MAJOR ARTICLE

# Poliomyelitis-Related Case-Fatality Ratio in India, 2002–2006

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***Background.*** On the basis of studies from developed countries, the case-fatality ratio (CFR) of poliomyelitis generally ranges from 2%–5% among children <5 years of age to 10%–30% among adults. However, little information is available for poliomyelitis-related CFR in developing countries. We conducted a study to determine the CFR in India, 1 of the 4 remaining countries with endemic wild poliovirus (WPV) circulation, during outbreaks of WPV infection during 2002 and 2006 and during the inter-epidemic years of 2003–2005.

***Methods.*** We conducted a descriptive analysis with use of data from the acute flaccid paralysis surveillance system in India. Variables analyzed included age, caregiver-reported vaccination status, date of paralysis onset, laboratory results, final case classification, and survival outcome. Our analysis also accounted for surveillance changes that occurred in 2005, impacting case definitions and final classification.

***Results.*** In 2006, 45 deaths occurred among 676 WPV cases in India, yielding a CFR of 6.7%. By comparison, in 2002, there were 66 deaths among 1600 reported WPV cases (CFR, 4.2%) and during 2002–2005, CFR was 1.5%–5.2%. All 45 deaths were among 644 (95%) WPV cases in children aged <5 years (CFR, 7.0%). Among those who died, 33 (73%) were children aged <2 years (CFR, 7.1%).

***Conclusions.*** The CFR among children aged <2 years in India is high compared with previously published CFRs for young children, in part because of improved case finding through enhanced surveillance techniques. Fatal cases emphasize the lethal nature of the disease and the importance of achieving polio eradication in India.

Paralytic poliomyelitis occurs in <1% of all poliovirus infections [1], and clinical presentation varies depending on the location of motor neuron damage. Previous studies conducted in the United States during polio epidemics before the introduction of oral polio vaccine (OPV) in 1961 indicate that the case-fatality ratio (CFR) for paralytic poliomyelitis is generally 2%–5% among children <5 years of age and increases with age to 10%–30% among adults, with most deaths secondary to complications from rapidly progressive bulbar paralysis [2, 3, 17]. An increased risk of poliovirus infection exists in India, 1 of the 4 remaining countries with endemic wild poliovirus (WPV) circulation, likely because of poor hygiene and more concentrated exposure to poliovirus [4–6]. Although CFRs from developed countries outside the United States have been documented during the 1990s based on outbreaks in adults [7], little literature is available that documents the CFR in India and other developing countries where WPV transmission continues to occur. Two studies from India during the 1990s, before intensified surveillance for poliomyelitis was initiated, estimated CFRs of 2%–3.3% [8, 9].

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India is now in the final stages of polio eradication, where highly sensitive acute flaccid paralysis (AFP) surveillance is required for rapid detection of WPV. Active surveillance began during October 1997, and since 2005, the rate of nonpolio AFP has been >5 cases/100,000 children aged <15 years, exceeding the recommended minimum AFP detection rate for countries of endemicity of >2 cases/100,000 children aged <15 years [10, 11]. Since AFP surveillance was established in India, large polio outbreaks have been documented during both 2002 and 2006. We conducted this study to determine the CFR in India during WPV outbreaks in 2002 and 2006 and during the 2002–2005 interepidemic years.

## METHODS

We conducted a descriptive analysis with use of data from the period 2002–2006 from the AFP surveillance system maintained by the National Polio Surveillance Project in India [12]. A case of AFP was defined as acute flaccid paralysis in a child aged <15 years or any paralytic illness in a person of any age when polio is suspected. The AFP surveillance database consists of data from the case investigation form, laboratory results of each case, clinical results at 60-day follow-up, and the final classification of all AFP cases based on the World Health Organization (WHO) virologic classification scheme [13, 14]. Individual case investigation forms detailing clinical presentation of the cases were also available for fatal WPV cases occurring in 2006.

