Outbreaks of Paralytic Poliomyelitis During 1996–2012: The Changing Epidemiology of a Disease in the Final Stages of Eradication

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Background. Despite substantial progress toward eradication of poliomyelitis, the risk of poliomyelitis outbreaks resulting from virus importations into polio-free areas persists. We reviewed the changing epidemiology of outbreaks in the final stages of the eradication initiative.

Methods. Available literature on outbreaks of poliomyelitis caused by wild polioviruses between 1996 and 2012 was reviewed.

Results. During this period, there were 22 outbreaks involving 39 countries. Outbreaks ranged in size from 1 to 1335 cases. These outbreaks caused 4571 cases, representing 21% of all cases reported during this period. Five outbreaks involved multiple countries. In 76% of outbreaks (16/21) with a known age distribution, cases concentrated among children aged <5 years; in 19% (4/21), most cases were among adolescents and adults. The outbreaks among adolescents and adults were associated with higher case-fatality ratios, ranging from 12% in Albania in 1994 to 41% in the Republic of Congo in 2010. The majority of outbreaks were controlled within 6 months with oral poliovirus vaccine.

Conclusions. Importations resulting in epidemic transmission of wild poliovirus caused thousands of cases of paralysis often in countries where poliomyelitis had not occurred for many years. The changing epidemiology, with cases and higher case-fatality ratios among adults, increased the severity of these outbreaks.

Keywords. poliomyelitis; outbreak; poliovirus eradication.

Since 1988, when the World Health Assembly resolved to eradicate poliomyelitis, the number of persons paralyzed every year because of wild poliovirus (WPV) has dropped from hundreds of thousands to several hundred worldwide (1352 confirmed cases in 2010, 650 in 2011, and 223 in 2012). Most of these cases were among young children, mirroring the immunity profile of these populations [1].

In 1996, there were 45 poliomyelitis-endemic countries, compared with 3 at the end of 2012 (Pakistan, Afghanistan, and Nigeria). During this period, poliovirus importations from polio-endemic countries to polio-free countries caused outbreaks of paralytic disease on multiple occasions. In most cases the outbreaks were rapidly controlled, but in 4 countries (Chad, Angola, Sudan, and the Democratic Republic of Congo) the circulation of WPV was reestablished following virus importation and persisted for several years [2]. The resolution of the 65th World Health Assembly in 2012 called for intensification of poliomyelitis eradication and declared the completion of poliovirus eradication a programmatic emergency for global public health [3]. The new strategic plan of the Global Polio Eradication Initiative envisions stopping WPV circulation by the end of 2014.

While the incidence of poliomyelitis is on the decline, the risk of outbreaks due to poliovirus importations from polio-endemic areas to polio-free areas is also declining. In 2010, 83% of paralytic polio cases were detected in non–polio-endemic countries, and 2 large outbreaks (in Tajikistan and Republic of Congo) contributed 898 paralytic cases, which represented two thirds of all cases in 2010 [1]. In 2012, however, the vast majority (97%) of polio cases were detected in polio-endemic...
countries; there was only 1 reported importation of WPV (from Nigeria to Niger), which caused a single case of paralytic disease (Figure 1).

In the last phase of polio eradication, the understanding of the changing epidemiology of poliomyelitis outbreaks and risks of outbreaks occurring in polio-free areas has become important to achieve the final goal of eradication. This article describes outbreaks detected worldwide between January 1996 and December 2012 that occurred in previously polio-free areas and discusses the changing epidemiology of poliomyelitis as global eradication nears.

METHODS

We reviewed available data on outbreaks of paralytic poliomyelitis that occurred from January 1996 through December 2012 and provided descriptive epidemiological analyses of the data. We used methods similar to those in the previous review of paralytic polio outbreaks that occurred during 1976–1995 [4].

As sources of data, we have consulted PubMed database, Polio Eradication Progress Updates, the World Health Organization Database of Acute Flaccid Paralysis, outbreak investigation reports, and published or unpublished presentations from meetings and conferences.

