

Descriptions of polio-like illnesses have been around since antiquity, including a funerary stele depicting a man with a withered leg leaning on a staff. Michael Underwood first described a debility of the lower extremities in children that was recognizable as poliomyelitis in England in 1789, but the disease was not observed in epidemics until the late 19th century. During the first half of the 20th century, developed countries in the Northern Hemisphere suffered epidemics each summer and fall that became increasingly severe. Polio infections peaked in the United States in 1952, with more than 21,000 paralytic cases. Following introduction of effective vaccines in 1955 (inactivated polio vaccine, IPV) and 1961 (oral poliovirus vaccine, OPV), polio incidence declined rapidly. The last case of wild poliovirus acquired in the United States was in 1979.

## Poliovirus

Poliovirus is a member of the enterovirus subgroup, family Picornaviridae. Picornaviruses are small, ether-insensitive viruses with an RNA genome.

There are three poliovirus serotypes (type 1, type 2, and type 3); immunity to one serotype does not produce significant immunity to the other serotypes.

Poliovirus is rapidly inactivated by heat, formaldehyde, chlorine, and ultraviolet light.

## Pathogenesis

The virus enters through the mouth and multiplies in the oropharynx and gastrointestinal tract. The virus is usually present in nasopharyngeal secretions for 1 to 2 weeks and can be shed in stools for several weeks after infection, even in individuals with minor symptoms or no illness. During intestinal replication, the virus invades local lymphoid tissue and may enter the bloodstream, and then infect cells of the central nervous system. Poliovirus-induced destruction of motor neurons of the anterior horn of the spinal cord and brain stem cells results in distinctive paralysis.

## Clinical Features

The incubation period for nonparalytic poliomyelitis is 3 to 6 days. For the onset of paralysis in paralytic poliomyelitis, the incubation period is usually 7 to 21 days. The risk of severe disease and death following primary infection with poliovirus increases with increasing age.

Approximately 70% of all polio infections in children are asymptomatic. Infected individuals without symptoms shed the

### Poliomyelitis

- First described by Michael Underwood in 1789
- Developed countries in Northern Hemisphere suffered increasingly severe epidemics in the first half of the 20th century
- More than 21,000 paralytic cases reported in the U.S. in 1952
- Last case of wild poliovirus acquired in the U.S. was 1979

### Poliovirus

- Enterovirus (RNA)
- Three serotypes: type 1, type 2, type 3
- Immunity to one serotype does not produce significant immunity to other serotypes
- Rapidly inactivated by heat, formaldehyde, chlorine, ultraviolet light

### Poliomyelitis Pathogenesis

- Entry through mouth
- Replication in oropharynx, gastrointestinal tract
- Invades local lymphoid tissue and may enter the bloodstream, and then infect cells of the central nervous system
- Destruction of motor neurons result in distinctive paralysis

# Poliomyelitis

## Poliomyelitis Clinical Features

- Incubation period
  - 3 to 6 days for nonparalytic poliomyelitis
  - 7 to 21 days for onset of paralysis in paralytic poliomyelitis
- Paralysis is often permanent
- Paralytic disease may be caused by wild-type polioviruses, attenuated polioviruses in oral vaccine, or by vaccine-derived polioviruses

virus in nasopharyngeal secretions and stool for several days or weeks and are able to transmit the virus to others.

Approximately 24% of polio infections in children consist of a minor, nonspecific illness without clinical or laboratory evidence of central nervous system invasion. This clinical presentation is known as abortive poliomyelitis, and is characterized by a low fever, sore throat, and complete recovery in less than a week.

Nonparalytic aseptic meningitis occurs in 1% to 5% of polio infections in children. The clinical presentation includes stiffness of the neck, back, or legs, usually following several days of a prodrome similar to that of minor illness. Increased or abnormal sensations (e.g., pain in the limbs, back, or neck), headache, and vomiting can also occur. Typically, symptoms last 2 to 10 days and are followed by complete recovery.