Eight WHO-accredited national laboratories in India conduct virologic testing of stool specimens [11]. Two stool specimens from each person with AFP are collected within 14 days of paralysis onset and sent to the laboratory for poliovirus isolation and intratypic differentiation of isolates as wild or vaccine-related virus. Cases from which WPV was isolated in at least 1 stool specimen are considered to be virologically confirmed paralytic poliomyelitis cases. Cases without any stool sample or with inadequate samples in persons who have residual paralysis after 60 days of onset are referred to an expert panel and classified as either nonpolio AFP or as polio-compatible cases [14, 15]. Poliovirus isolates were further characterized by sequencing the VP1 protein coding region of the genome with use of standard methods, as described elsewhere [16]. Construction of dendograms showing genetic sequence relatedness among the WPV isolates was conducted at the Enterovirus Research Centre of the Indian Council of Medical Research in Mumbai.

Changes occurred in the AFP surveillance system during the period covered by our analysis. During 2002–2004, stool samples were collected from close contacts (siblings, persons in the same household, or neighbors) of persons with AFP from whom adequate samples could not be obtained [14]. However, even if WPV was isolated from contact stool samples, the index case was not classified as a WPV case. Thus, persons with AFP who died before specimen collection were considered to have compatible cases and were not included in the official WPV case count for that year. In 2005, the case definition guidelines were changed such that the index AFP case was considered a WPV case if WPV was isolated from any stool samples of any of the case contacts [14]. In addition, in 2005, in the Moradabad district of Uttar Pradesh (UP) state, a surveillance medical officer was assigned specifically for AFP surveillance activities, in contrast to all other districts in India, where the surveillance medical officers had other responsibilities, such as monitoring and training for immunization activities.

Variables in the AFP surveillance database analyzed included age, religion, caregiver-reported vaccination status, including date of last OPV dose, date of paralysis onset, laboratory results, final case classification, and survival at 60-day follow-up. For the purposes of our analysis, case patients were assigned underserved status if they belonged to a population with low socioeconomic status, marginalized status, high population mobility, or poor sanitation [11]. In addition, a field investigation was conducted in Moradabad district in UP state to obtain supplemental information on clinical presentation and date of primary contact with a health care provider for all WPV cases and persons who died during the 2006 outbreak.

To account for varying risk of WPV infection, CFRs were calculated separately for India, UP state, and Moradabad district and were stratified by age group. To account for the change in case definition guidelines beginning in 2005, CFRs were calculated for 3 different polio case categories: restricted cases (WPV isolated from stool samples collected from patients with AFP), restricted cases for which the isolated WPV was type 1 (WPV1), because there were no fatalities among patient with type 3 (WPV3) cases in 2006, and the total number of cases (restricted cases plus AFP cases in which WPV was isolated from a contact stool specimen). Rates for each category were compared with the total CFR for the year, regardless of surveillance changes. Comprehensive descriptive analyses were also conducted on data from the 2 previous major outbreaks during 2002 and 2006. Data were analyzed using EpiInfo, version 3.4.1 (Centers for Disease Control and Prevention [CDC]); 95% confidence intervals were calculated using the EpiTable program in EpiInfo, version 6.04 (CDC).

## RESULTS

### India Overall

During the 2002 outbreak in India, clinical follow-up data were available for 1584 of 1600 total WPV cases, and the CFR was 4.1% overall (66 of 1600), 3.9% (58 of 1484) among WPV1 cases, and 7.1% (8 of 113) among WPV3 cases. During the 2006 outbreak, clinical follow-up data were available for

**Table 1. Poliomyelitis Case-Fatality Ratio (CFR), India, 2002–2006**

| Year | No. of deaths among WPV cases | Total WPV cases | CFR, % (95% CI) |
|---|---|---|---|
| 2002 | 66 | 1600 | 4.1 (3.2–5.2) |
| 2003 | 8 | 225 | 3.6 (1.7–6.6) |
| 2004 | 7 | 134 | 5.2 (2.3–10.0) |
| 2005 | 1 | 66 | 1.5 (0.07–7.2) |
| 2006 | 45 | 676 | 6.7 (5.0–8.7) |
| Total | 128 | 2701 | 4.7 (4.0–5.6) |

**NOTE**. CI, confidence interval; WPV, wild poliovirus.

673 of 676 total WPV cases, and the CFR was 6.7% (45 of 676) overall, 7.3% (45 of 618) among WPV1 cases, and 0% (0 of 58) among WPV3 cases. The annual CFR during the 2003–2005 interepidemic period ranged from 1.5% in 2005 to 5.2% in 2004 (Table 1). The mean monthly CFR was 3.9 from January through July 2002 and 9.6 from January through July 2006 (Figure 1).