For the purposes of this publication, a polio outbreak was defined as a 2.5-fold increase in the incidence of paralytic polio during the 12-month period preceding the index case or a case of paralytic polio that occurred in the context of the complete absence of reported cases [4]. We excluded events representing an increase in the number of polio cases detected in the same geographical area as endemic-poliovirus transmission. We also excluded outbreaks caused by circulating vaccine-derived polioviruses.

When describing age distribution of case patients, we divided the outbreaks into 2 groups based on the predominant age group of case patients. We classified outbreaks as involving predominantly young individuals if at least 50% of reported cases were among children <5 years of age and as involving predominantly old individuals if at least 50% of reported cases were among individuals >15 years of age.

We used the United Nations Development Program tables for the human development index (HDI), which categorizes countries as having a very high, high, medium, or low HDI, and we used the same classification to estimate socioeconomic development in the outbreak countries [5].

RESULTS

We identified 22 outbreaks as having occurred during January 1996–December 2012, of which 5 involved multiple countries. These outbreaks were caused by poliovirus importations into polio-free countries or, in 2 cases, into polio-free areas of infected countries (Table 1).

The total number of cases detected in these outbreaks was 4571, which represented 21% of 21,341 paralytic polio cases detected during this period worldwide. The total number of countries affected by the outbreaks was 39 [2, 6–61].

The majority of the outbreaks (16/22 [73%]) were caused by WPV1. In 5 outbreaks, both WPV1 and WPV3 cocirculation was detected, and 1 outbreak was caused by WPV3 alone.
Table 1. Summary of Outbreaks of Paralytic Poliomyelitis, 1996–2012

