <15 years old in the affected and neighboring prefectures.

Between 3 July and 9 October 2011, 21 WPV1 cases were confirmed in southern Xinjiang, with 13 in Hotan, 6 in Kashgar, 1 in Bazhou, and 1 in Akesu. Ten cases were <15 years old in the affected and neighboring prefectures.

In October 2000, China, with all other countries in the Western Pacific Region of WHO, was certified as free of polio. Since

Figure 3. Incidence of reported cases of nonpoliovirus acute flaccid paralysis during 1992–2012 in China.
of age, and age range of the remaining 11 cases was 15–53 years. WPV1 was also isolated from 14 contacts of AFP cases and 13 healthy persons in Hotan, Kashgar, Bazhou, and Akesu. Three WPV1 strains were isolated in Beijing among healthy students from Hotan. Two WPV1-positive environmental samples were found in Hotan Prefecture. Sequence analysis showed that this outbreak was caused by an imported WPV strain originating from Pakistan.

A level 2 public health emergency was declared in Xinjiang after outbreak confirmation on 25 August 2011, and the Ministry of Health called an emergency meeting to launch the response, coordinating and mobilizing all government and civil society resources. On August 26, WHO was informed about the Xinjiang poliomyelitis outbreak, and a request for assistance in determining the origin of the poliovirus was made. AFP surveillance was enhanced with zero-daily reporting from all public and private hospitals at the township level and above from August 28. At the same time, staff at all levels received training in AFP surveillance and SIA implementation. The first vaccination campaign was launched in Hotan and other prefectures of Xinjiang by 8 September. In total, 5 rounds of SIAs were conducted among the target population 0–39 years old in southern Xinjiang and among the target children 0–15 years old, with 43 million doses of OPV given. Three rounds used trivalent OPV, and 2 rounds used monovalent OPV type 1 vaccine. Surveys following the SIAs showed >95% coverage. A serosurvey following the vaccination campaign showed 98% seropositivity.

The circulation of imported WPV in Xinjiang was interrupted within 1.5 months of laboratory confirmation, and China was subsequently certified by WHO as remaining free of polio. China’s comprehensive response succeeded in stopping the outbreak in record time and was said by the Regional Commission for the Certification of Polio Eradication to be a model of polio emergency response for the world.

The Ministry of Health implemented registration and inventory of WPVs in biomedical laboratories nationwide beginning in 2005. A total of 50 350 laboratories were surveyed in 2006, and only a very small number (28) still contain WPV/potentially infectious materials in the Ministry of Health system. China completed phase 1 (survey and inventory of WPV/potentially infectious materials) at the end of 2007. In 2012, the national inventory of WPV/potentially infectious materials was updated. Strategies for dealing with WPV materials held under locked storage in the provincial laboratories of the polio laboratory network were developed. WPV materials will be transferred to CCDC before 2015 for further containment. Other WPV materials will be destroyed with documentation by the laboratories where they are stored.

### DISCUSSION

Poliomyelitis cases declined dramatically in China after introduction of poliomyelitis vaccines and implementation of the EPI, SIAs, and AFP surveillance. China was certified in 2000 as free of polio. Through maintaining high coverage of OPV, maintaining a high quality of AFP surveillance, and conducting SIAs, China maintained its polio-free status for over a decade. However, there was a poliomyelitis outbreak caused by imported WPV from Pakistan in Xinjiang in 2011. After intensified AFP surveillance and 5 rounds of SIAs, WPV transmission was interrupted in record time.

Routine immunization activities have been very important measures for eradicating poliomyelitis and maintaining polio-free status. SIAs have been used to increase coverage of OPV within a short time to interrupt the circulation of WPV. A high level of routine immunization and many rounds SIAs raised the level of population immunity necessary to interrupt the transmission of indigenous WPV. After 2000, China continued to strengthened routine immunization and conducted SIAs to remain free of polio. AFP surveillance has been used to detect imported WPV and VDPV cases so that emergency response measures can be taken to stop poliovirus transmission. Emergency responses have been essential measures for interrupting the circulation of imported WPV or VDPV during China’s polio-free period. Essential elements required for successful

### Table 1. Main Indicators of Acute Flaccid Paralysis (AFP) Surveillance During 2000–2012 in China

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<tr>
<td>Investigation within 48 h of notification</td>
<td>97%</td>
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<td>98%</td>
<td>98%</td>
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<td>98.7%</td>
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<td>Adequate stool specimen obtained</td>
<td>89%</td>
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<td>88%</td>
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<td>90.9%</td>
<td>91.5%</td>
<td>92.6%</td>
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<tr>
<td>Stool specimens sent by county CDC within 7 d</td>
<td>92%</td>
<td>92%</td>
<td>96%</td>
<td>97%</td>
<td>96%</td>
<td>96%</td>
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<td>97.2%</td>
<td>97.8%</td>
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<tr>
<td>Follow-up after 60 d</td>
<td>89%</td>
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<td>92%</td>
<td>92.6%</td>
<td>94.3%</td>
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<td>Laboratory results within 28 d</td>
<td>92%</td>
<td>92%</td>
<td>94%</td>
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<td>96%</td>
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<td>96%</td>
<td>95.5%</td>
<td>96.9%</td>
<td>97.2%</td>
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<tr>
<td>Positive specimens sent by provincial CDC within 14 d</td>
<td>91%</td>
<td>91%</td>
<td>84%</td>
<td>71%</td>
<td>91%</td>
<td>92%</td>
<td>45%</td>
<td>77%</td>
<td>35%</td>
<td>78%</td>
<td>92.3%</td>
<td>91.3%</td>
<td>92.9%</td>
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Data are % of AFP cases.