Children aged <5 years accounted for 65 (98%) of 66 WPV-related deaths during the 2002 outbreak and all 45 WPV-related deaths during the 2006 outbreak. The CFR was higher in all groups of children aged <5 years in 2006 than in 2002, but this finding was statistically significant ($P < .05$) for only the <12 month age group (Table 2). The underserved population accounted for 44 (67%) of 66 fatal cases and 910 (57%) of 1600 WPV cases in 2002, and 24 (53.3%) of 45 fatal cases and 377 (55.8%) of 676 WPV cases in 2006; thus, underserved status was not associated with increased CFR among WPV cases.

### UP State and Moradabad District

In 2002, the CFR in UP was 4.3% overall (54 deaths among 1242 WPV cases), 4.0% (46 of 1139) among WPV1 cases, and 8.0% (8 of 100) among WPV3 cases. The CFR in Moradabad in 2002 was 7.6% overall (6 of 79), 8.0% (6 of 75) among WPV1 cases, and 0% (0 of 4) among WPV3 cases. In 2006, the CFR in UP was 6.9% overall (38 deaths among 548 WPV cases), 7.5% (38 of 520) among WPV1 cases, and 0% (0 of 28) among WPV3 cases. In 2006, the CFR in Moradabad was 12.3% (8 of 65) overall, 15.4% (8 of 52) among WPV1 cases, and 0% (0 of 13) among WPV3 cases.

Children aged <5 years accounted for 53 (98%) of 54 WPV-related deaths in UP and all 6 deaths in Moradabad during the 2002 outbreak; all deaths in both UP and Moradabad during the 2006 outbreak were among children aged <5 years. In UP, the CFR was higher in all <5 year age groups in 2006 than in 2002 (Table 2). In Moradabad, the CFR was higher in 2006 than in 2002 in the <12 month and 12–23 month age groups (Table 2). Small numbers limited statistical comparisons of age-specific CFRs.

Additional clinical data available for cases in 2006 indicated that, of the total 45 persons with fatal WPV, 23 (50%) presented with classic rapidly progressive bulbar paralysis. Seven of these 23 deaths with rapidly progressive paralysis were from Moradabad district, where a more detailed investigation was conducted.

Moradabad had 65 WPV cases reported with paralysis onset in 2006, the highest number of WPV cases for any district in India during the 2006 outbreak. Eight deaths were reported (CFR, 12.3%). All deaths were among 50 WPV case patients aged <2 years, yielding a higher CFR of 16%. The deaths were reported from April through July 2006 from 7 of the 14

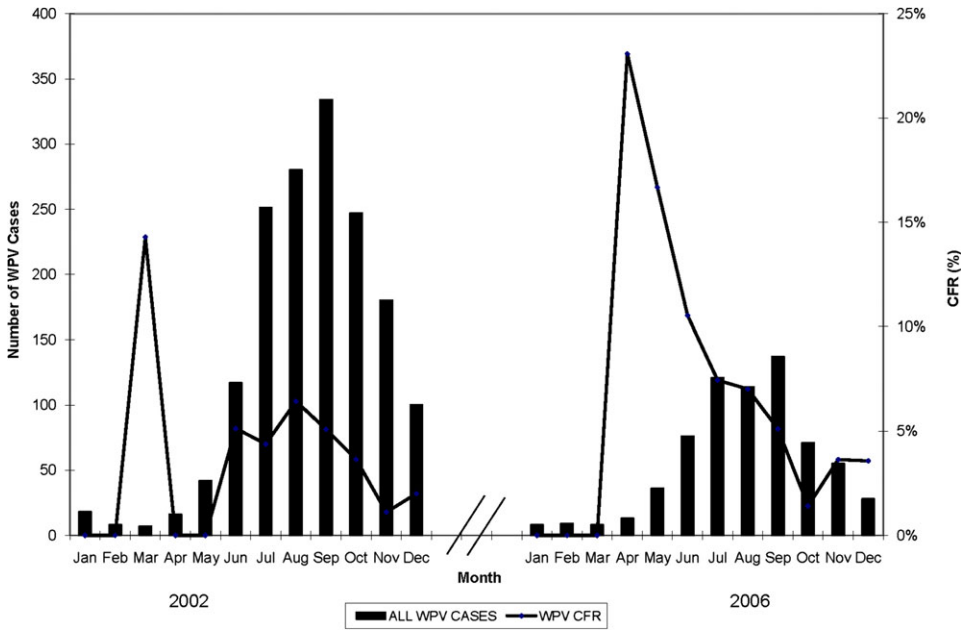


**Figure 1.** Wild poliovirus (WPV) cases and case-fatality ratio (CFR), by month of paralysis onset, India, 2002 and 2006.