<table>
<thead>
<tr>
<th>Affected Country or Area</th>
<th>Year First Case Reported</th>
<th>Cases, No.</th>
<th>Duration, mo</th>
<th>POL3 Coverage, Cases, %</th>
<th>Preoutbreak POL3 Coverage, %</th>
<th>Age, Cases, %</th>
<th>CFR</th>
<th>Poliovirus Type</th>
<th>Poliovirus Origin</th>
</tr>
</thead>
<tbody>
<tr>
<td>Albania</td>
<td>1996</td>
<td>138</td>
<td>8</td>
<td>NR</td>
<td>NR</td>
<td>94</td>
<td>11</td>
<td>70</td>
<td>12</td>
</tr>
<tr>
<td>Northern Afghanistan</td>
<td>1999</td>
<td>26</td>
<td>5</td>
<td>NR</td>
<td>NR</td>
<td>24–58</td>
<td>NR</td>
<td>WPV1, WPV3</td>
<td>Same country&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
<td>Angola</td>
<td>1999</td>
<td>1100</td>
<td>6</td>
<td>23</td>
<td>28</td>
<td>33</td>
<td>80</td>
<td>0</td>
<td>10</td>
</tr>
<tr>
<td>Iraq</td>
<td>1999</td>
<td>16</td>
<td>3</td>
<td>69</td>
<td>NR</td>
<td>86</td>
<td>88</td>
<td>&lt;12</td>
<td>NR</td>
</tr>
<tr>
<td>Cape Verde</td>
<td>2000</td>
<td>33</td>
<td>3</td>
<td>NR</td>
<td>25</td>
<td>75</td>
<td>33</td>
<td>21</td>
<td>21</td>
</tr>
<tr>
<td>Bulgaria</td>
<td>2001</td>
<td>2</td>
<td>1</td>
<td>100</td>
<td>0</td>
<td>94</td>
<td>100</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>West and Central Africa&lt;sup&gt;b&lt;/sup&gt;</td>
<td>2003</td>
<td>63</td>
<td>15</td>
<td>31</td>
<td>19</td>
<td>46–83</td>
<td>82</td>
<td>NR</td>
<td>WPV1, WPV3</td>
</tr>
<tr>
<td>Horn of Africa, West Africa, Southern Africa, Middle East, and Indonesia&lt;sup&gt;c&lt;/sup&gt;</td>
<td>2004</td>
<td>1335</td>
<td>14</td>
<td>16–58</td>
<td>11–39</td>
<td>26–85</td>
<td>70–98</td>
<td>0–2</td>
<td>NR</td>
</tr>
<tr>
<td>Sudan</td>
<td>2004</td>
<td>127</td>
<td>Established</td>
<td>16</td>
<td>39</td>
<td>65</td>
<td>92</td>
<td>1</td>
<td>NR</td>
</tr>
<tr>
<td>Ethiopia</td>
<td>2004</td>
<td>40</td>
<td>...</td>
<td>40</td>
<td>15</td>
<td>69</td>
<td>70</td>
<td>2</td>
<td>NR</td>
</tr>
<tr>
<td>Yemen</td>
<td>2004</td>
<td>478</td>
<td>...</td>
<td>17</td>
<td>29</td>
<td>85</td>
<td>94</td>
<td>0</td>
<td>NR</td>
</tr>
<tr>
<td>Somalia</td>
<td>2004</td>
<td>215</td>
<td>...</td>
<td>58</td>
<td>15</td>
<td>26</td>
<td>98</td>
<td>0</td>
<td>NR</td>
</tr>
<tr>
<td>Indonesia</td>
<td>2004</td>
<td>305</td>
<td>...</td>
<td>37</td>
<td>11</td>
<td>84</td>
<td>78</td>
<td>1</td>
<td>NR</td>
</tr>
<tr>
<td>Angola and Democratic Republic of Congo&lt;sup&gt;d&lt;/sup&gt;</td>
<td>2005</td>
<td>435</td>
<td>Established</td>
<td>7</td>
<td>29</td>
<td>83</td>
<td>96</td>
<td>0</td>
<td>11</td>
</tr>
<tr>
<td>Nepal&lt;sup&gt;e&lt;/sup&gt;</td>
<td>2005–2010</td>
<td>26</td>
<td>...</td>
<td>NR</td>
<td>NR</td>
<td>83</td>
<td>83</td>
<td>0</td>
<td>NR</td>
</tr>
<tr>
<td>Namibia</td>
<td>2006</td>
<td>19</td>
<td>2</td>
<td>NR</td>
<td>NR</td>
<td>74</td>
<td>0</td>
<td>100</td>
<td>32</td>
</tr>
<tr>
<td>Bangladesh</td>
<td>2006</td>
<td>18</td>
<td>11</td>
<td>6</td>
<td>72</td>
<td>93</td>
<td>78</td>
<td>0</td>
<td>NR</td>
</tr>
<tr>
<td>Myanmar</td>
<td>2007</td>
<td>11</td>
<td>3</td>
<td>18</td>
<td>11</td>
<td>84</td>
<td>100</td>
<td>0</td>
<td>NR</td>
</tr>
<tr>
<td>West, Central, East, and Horn of Africa&lt;sup&gt;f&lt;/sup&gt;</td>
<td>2008</td>
<td>351</td>
<td>18</td>
<td>22</td>
<td>27</td>
<td>53–88</td>
<td>85</td>
<td>1</td>
<td>NR</td>
</tr>
<tr>
<td>Tajikistan, Central Asia, and Russia</td>
<td>2010</td>
<td>475</td>
<td>10</td>
<td>0–29</td>
<td>7–100</td>
<td>95–98</td>
<td>0–69</td>
<td>0–29</td>
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</tr>
<tr>
<td>Tajikistan</td>
<td>2010</td>
<td>457</td>
<td>...</td>
<td>...</td>
<td>...</td>
<td>95</td>
<td>69</td>
<td>12</td>
<td>6</td>
</tr>
<tr>
<td>Kazakhstan</td>
<td>2010</td>
<td>1</td>
<td>...</td>
<td>...</td>
<td>100</td>
<td>98</td>
<td>0</td>
<td>0</td>
<td>0</td>
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<tr>
<td>Turkmenistan</td>
<td>2010</td>
<td>3</td>
<td>...</td>
<td>...</td>
<td>100</td>
<td>96</td>
<td>33</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Russian Federation</td>
<td>2010</td>
<td>14</td>
<td>...</td>
<td>29</td>
<td>7</td>
<td>98</td>
<td>43</td>
<td>29</td>
<td>0</td>
</tr>
<tr>
<td>Republic of Congo</td>
<td>2010</td>
<td>442</td>
<td>3</td>
<td>58</td>
<td>22</td>
<td>68</td>
<td>18</td>
<td>70</td>
<td>41</td>
</tr>
<tr>
<td>China</td>
<td>2011</td>
<td>21</td>
<td>4</td>
<td>25</td>
<td>20</td>
<td>&gt;95</td>
<td>45</td>
<td>55</td>
<td>NR</td>
</tr>
<tr>
<td>West Africa&lt;sup&gt;g&lt;/sup&gt;</td>
<td>2011</td>
<td>50</td>
<td>7</td>
<td>12</td>
<td>10</td>
<td>53–88</td>
<td>84</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Niger</td>
<td>2011</td>
<td>4</td>
<td>6</td>
<td>0</td>
<td>0</td>
<td>73</td>
<td>100</td>
<td>0</td>
<td>...</td>
</tr>
</tbody>
</table>
Major Outbreaks Detected