Less than 1% of all polio infections in children result in flaccid paralysis. The course may be biphasic in children, with initial minor illness that lasts several days, a symptom-free period of 1 to 3 days, followed by the major illness with paralysis, fever and muscle pain. Paralysis usually progresses within 2 to 3 days. Among adolescents and adults, the minor illness is often absent and they suffer more severe pain and paralysis. Paralysis is typically asymmetrical, more severe proximally, and associated with absent or reduced deep tendon reflexes and intact sensation. Patients usually do not experience changes in cognition.

Paralysis is often permanent, although total or partial recovery can occur through compensation by muscles not affected. Weakness or paralysis present 12 months after onset, which occurs in two-thirds of patients with paralysis, is usually permanent.

Paralytic polio is classified into three types, depending on the level of involvement. Spinal polio is most common, and during 1969–1979 accounted for 79% of paralytic cases. It is characterized by asymmetric paralysis that most often involves the legs. Bulbar polio presents with weakness of facial, oropharyngeal, and respiratory muscles innervated by cranial nerves and accounted for 2% of cases during this period. Bulbospinal polio, a combination of bulbar and spinal paralysis, accounted for 19% of cases.

The case fatality ratio for paralytic polio is generally 2% to 5% among children and up to 15% to 30% among adolescents and adults. It increases to 25% to 75% with bulbar involvement.

Paralytic disease with similar clinical manifestations may be caused by naturally occurring wild-type polioviruses, by the attenuated polioviruses contained in the oral poliovirus vaccine (Sabin strains) in extremely rare occasions, or by vaccine-derived

polioviruses (VDPVs), which are Sabin vaccine strains that have reverted and re-acquired the virulence and transmissibility of wild polioviruses.

After an interval of 15 to 40 years, 25% to 40% of persons who contracted paralytic poliomyelitis in childhood experience new muscle pain and exacerbation of existing weakness or develop new weakness or paralysis. This disease entity is referred to as post-polio syndrome. Post-polio syndrome is not an infectious process, and persons experiencing this syndrome do not shed poliovirus.

## Laboratory Testing

The greatest yield for poliovirus is from viral culture of stool specimen; it is less likely to be recovered from the pharynx, and only rarely recovered from cerebrospinal fluid (CSF) or blood. If poliovirus is isolated, reverse transcriptase polymerase chain reaction (RT-PCR) and genomic sequencing are used to determine the serotype (i.e., 1, 2, or 3), and whether the virus is a wild, vaccine (Sabin), or VDPV strain.

Because viral shedding may be intermittent and the amount of virus declines after paralysis onset, it is recommended to collect two stool specimens at least 24 hours apart and within 14 days of onset of symptoms. Poliovirus may be detected during the first 3 to 10 days after paralysis onset in oropharyngeal specimens, but stool specimens are preferred.

## Serology

Serology for all three types of poliovirus is currently not available in most laboratories because of new regulations for poliovirus containment. Furthermore, serology has several limitations. Two specimens are needed, one early in the course of the illness and another three weeks later. A four-fold rise in the titer of the second specimen suggests poliovirus infection, and two negative specimens may rule out poliovirus infection. However, immunocompromised patients may have two titers with no antibody detected and still be infected with poliovirus. Among immunocompetent patients, the four-fold increase may not be observed because neutralizing antibodies appear early and may exist at the time of hospitalization, or the patient may have antibodies from prior vaccination.

## Epidemiology

### Occurrence

At one time, poliovirus infection occurred throughout the world. Vaccination resulted in reduced circulation of wild poliovirus and its elimination from the United States in 1979. A polio eradication program conducted by the Pan American Health Organization led to elimination of polio in the Western Hemisphere in 1991. The Global Polio Eradication Program has

### Poliovirus Epidemiology

- Reservoir
  - Human
- Transmission
  - Fecal-oral or oral-oral
- Temporal pattern
  - Peaks in the summer in temperate climates; no season pattern in tropical climates
- Communicability
  - Highly infectious days before and after onset of symptoms
  - Most infectious in the days immediately before and after onset of symptoms

dramatically reduced wild poliovirus transmission throughout the world. Type 2 and 3 wild poliovirus have been eradicated worldwide and endemic circulation of type 1 wild poliovirus persists only in two countries.