**Table 2. Case-Fatality Ratio (CFR), by Age in Months, India, Uttar Pradesh (UP) and Moradabad, 2002 and 2006**

| Year | | India | | | | | UP | | | | | Moradabad | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Age in months | | | | | Age in months | | | | | Age in months | | | | |
| | | <12 | 12–<24 | 24–<60 | ≥60 | TOTAL | <12 | 12–<24 | 24–<60 | ≥60 | TOTAL | <12 | 12–<24 | 24–<60 | ≥60 | TOTAL |
| 2002 | Deaths among WPV cases[a] | 33 | 21 | 11 | 1 | 66 | 25 | 19 | 9 | 1 | 54 | 4 | 1 | 1 | 0 | 6 |
| | WPV cases | 708 | 623 | 249 | 20 | 1600 | 550 | 495 | 188 | 9 | 1242 | 30 | 42 | 6 | 1 | 79 |
| | CFR, % | 4.7 | 3.4 | 4.4 | 5.0 | 4.13 | 4.55 | 3.84 | 4.79 | 11.11 | 4.35 | 13.33 | 2.38 | 16.67 | 0.00 | 7.59 |
| 2006 | Deaths among WPV cases | 20 | 13 | 12 | 0 | 45 | 16 | 12 | 10 | 0 | 38 | 4 | 4 | 0 | 0 | 8 |
| | WPV cases | 236 | 231 | 177 | 32 | 676 | 199 | 195 | 136 | 18 | 548 | 19 | 31 | 15 | 0 | 65 |
| | CFR, % | 8.47[±] | 5.63 | 6.78 | 0.00 | 6.70[b] | 8.04 | 6.15 | 7.35 | 0.00 | 6.93[b] | 21.05 | 12.90 | 0.00 | 0.00 | 12.31 |

[a] Total cases (all WPV-positive cases, including those with only contact-positive stool specimens, as listed in the database for each year).

[b] Statistically significant increase in CFR in 2006, compared with 2002($P < .05$).

subdistrict blocks in the district (Figure 2); the dates of paralysis onset were from 15 April 2006 through 3 July 2006.

All fatal cases in Moradabad district were reported to the surveillance unit within 7 days after paralysis onset. The mean time from notification to investigation was <1 day; the mean time from paralysis onset to investigation was 3.5 days. All persons with fatal cases were seen by a qualified local pediatrician before death; 7 were seen by a pediatrician within 2 days after paralysis onset, and 1 was seen within 4 days. Three patients were hospitalized. All 8 deaths occurred within 7 days after paralysis onset, and 7 presented with rapidly progressive bulbar paralysis. The other death occurred in a child who was severely malnourished and emaciated, with complete paralysis in only 1 limb. Case classification was based on WPV isolated from stool specimens for 5 patients and on WPV isolated from a contact stool specimen for 3 patients.

Among the 8 deaths, 5 (62.5%) were from the underserved population and 4 (50%) were <1 year of age. Three children were >15 months of age at the time of paralysis onset and had received >7 doses of OPV. Three children, of whom 2 were <6 months of age, received <4 doses of OPV. All children were reported as having been vaccinated during the April 2006 immunization rounds; 7 (87.5%) received their last OPV dose within 0–6 weeks before death. For 5 children who died, the earliest date of OPV administration was June 2005. The maximum number of OPV doses received among all children who died in Moradabad was 9 doses for a 22-month-old child.