The outbreak eventually covering the largest geographic area was a WPV1 outbreak that originated in Nigeria in 2004 and spread into Central, West, and Southern Africa; the Horn of Africa; and the Middle East and Indonesia. The exported virus found pockets of low population immunity and caused 1335 documented cases of paralysis in 16 countries that had been mostly free of polio for many years. In Sudan, the importation resulted in reestablished transmission lasting several years [18]. One of the hypotheses is that the spread of the virus followed transit routes from Nigeria through Central Africa and the Horn of Africa during the annual Muslim pilgrimage to Mecca. It is hypothesized that pilgrims from Indonesia and other Middle Eastern countries visiting Mecca may have carried the virus back to their countries of origin (Figure 2).

Importations of WPV1 and WPV3 from India into Angola in 2005 (and again in 2008–2009) started an outbreak that subsequently spread into the Democratic Republic of Congo (DRC), Namibia, and the Republic of Congo. In Angola and the DRC, the circulation of poliovirus was reestablished for several years and caused 116 paralytic cases in Angola and 319 in the DRC [18].

Outbreaks in West Africa caused by importations from Nigeria were detected in 2003, 2004, 2008, 2011, and 2012. Both WPV1 and WPV3 were implicated.

In 2010, 2 large WPV1 outbreaks were detected: one, in central Asia, was caused by virus imported from India; and the second, in the Republic of Congo, was caused by virus imported from Angola. Both of these outbreaks were characterized by rapid onset, a high number of older case patients, and higher mortality, especially in the Republic of Congo.

In 2011, an outbreak caused by virus imported from Pakistan was reported in China. The outbreak was limited to western parts of China and was rapidly controlled with high-impact immunization activities that used oral poliovirus vaccine.

Magnitude and Duration

The reported number of cases in an outbreak ranged from 1 to 1335. The attack rate was unavailable for most of the outbreaks; when available, it ranged from 7.6 to 42.2 cases per 100 000 population. Over half of the outbreaks (12/22 [55%]) were controlled within 6 months.

In most of the outbreaks (West Africa in 2008, Angola in 2005, and Nepal in 2010), the number of detected cases slowly increased or remained stable over weeks or months; in several other instances (Angola in 1999, Somalia 2005, and Tajikistan and Republic of Congo in 2010), the outbreak had very rapid onset, affecting hundreds within days.

Age Distribution of Case Patients

We identified data on the age distribution of case patients from 21 of 22 outbreaks (95%). Sixteen of 21 outbreaks (76%) involved case patients classified as predominantly young, and 4
(19%) involved case patients classified as predominantly old. The Cape Verde outbreak in 2000 included both younger and older case patients in approximately equal proportions. The proportion of case patients <5 years of age ranged from 0%–100%, as did the proportion of case patients aged ≥15 years, pointing to significantly different age distributions between outbreaks.

The outbreak in Angola in 2005 that subsequently spread to Namibia in 2006 [14, 17, 24] was caused by WPV1 that had been imported into Angola from India in 2005. In Angola, the outbreak affected predominantly young children, with 96% of cases in children <5 years of age, but in Namibia, the outbreak affected exclusively adults (100% of cases involved individuals aged >15 years). A similar observation was made during an outbreak in 2010 in the Republic of Congo, where males 15–25 years of age were predominantly affected (68%). As in Namibia, virus in the Congo outbreak in 2010 originated in India and spread from Angola [62].