Abbreviation: CDC, centers for disease control.
implementation of these activities included provision of high-level political commitment; clarification of organizational responsibilities; development and implementation of a national action plan and guideline for polio eradication; social mobilization to ensure high levels of support for polio eradication activities; training to improve technical capacity of health staff; strengthening supervision and increasing of health staff; strengthening supervision and increasing technical and financial support in weak areas; provision of sufficient funds, equipment, and staff; and fully collaborating with international organizations participating in the polio eradication initiative.

Remarkable progress in poliomyelitis eradication has been made in China since 1989. However, China still faces many difficulties and challenges to remain free of polio. Many previously polio-free countries have experienced outbreaks following WPV importation [6–9]. Until WPV transmission is interrupted globally, the risk of WPV importation will exist in all countries currently free of poliomyelitis. During 2002–2009, 39 previously polio-free countries experienced outbreaks following importation of WPV from poliomyelitis-endemic countries [10–12]. Three genetically distinct WPVs from India were exported to Angola during 2005–2008, which resulted in outbreaks of paralytic poliomyelitis, reestablished WPV transmission, and the subsequent reintroduction of WPV to other countries [13]. In 2010, the importation of WPV into the WHO European Region resulted in 458 confirmed cases in Tajikistan and an additional 18 cases in elsewhere in the region [7]. Pakistan and Afghanistan border China, and Nigeria has increasing contacts with China. Therefore, the risk of importing WPV to China remains high, with the poliomyelitis outbreak in Xinjiang in 2011 serving as an example of imported WPV. However, immunization levels are lower in some border areas in China. OPV coverage is estimated to be <80% in some areas, raising concerns that local transmission could return following WPV importations.

VDPVs can result from the continued reintroduction into the human population of the attenuated polioviruses contained in the oral poliomyelitis vaccine. Since circulation of VDPV in Haiti in 2000, VDPV outbreaks have occurred in 19 OPV-using countries, and 648 cases were reported through 2012 [14, 15]. There was an outbreak of poliomyelitis caused by type 1 VDPV in Guizhou Province in 2004 [16]. The severe adverse event following immunization of OPV is vaccine-associated paralytic poliomyelitis (VAPP). WHO estimated that 250–500 VAPP cases might have occurred annually in OPV–using countries during 2002–2003 [17]. OPV has played critical roles in poliomyelitis eradication and polio-free maintenance in China. The risks of occurrence of VDPV and VAPP cases exist with OPV use, which hinders polio-free maintenance in China.

All wild, vaccine-related, and Sabin polioviruses must be eradicated and contained, such that no child ever again has paralytic poliomyelitis. Because of the long-term risks of VAPP and VDPVs, the use of specific OPV serotypes will be phased out globally from all routine immunization programs in a synchronized manner. All countries are recommended to introduce at least 1 dose of IPV into their routine immunization programs at least 6 months before cessation of type 2 OPV delivery. After certification of WPV and VDPV interruption, OPV use will ultimately stop. However, there are challenges and difficulties for switching from OPV to IPV in China. First, there are currently no local IPVs or bivalent (1 + III) OPVs produced in China in 2013; however, licensure of a Sabin IPV and bivalent OPV are anticipated before 2015. Second, the number of newborns in China is 16 million annually, and the stock of local IPV products may not be large enough to meet the requirement of at least 1 dose of IPV per child. Third, high-price vaccine leads to low accessibility and affordability of IPV. The IPV cost is 100-fold higher than the OPV cost. Fourth, IPV introduction requires adjustment of the immunization schedule and vaccination standard, requiring substantial training for health staff at all levels.

To maintain its polio-free status until poliomyelitis eradication, China should take the following strategies and measures. First, the country should check for limitations in the routine immunization program and strengthen it in remote areas and hard-to-reach populations. The coverage rate for 3 doses of OPV/IPV should be maintained at >90%. Second, China should conduct a risk assessment and then implement SIA in high-risk areas and among susceptible children. Third, China should introduce at least 1 dose of IPV and bivalent OPV during routine immunization and synchronize OPV cessation with global cessation of OPV use after certification of WPV interruption. Fourth, the country should maintain a high quality of AFP surveillance and conduct rigorous response to imported WPV and circulating VDPV. The WPV-specific preparedness plan should be improved to effectively prevent WPV importation and transmission. Serologic surveillance of immunization levels and environmental poliovirus surveillance should be conducted in weak and border areas. Fifth, China should contain WPV and VDPV infectious or potentially infectious materials.

Notes

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