### Surveillance Sensitivity and CFR

Because of the changes in surveillance during 2002–2006, we applied similar criteria to cases in 2006 as would have been used in 2002 for CFR calculations. In this analysis, we removed any WPV case in 2006 that was classified on the basis of a WPV isolate from a contact stool sample and only included cases for which WPV was isolated from the case patient's stool specimen (restricted cases) (Table 3). For restricted cases in 2002, the CFR was 4.1% (66 deaths among 1600 WPV cases) overall in India and 4.3% (54 of 1242) in UP and 7.6% in Moradabad. By comparison, for restricted cases in 2006, the CFR was 3.7% (24 of 645) overall in India, 3.4% (18 of 523) in UP, and 8.1% (5 of 62) in Moradabad. There were no statistically significant differences in CFR between 2002 and 2006, when comparing rates among restricted cases. Because the majority of cases were WPV1 during the years studied, we did not calculate a difference between WPV1 and WPV3 because of the absence of fatalities for WPV3 cases in 2006.

### Genetic Clustering of WPV Isolates

To address the issue of potential contributions of viral determinants contributing to differences in the CFR, genetic relationships among the isolates from fatal cases were


**Figure 2.** Moradabad district and location of WPV1 deaths, by block, 2006. Dots are randomly distributed in the block.

compared with all isolates from the same year. The majority of WPV1 strains responsible for the outbreak in UP in 2006 were derived from a single indigenous genetic cluster seen in western UP in the previous year with smaller numbers primarily from 2 other genetic clusters. As a result, most strains in 2006 in UP and Moradabad were highly related genetically. Virus isolates from persons with fatal cases came from all active genetic clusters in approximate proportion to the number of WPV cases from those genetic clusters. All virus isolates from persons with both fatal and nonfatal WPV cases in Moradabad in 2006 were derived from one genetic cluster, and none of the viruses from the other genetic clusters were observed in Moradabad, although they were present in other parts of UP. In addition, no specific genetic subclustering of virus isolates from the 8 patients with fatal WPV cases in Moradabad was observed.

## DISCUSSION

The CFR found in this study for India in 2006 is higher than in previous years with a similar surveillance system (2002) and higher than was previously reported in India [8, 9]. Comparable studies from Nigeria found CFRs of 0.9%–6.3% since 2005, with CFRs for WPV1 cases of 0.9%–1.8% and for WPV3 cases of 3.2%–6.3% (S Wassilak, personal communication). Limited CFR data are available from other countries in Southeast Asia;

**Table 3. Case-Fatality Ratio (CFR), by Case Category, 2002 and 2006**

| | | India | | | UP | | | Moradabad | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Year | Category[a] | Restricted | Restricted WPV1 | Actual | Restricted | Restricted PV1 | Actual | Restricted | Restricted WPV1 | Actual |
| 2002 | WPV died (a) | 66 | 58 | 66 | 54 | 46 | 54 | 6 | 6 | 6 |
| | WPV (b) | 1600 | 1484 | 1600 | 1242 | 1139 | 1242 | 79 | 75 | 79 |
| | CFR (a/b*100) | 4.13 | 3.90 | 4.13 | 4.35 | 4.04 | 4.35 | 7.59 | 8.0 | 7.59 |
| 2006 | WPV died (a) | 24 | 24 | 45 | 18 | 18 | 38 | 5 | 5 | 8 |
| | WPV (b) | 645 | 617 | 676 | 523 | 495 | 548 | 62 | 49 | 65 |
| | CFR (a/b*100) | 3.72 | 3.89 | 6.70[b] | 3.44 | 3.63 | 6.93[b] | 8.06 | 10.2 | 12.31 |

**NOTE.** Restricted WPV1 = WPV case with positive stool where poliovirus type was WPV1. Total = All WPV positive cases (including those with only contact positive stool) as listed in database for each year.

[a] Restricted = WPV case with positive stool (contacts excluded).

[b] Significant difference in CFR between 2002 and 2006 ($P < .05$).

however, the numbers are small and surveillance sensitivity is not as high as in India. An outbreak during 2005–2006 in Indonesia led to 305 WPV cases, among which there were 4 deaths (CFR, 1.3%). In 2005, Nepal reported 4 WPV cases, for which no death was reported, and in 2006, there were 5 cases from Nepal with 1 WPV1 death reported. In 2006, 18 cases were reported, with no deaths in Bangladesh [18].