## Reservoir

Humans are the only known reservoir of poliovirus, which is transmitted most frequently by persons with inapparent infections. There is no asymptomatic carrier state except in immunocompromised persons.

## Transmission

Person-to-person spread of poliovirus occurs via the fecal-oral or oral-oral routes. The fecal-oral route is the most important transmission pathway in settings with suboptimal hygiene and sanitation.

## Temporal Pattern

Poliovirus infection typically peaks in the summer months in temperate climates. There is no seasonal pattern in tropical climates.

## Communicability

Poliovirus is highly infectious, with seroconversion rates among susceptible household contacts of children nearly 100%, and greater than 90% among susceptible household contacts of adults. Persons infected with poliovirus are most infectious in the days immediately before and after the onset of symptoms, but poliovirus may remain present in the stool for up to 6 weeks.

## Secular Trends in the United States

Before the 18th century, polioviruses probably circulated widely. Initial infections with at least one type probably occurred in early infancy, when transplacentally acquired maternal antibodies were high and protected infants from infection-causing paralysis.

In the immediate prevaccine era, during the first half of the 20th century, improved sanitation resulted in less frequent exposure and increased the age of primary infection, resulting in large epidemics with high numbers of deaths. The incidence dramatically decreased after the introduction of inactivated polio vaccine (IPV) in 1955 and continued to decline following oral polio vaccine (OPV) introduction in 1961. From the more than 21,000 paralytic cases reported in 1952, only 2,525 cases were reported in 1960 and 61 cases in 1965.

The last cases of locally-acquired paralytic poliomyelitis caused by wild poliovirus in the United States were reported in 1979, during an outbreak in Amish communities in several

### Poliovirus Secular Trends in the United States

- Before the 18th century, polioviruses probably circulated widely
- In immediate prevaccine era, improved sanitation resulted in less frequent exposure and increased age of primary infection, resulting in large epidemics with high death count
- Incidence dramatically decreased following inactivated polio vaccine (IPV) introduction in 1955
- Last cases of locally-acquired paralytic poliomyelitis caused by wild poliovirus in the U.S. reported in 1979
- Last case of vaccine-associated paralytic polio (VAPP) acquired in the U.S. reported in 1999

Midwestern states. Epidemiologic and virologic evidence indicated that this outbreak was seeded by an importation from the Netherlands.

From 1980–1999, 162 confirmed cases of paralytic poliomyelitis were reported in the United States, an average of 8 cases per year. Six cases were caused by wild poliovirus acquired outside the United States and two cases were classified as indeterminant (no poliovirus isolated from samples obtained from the patients, and patients had no history of recent vaccination or direct contact with a vaccine recipient). The remaining 154 (95%) cases were vaccine-associated paralytic polio (VAPP) caused by the Sabin poliovirus strains contained in OPV vaccine.

In order to eliminate VAPP from the United States, the Advisory Committee on Immunization Practices (ACIP) recommended in 2000 exclusive use of IPV vaccine. The last case of VAPP acquired in the United States was reported in 1999. Paralysis caused by VDPV was reported in an immunocompromised person in 2009, who was likely infected with vaccine poliovirus 12 years prior to the onset of paralysis. In 2005, asymptomatic infections with a circulating VDPV were detected in several unvaccinated children in Minnesota. The source of the virus was not determined, but it appeared to have been circulating undetected in an unidentified location, possibly another country, for at least 2 years based on genetic changes in the virus.

Among children born during 2015 or 2016, 92.7% had received at least 3 doses of poliovirus vaccine by age 24 months, compared to 91.7% for children born during 2013 or 2014.

## Eradication

Following the widespread use of poliovirus vaccine in the mid-1950s, the incidence of poliomyelitis declined rapidly in many industrialized countries.