**Case-Fatality Ratio (CFR)**

When reported (9/22 outbreaks [41%]), the CFR ranged from 0% to 41%. The 2 highest CFRs (32% in Namibia and 41% in the Congo) were in outbreaks involving individuals classified as predominantly old. The observation of a higher CFR among older age groups is in agreement with previous data. [4]

**HDI in Outbreak Countries**

All outbreaks involving individuals classified as predominantly old were in countries with a medium HDI. The outbreaks involving predominantly young individuals were in both medium- and low-HDI countries. There was a higher likelihood of an outbreak involving predominantly old individuals in countries with a higher HDI. The association between the age distribution of case patients and the HDI was statistically significant (P < .05).
Immunization Status
The reported national coverage with a third dose of polio vaccine during the year before the outbreak among children <2 years of age ranged from 24% in Afghanistan to >98% in the Russian Federation, China, and Kazakhstan. We did not observe an association between the reported vaccination coverage at the national level and either the age distribution of case patients or the CFR. The proportion of outbreak-associated case patients with no past history of polio vaccination (ie, 0-dose cases) ranged between 0% and 100%. The reports reviewed suggested that the proportion of 0-dose cases was considered to be the most important predictor of the severity and magnitude of the outbreak.

Laboratory Data
All outbreaks were confirmed by and viruses were genotyped in one of the World Health Organization (WHO)–accredited polio laboratories. Genotyping of the WPVs by use of genomic sequencing revealed epidemiological links that enabled determination of the origin and allowed tracking of the outbreaks (Table 1). This method also revealed whether one or multiple importations of polioviruses occurred, which was the case in Angola in 2005–2009, when 3 distinct importations of polioviruses from India occurred; in West Africa 2003 and 2008, with multiple importations from Nigeria; and in Nepal 2010, with multiple importations from India. Both short-distance importations across borders (from Nigeria to neighboring countries; from India to Nepal, Bangladesh, and Myanmar; and from Angola to Namibia and the DRC) and long-distance spread involving air travel (from India to Angola, from Saudi Arabia to Indonesia, and from India to Tajikistan) were reported.

Control Measures
In most cases, outbreaks were rapidly controlled by mass vaccination campaigns using oral polio vaccines either in trivalent, bivalent, or monovalent forms. The recommended schedule of at least 2 large-scale mass vaccination campaigns after the last reported case was adhered to in most outbreaks and likely prevented further spread of the virus. In many outbreaks, more than the recommended number of vaccination campaigns were performed. Typically, mass vaccination campaigns targeted children <5 years of age, but when outbreaks involved larger proportions of older patients (Namibia in 2006 and the Republic of Congo and Tajikistan in 2010), the target age group for campaigns was expanded to 15 years or included the entire population.

Causes of Outbreaks
The most cited cause of outbreaks in the reviewed reports was low population immunity against polioviruses. Low routine vaccination coverage and absence or poor quality of vaccination campaigns was stated most frequently in the articles and reports reviewed. The reasons for low immunization coverage that were cited most often were poor program management, problems with the cold chain, civil conflict, and missed population subgroups, such as migrants or minorities. In one case (Sudan in 2004), there was undetected circulation of WPV3 for several years, pointing to gaps in polio surveillance.

Apart from low population immunity against polio, other risk factors for virus importations and spread were identified in the reports. These risk factors included close proximity to and travel links with infected areas; presence of vulnerable or underserved population groups, including mobile groups; poor status of health system; and low level of sanitation and hygiene.

DISCUSSION
During the period covered by this article, a new epidemiological phenomenon occurred: outbreaks of poliomyelitis affected adult populations almost exclusively, causing high rates of mortality. More data are needed to understand whether this new trend is due to gaps in historical immunization coverage affecting older age groups today or to waning immunity. The outbreak among adult males in the Republic of Congo in 2010 was attributed to a low rate of childhood polio vaccination among young adults and a protracted period without WPV1 transmission in the area [63].