The sensitivity of AFP surveillance in India increased during 2002–2006, which might have resulted in detection of WPV cases or WPV-related deaths that were missed in previous years. It might have been expected that the increased surveillance sensitivity would have led to a decrease in CFR because a more sensitive system may result in increased reporting of less severe disease (eg, transient paralysis or atypical symptoms). However, the reported CFR was increased in 2006, compared with 2002, primarily because of inclusion of patients with AFP from whom stool samples could not be obtained but whose contacts had a WPV stool isolate. When the analysis was restricted to fatal cases with a WPV stool isolate, CFRs in 2002 and 2006 were similar. Thus, the observations in this study provide a more accurate picture of the spectrum of poliomyelitis and CFRs in India than was previously available, in part because of intensified surveillance activities and identification of cases that might otherwise have been missed as the result of inadequate stool specimens. This is especially relevant in Moradabad district, where extremely ill children were able to be identified even after death because of contact stool sampling.

Although an epidemiologic clustering of deaths occurred in Moradabad from April through June 2006, the isolates from these cases did not represent a distinct genetic cluster. Our study did not identify human genetic factors responsible for the higher CFR in Moradabad in early 2006, and further studies are needed to assess the role of factors that might increase risk of cases with classic clinical symptoms and rapid progression to bulbar paralysis and death.

In 2006, >70% of WPV cases and deaths were reported among children who had received >3 doses of OPV. This finding may in part represent a limitation of how polio vaccine doses are recorded during supplementary immunization activity (SIA) rounds. SIA campaigns aim to maximize vaccination coverage in which all children aged <5 years receive 1 OPV dose regardless of vaccination history and the OPV dose given is not recorded on the child's immunization card [11]; the information about number of doses received is obtained from parental reports, which might overestimate the actual number of doses received. Another contributing factor may be the challenge of inducing immunity to WPV and protection from paralytic poliomyelitis among children after vaccination with OPV in developing countries and in regions such as UP and Moradabad district, where high population density, poor sanitation, malnourishment, and coexisting enteric virus circulation may limit seroconversion and protection among OPV recipients [11, 19–22]. The presence of WPV infection and death in children <2 years of age in India, based on this study, is concerning because it may indicate both a high failure rate of seroconversion after vaccination and other possible coexisting risk factors, such as malnutrition, diarrheal disease, and dehydration, that may have contributed to the cause of death.

A limitation in our study was the lack of complete clinical and laboratory information on AFP cases in India. The AFP surveillance system in India does not include determination of other coexisting infections or conditions other than WPV infection. The clinical investigations of the deaths presented in this study provide strong evidence that WPV infection was the cause of death; however, the other diseases or conditions may also present with similar clinical signs and symptoms [23–25]. Further investigation of causes of death for fatal WPV cases, including testing of stool and other specimens to investigate possible coinfections (such as other enteroviruses prevalent because of poor sanitation and overcrowding conditions), might

provide a more comprehensive explanation of why the case-fatality ratio was increased among young children, compared with what has been previously noted in the literature [2, 3,7–9].

Since the World Health Assembly resolved in May 1988 to eradicate poliomyelitis, the majority of children in India are vaccinated, and current poliovirus circulation in India is limited primarily to the 2 northern states of UP and Bihar. The CFR among children aged <2 years in India is higher than was previously reported for young children. This more accurate assessment of CFR of polio in India is a result of improvements in surveillance sensitivity and methodology. The high CFRs among children emphasize the lethal nature of WPV infection and the importance of achieving polio eradication in India.