In 1985, the member countries of the Pan American Health Organization adopted the goal of eliminating poliomyelitis from the Western Hemisphere by 1990. The strategy to achieve this goal included increasing vaccination coverage; enhancing surveillance for suspected cases (i.e., surveillance for acute flaccid paralysis); and using supplemental immunization strategies such as national immunization days, house-to-house vaccination, and containment activities. In 1994, an international commission certified the Western Hemisphere to be free of indigenous wild poliovirus.

Following the success in the Americas, the World Health Assembly adopted the goal of global eradication of poliovirus in 1988. The polio eradication initiative is led by a coalition of

## Poliomyelitis Eradication

- **Mid-1950s**—Widespread use of poliovirus vaccine
- **1988**—Polio paralyzed ~350,000 individuals per year in more than 125 countries
- **1994**—Western Hemisphere free of indigenous wild poliovirus
- **2015**—Type 2 wild poliovirus eradicated
- **2019**—Type 3 wild poliovirus eradicated
- **2019**—Only 125 cases caused by wild poliovirus globally (99% reduction from 1988) and endemic in only two countries
- **2019**—Low routine immunization and poor vaccination campaigns resulted in re-emergence of type 2 VDPV

## Wild Poliovirus 1988



## Wild Poliovirus 2018



international organizations including WHO, the United Nations Children's Fund (UNICEF), CDC, Rotary International, the Bill and Melinda Gates Foundation, and Gavi.

Substantial progress has been made towards polio eradication. In 1988, polio paralyzed an estimated 350,000 individuals per year in more than 125 countries. By 2019, only 125 cases caused by wild poliovirus were reported globally, a reduction of more than 99% from 1988, and polio remained endemic in only two countries. The Global Commission for the Certification of Poliomyelitis Eradication declared type 2 wild poliovirus eradicated in 2015 and type 3 wild poliovirus eradicated in 2019. Unfortunately, low coverage with routine immunization and poor quality of vaccination campaigns conducted before the trivalent-to-bivalent switch have resulted in re-emergence of type 2 VDPV. In 2019, circulating type 2 VDPV caused outbreaks in 20 countries in Africa and Asia and paralyzed 369 children.

## Poliovirus Vaccines

- IPV (IPOL)
- Combination vaccines
  - DTaP-HepB-IPV (Pediarix)
  - DTaP-IPV/Hib (Pentacel)
  - DTaP-IPV (Kinrix)
  - DTaP-IPV (Quadracel)
  - DTaP-IPV-Hib-HepB (Vaxelis) (licensed but not yet available for use)

## Poliovirus Vaccines

Inactivated poliovirus (IPV) vaccine was licensed for use in 1955 and was used extensively from that time until the early 1960s.

In 1961, type 1 and 2 monovalent oral poliovirus (mOPV) vaccines were licensed, followed by type 3 mOPV vaccine in 1962, and trivalent OPV (tOPV) vaccine in 1963. Oral poliovirus (OPV) vaccine contains live poliovirus strains (Sabin) derived from wild polioviruses and attenuated by repeated passages through cells to induce mutations that reduce their neurovirulence and transmissibility.

Upon ingestion of OPV vaccine, the live attenuated polioviruses replicate in the intestinal mucosa and lymphoid cells in the oropharynx and intestine, in a similar manner to wild poliovirus infection. Vaccine viruses are excreted in the stool of the vaccinated person for up to 6 weeks after a dose, with maximum shedding in the first 1 to 2 weeks after vaccination. Vaccine viruses may spread from the recipient to contacts. Persons in contact with fecal material of a vaccinated person may be exposed and infected with vaccine virus. Replication and shedding of vaccine virus in stools may occur upon intake of a new OPV vaccine dose, but the duration of shedding is usually short and virus concentration in stools is lower.

Trivalent OPV vaccine largely replaced IPV vaccine as the vaccine of choice in the United States and most other countries of the world until the late 1990s. The nearly exclusive use of tOPV vaccine led to elimination of wild poliovirus from the United States in less than 20 years. However, one case of VAPP occurred for every 2 to 3 million doses of tOPV vaccine administered. The burden of VAPP in industrialized countries resulted in progressive discontinuation of OPV vaccine.