Reported national immunization coverage alone was not a useful predictor of the risk of a polio outbreak following importation of poliovirus. The national estimates, reported annually, do not provide sufficient information about areas or age groups with low immunization coverage. For example, Tajikistan reported >90% 3-dose polio vaccine coverage nationwide 1 year before the explosive poliomyelitis outbreak in 2010.

Multiple importations of WPVs from Nigeria into West Africa underline the importance of sensitive surveillance, strong routine immunization, and preventive vaccination campaigns in that region, as well as the need to stop WPV circulation in northern Nigeria.

The large outbreaks witnessed in 2010 in Tajikistan and the Congo point to important immunity gaps to polioviruses that likely exist in distinct geographical areas and population age groups. The immunity gap is most often a result of a poor immunization program, although waning or incomplete mucosal immunity to polioviruses in vaccinated individuals is another factor that likely contributed to the spread of the virus. Such outbreaks are a reminder that if eradication is not successful, these events could occur more frequently and be more widespread.

The observations from the outbreaks in Angola in 2005 and Namibia in 2006 demonstrate that the age distribution of cases in an outbreak is likely determined by immunity gaps in different population groups, rather than by the genotype or serotype of the poliovirus. Genotyping of WPVs is important for providing information about the origins of polioviruses. In addition,
genotyping can be used to measure progress toward polio eradication: during the period covered by this article, the genetic diversity of both WPV1 and WPV3 circulating in countries of endemicity significantly decreased, which points to successful eradication of different poliovirus genotypes. For example, in India, in 2006 there were 9 genetic clusters of WPV1, while in 2008 there were 3, and in 2010 there was only 1 [64].

No outbreaks were reported from countries classified as having a very high HDI. Because of established travel links between poliovirus-endemic countries and industrialized countries, poliovirus importation events are likely to occur. However, immunization strategies in these countries, together with lower force of infection in industrialized countries owing to better sanitation, seem to provide sufficient prevention from post-importation spread of polioviruses.

In 2011, a systematic regional risk assessment of transmission of WPV after importation into previously polio-free areas was intensified. This initiative was performed partially as a response to the outbreak in Tajikistan. When finalized, countries will have a standard tool to assess their risk of polio outbreak. Preventive measures could be recommended if the risk is found high [65].

A number of important milestones in polio eradication have been achieved during the period covered by this article. Two additional World Health Organization regions have been declared polio free. After the WHO American Region was certified as polio free in 1994, the WHO Western Pacific Region (37 countries and areas, including China) was certified in 2000, followed by the WHO European Region (51 countries) in June 2002 [66]. The South-East Asia Region will be the next to become certified polio free, with India becoming in February 2012 the latest country to be removed from the list of poliovirus-endemic countries. The number of poliovirus-endemic countries decreased from 45 in 1996 to 3 in 2012 (Figure 1). Improved surveillance and higher quality of polio vaccination campaigns; research, licensing, and use of monovalent and bivalent oral polio vaccines; and better understanding of mucosal immunity to polioviruses provided basis for these achievements.

In 2006, the World Health Assembly issued a resolution on responding to polio outbreaks. The resolution urged polio-free member states to take immediate actions in case of poliovirus detection, including 3 rounds of vaccination campaigns. This resolution makes polio one of the very few diseases in which international guidelines for outbreak response exist and are implemented [67]. When the outbreak response followed these guidelines, was rapid, and reached high coverage even among vulnerable population subgroups, the outbreaks were stopped within 6 months.

Despite the progress, polio is still not eradicated. The lesson learned from the recent outbreaks is that to succeed with polio eradication, the polio partnership needs not only to continue delivering high-quality vaccination campaigns and maintaining sensitive polio surveillance in poliovirus-endemic areas, but also to sustain identification of polio-free areas that are at high risk of virus importation and ensure that population immunity in these areas is maintained. This strategy must emphasize strengthening of routine immunization and, in some cases, implementation of preventive vaccination campaigns together with recommendations of vaccine requirements for travelers from areas with documented WPV circulation [68].

Notes

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