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## References

1. Sutter RW, Cochi SL, Melnick J. Live attenuated poliovirus vaccines. In: Plotkin S, Orenstein WA, eds. Vaccines. Philadelphia: WB Saunders, 1999; 364–408.
2. Greenberg M, Siegel M, Magee M. Poliomyelitis in New York City, 1949. N Y State J Med **1950**; 50:1119–23.
3. Patriarca PA, Sutter RW, Oostvogel PM. Outbreaks of paralytic poliomyelitis, 1976–1995. J Infect Dis **1997**; 175(Suppl 1):S165–72.
4. Pal S, Banerjee G, Aikat B. Serological investigation on endemicity of poliomyelitis in Calcutta and in a neighboring rural area. Indian J Med Res **1966**; 54:507–11.
5. Sutter RW, Patriarca PA, Suleiman AJ, et al. Paralytic poliomyelitis in Oman: association between regional differences in attack rate and variations in antibody responses to oral poliovirus vaccine. Int J Epidemiol **1993**; 22:936–44.
6. Bernkopf H, Medalie J, Yekutiel M. Antibodies to poliomyelitis virus and socioeconomic factors influencing their frequency in children in Israel. Am J Trop Med **1957**; 1957:697–703.
7. Prevots DR, Ciofi degli Atti ML, Sallabanda A, et al. Outbreak of paralytic poliomyelitis in Albania, 1996: high attack rate among adults and apparent interruption of transmission following nationwide mass vaccination. Clin Infect Dis **1998**; 26:419–25.
8. Wyatt HV. Poliomyelitis in India: past, present and future. Indian J Pediatr **1998**; 65(Suppl 1):SI-VIII:SI–98.
9. Deivanayagam N, Nedunchelian K. Epidemiological and clinical features of acute poliomyelitis children admitted in an urban hospital. Indian Pediatr **1992**; 29:25–8.
10. Kohler KA, Hlady G, Banerjee K, Sutter RW. Outbreak of poliomyelitis due to type 3 poliovirus, northern India, 1999–2000: injections a major contributing factor. Int J Epidemiol **2003**; 32:272–277.
11. Centers for Disease Control and Prevention. Progress toward poliomyelitis eradication—India, January 2005–June 2006. MMWR Morb Mortal Wkly Rep **2006**; 55:772–6.
12. Banerjee K, Hlady WG, Andrus JK, Sarkar S, Fitzsimmons J, Abeykoon P. Poliomyelitis surveillance: the model used in India for polio eradication. Bull World Health Organ **2000**; 78:321–9.
13. WHO. Global Programme for Vaccines and Immunization. Report of the Technical Consultative Group (TCG) on the Global eradication of poliomyelitis, 29–30 Apr 1996. Geneva: World Health organization, 1997.
14. Surveillance of acute flaccid paralysis. Field guide, 3rd edition. New Delhi: Child Health Division, Department of Family Welfare, Ministry of Health and Family Welfare, 2005.
15. Kohler KA, Hlady WG, Banerjee K, et al. Compatible poliomyelitis cases in India during 2000. Bull World Health Organ **2003**; 81:2–9.
16. Liu HM, Zheng DP, Zhang LB, Oberste MS, Pallansch MA, Kew OM. Molecular evolution of a type 1 wild-vaccine poliovirus recombinant during widespread circulation in China. J Virol **2000**; 74:11153–61.
17. Sabin AB. Paralytic consequences of poliomyelitis infection in different parts of the world and in different population groups. Am J Public Health **1951**; 41:1215–30.
18. Who, Searo. Line list of laboratory confirmed polio cases. 2007.
19. Patriarca PA, Wright PF, John TJ. Factors affecting the immunogenicity of oral poliovirus vaccine in developing countries: review. Rev Infect Dis **1991**; 13:926–39.
20. Posey DL, Linkins RW, Oliveria MJ, Monteiro D, Patriarca PA. The effect of diarrhea on oral poliovirus vaccine failure in Brazil. J Infect Dis **1997**; 175(Suppl. 1):S258–63.
21. Grassly NC, Fraser C, Wenger J, et al. New strategies for the elimination of polio from India. Science **2006**; 314:1150–3.
22. Grassly NC, Wenger J, Durrani S, et al. Protective efficacy of a monovalent oral type 1 poliovirus vaccine: a case-control study. Lancet **2007**; 369:1356–62.
23. Marx A, Glass JD, Sutter RW. Differential diagnosis of acute flaccid paralysis and its role in poliomyelitis surveillance. Epidemiol Rev **2000**; 22:298–316.
24. Morris AM, Elliott EJ, D'Souza RM, Antony J, Kennett M, Longbottom H. Acute flaccid paralysis in Australian children. J Paediatr Child Health **2003**; 39:22–6.
25. Pal SR, Dastur DK, Kaiwar R, Prasad SR. Enterovirus-70 antigen in spinal cord cells of patients with poliomyelitis-like illness. Indian J Med Res **1986**; 83:108–10.