In 1996, the Advisory Committee on Immunization Practices (ACIP) recommended an increase in use of IPV through a sequential schedule of IPV followed by tOPV to reduce the occurrence of VAPP. The sequential schedule eliminated VAPP among vaccine recipients by producing humoral immunity to polio with inactivated polio vaccine prior to exposure to live vaccine virus. Since tOPV was still used for the third and fourth doses, a risk of VAPP would continue to exist among contacts of vaccine recipients, who were exposed to live vaccine virus in the stool of vaccine recipients.

The sequential IPV–OPV polio vaccination schedule was widely accepted by both providers and parents. Fewer cases of VAPP were reported in 1998–1999, suggesting an impact of the increased use of IPV vaccine. To further the goal of complete elimination of paralytic polio in the United States, in 1999 ACIP recommended that IPV vaccine be used exclusively. Exclusive use of IPV vaccine eliminated the shedding of live vaccine virus, eliminating any indigenous VAPP.

Among the 3 wild poliovirus types, type 2 was declared eradicated in 2015. To remove the risk for infection with circulating type 2 VDPV (cVDPV2), in 2016 all OPV-using countries simultaneously switched from tOPV to bivalent OPV (bOPV) vaccine, which contains only types 1 and 3 polioviruses, following a directive from the World Health Organization. One or several doses of IPV vaccine is used in all countries, either exclusively or in combined schedules with bOPV. Use of mOPV2 in response to cVDPV2 outbreaks must be approved by the Director General of the WHO; the mOPV2 Advisory Group makes recommendations for use.

Two single-antigen inactivated poliovirus (IPV) products are currently licensed for use in the United States, but only one vaccine, IPOL, is currently distributed.

There are five combination vaccines that contain IPV vaccine. DTaP–HepB–IPV (Pediarix), DTaP–IPV/Hib (Pentacel), DTaP–IPV (Kinrix), DTaP–IPV (Quadacel), and DTaP–IPV–Hib–HepB (Vaxelis) are licensed and available for use in the United States.

## Characteristics

IPV contains wild poliovirus strains grown individually in Vero cells and inactivated with formaldehyde. The initial formula developed by Jonas Salk in the 1950s was replaced by an enhanced potency formula in the late 1980s, which contains 40:8:32 units of serotypes 1, 2, and 3, respectively. IPV vaccine is administered by either subcutaneous or intramuscular injection. Each dose of IPV vaccine contains antibiotics neomycin, streptomycin, and polymyxin B, and the preservative 2-phenoxyethanol. It contains no adjuvant. Specific ingredients to combination vaccines containing IPV vaccine differ.

### Poliovirus Vaccine Characteristics (IPV)

- Grown in monkey kidney (Vero) cells
- Inactivated with formaldehyde
- Contains serotypes 1, 2, and 3
- Administered by either subcutaneous or intramuscular injection
- Contains neomycin, streptomycin, polymyxin B, 2-phenoxyethanol

## Polio Vaccination Schedule (IPV)

- Typically administered at age 2, 4, 6 through 18 months, and 4 through 6 years
- Recommended interval between each of the first 3 doses is 2 months
- Recommended interval between dose 3 and dose 4 is at least 6 months
- Minimum interval between doses is 4 weeks\*
- Minimum age for dose 1 is 6 weeks\*
- A dose on or after age 4 years is recommended regardless of number of previous doses

\*Recommended only if vaccine recipient is at risk for imminent exposure to circulating poliovirus (e.g. outbreak or travel to endemic region)

## Vaccination Schedule and Use

The first dose of IPV vaccine may be administered as early as age 6 weeks but is usually administered at age 2 months, with a second dose at age 4 months. The third dose should be given at age 6 through 18 months of age. The recommended interval between the doses in the primary series is 2 months. However, if accelerated protection is needed, the minimum interval between each of the first 3 doses of IPV vaccine is 4 weeks. The final dose in the IPV series should be administered at age 4 through 6 years and at least 6 months after the previous dose. A dose of IPV vaccine on or after age 4 years is recommended regardless of the number of previous doses.

Shorter intervals between doses or beginning the series at a younger age may lead to lower seroconversion rates. Consequently, the use of the minimum age (6 weeks) and minimum intervals between doses in the first 6 months of life is recommended only if the vaccine recipient is at risk for imminent exposure to circulating poliovirus (e.g., during an outbreak or because of travel to a polio-endemic region).

IPV vaccine should be given at the same visit as other recommended vaccines.

## Combination Vaccines

### DTaP-HepB-IPV (Pediarix)

DTaP-HepB-IPV vaccine is approved for use as a 3-dose series for children age 6 weeks through 6 years. It is administered to infants at age 2, 4, and 6 months. The minimum intervals for DTaP-HepB-IPV vaccine are determined by the DTaP component. The 3 doses must be separated by at least 4 weeks between doses. Because the minimum age for the first dose of DTaP-HepB-IPV vaccine is 6 weeks, this vaccine cannot be used for the birth dose of hepatitis B (HepB) vaccine. The final dose of DTaP-HepB-IPV vaccine should be administered at age 24 weeks or older, the minimum age for completion of the hepatitis B vaccine series. When DTaP-HepB-IPV vaccine is used to provide 3 doses at age 2, 4, and 6 months (based on the DTaP and IPV schedules), this will result in a 4-dose HepB vaccine series, which is acceptable.

### DTaP-IPV/Hib (Pentacel)

DTaP-IPV/Hib vaccine is approved for use as a 4-dose series for children age 6 weeks through 4 years. It is administered to infants at age 2, 4, 6, and 15 through 18 months. The minimum intervals for DTaP-IPV/Hib vaccine are determined by the DTaP component. The first 3 doses must be separated by at least 4 weeks between doses. Dose 4 must be separated from dose 3 by at least 6 months, and should not be administered before age 12 months. When DTaP-IPV/Hib vaccine is used to provide 4 doses at age 2, 4, 6, and between 15 through 18 months (based on the DTaP and Hib schedules), an additional



booster dose with IPV-stand alone or DTaP-IPV vaccine should be administered at age 4 through 6 years. This will result in a 5-dose IPV vaccine series, which is acceptable.

### **DTaP-IPV-Hib-HepB (Vaxelis)**

DTaP-IPV-Hib-HepB is approved for use as a 3-dose series for children age 6 weeks through 4 years. It is administered to infants at age 2, 4, and 6 months. The minimum intervals for DTaP-IPV-Hib-HepB vaccine are determined by the DTaP component. The 3 doses must be separated by at least 4 weeks between doses. Because the minimum age for the first dose of DTaP-IPV-Hib-HepB vaccine is 6 weeks, this vaccine cannot be used for the birth dose of hepatitis B (HepB) vaccine. The final dose of DTaP-IPV-Hib-HepB vaccine should be administered at age 24 weeks or older, the minimum age for completion of the hepatitis B vaccine series. When DTaP-IPV-Hib-HepB vaccine is used to provide 3 doses at age 2, 4, and 6 months (based on the DTaP and IPV schedules), this will result in a 4-dose HepB vaccine series, which is acceptable.

### **DTaP-IPV (Kinrix)**

DTaP-IPV (Kinrix) vaccine is approved only for dose 5 of DTaP vaccine and dose 4 of IPV vaccine in children age 4 through 6 years whose previous DTaP vaccine doses have been with Infanrix and/or Pediarix for dose 1, 2, and 3 and Infanrix for dose 4. However, if DTaP-IPV (Kinrix) vaccine is administered to children who received another brand of DTaP vaccine for prior DTaP vaccine doses, or if administered as dose 1, 2, 3, or 4 of the DTaP vaccine series or dose 1, 2, or 3 of the IPV vaccine series, the dose of DTaP-IPV (Kinrix) does not need to be repeated.

### **DTaP-IPV (Quadracel)**

DTaP-IPV (Quadracel) vaccine is approved only for dose 5 of DTaP vaccine and dose 4 or 5 of IPV vaccine in children age 4 through 6 years who have received 4 doses of Pentacel and/or Daptacel vaccine. However, if DTaP-IPV (Quadracel) vaccine is administered to children who received another brand of DTaP vaccine for prior DTaP vaccines doses, or if administered as dose 1, 2, 3, or 4 of the DTaP vaccine series or dose 1, 2, or 3 of the IPV series, the dose of DTaP-IPV (Quadracel) does not need to be repeated.

### **Polio Vaccination of Adults**

Routine vaccination of adults (age 18 years or older) who reside in the United States is not necessary or recommended because most adults are already immune due to childhood vaccination and have a very small risk of exposure to wild poliovirus in the United States.

Some adults, however, are at increased risk of exposure to poliovirus. These include laboratory workers handling specimens that may contain polioviruses, healthcare personnel

#### **Poliovirus Vaccination of Adults**

- Routine vaccination of adults age 18 or older in the U.S. is not necessary or recommended
- Laboratory workers handling poliovirus-containing specimens, healthcare personnel treating patients with possible polio, and travelers to areas where poliomyelitis is endemic or epidemic may need vaccination
  - Adults at risk without record of polio vaccination should receive primary immunization

treating patients who could have polio or have close contact with a person who could be infected with poliovirus, and travelers to areas where poliomyelitis is endemic or epidemic.

Recommendations for poliovirus vaccination of these adults depends upon previous vaccination history and time available before protection is required.

When an adult at increased risk of exposure to poliomyelitis has never received polio vaccine or does not have a written record of polio vaccination, primary immunization with IPV is recommended. The recommended schedule is 2 doses separated by 1 to 2 months, and a third dose administered 6 to 12 months after the second dose. The minimum interval between dose 2 and dose 3 is 6 months.

In some circumstances time will not allow completion of this schedule. If 8 weeks or more are available before protection is needed, 3 doses of IPV vaccine should be given at least 4 weeks apart. If 4 to 8 weeks are available before protection is needed, 2 doses of IPV vaccine should be given at least 4 weeks apart. If less than 4 weeks are available before protection is needed, a single dose of IPV vaccine is recommended. In all instances, the remaining doses of vaccine should be given later, at the recommended intervals, if the person remains at increased risk.

## **Poliovirus Vaccine Efficacy (IPV)**

- Highly effective in producing immunity to poliovirus
- 90% or more immune after 2 doses
- At least 99% immune after 3 doses
- Duration of immunity not known with certainty, although probably lifelong

## **Immunogenicity and Vaccine Efficacy**

IPV vaccine is highly effective in producing immunity to poliovirus and protection from paralytic poliomyelitis. Ninety percent or more of vaccine recipients develop protective antibody to all three poliovirus types after 2 doses, and at least 99% are immune following 3 doses.

IPV vaccine prevents wild poliovirus from reaching the central nervous system in recipients, thus preventing paralysis. Protection against paralytic disease correlates with the presence of antibody after vaccination. IPV vaccine appears to produce less local gastrointestinal immunity than does OPV vaccine. Individuals who receive IPV vaccine usually do not shed virus in nasopharynx but excrete virus in stools following exposure to wild or vaccine poliovirus. The duration of shedding and amount of virus in the stool of IPV-vaccinated individuals is similar to that of unvaccinated individuals, if they have never been exposed to live poliovirus (vaccine or wild). The duration of immunity with IPV is not known with certainty, although it probably provides lifelong immunity after a complete series.

OPV vaccine is highly effective in producing immunity to poliovirus. Because of interference among serotypes during intestinal replication, a single dose of tOPV produces immunity to all three vaccine viruses in approximately 50% of recipients. OPV vaccine produces local intestinal immunity, which reduces

shedding of virus upon re-infection with poliovirus of the same serotype and reduces potential transmission. Subsequent doses cause less interference during intestinal replication and 3 doses produce immunity to all three poliovirus types in more than 95% of recipients in industrialized countries. As with other live-virus vaccines, immunity from oral poliovirus vaccine is probably lifelong.

## Contraindications and Precautions to Vaccination

As with other vaccines, a history of a severe allergic reaction (anaphylaxis) to a vaccine component or following a prior dose is a contraindication to further doses. Moderate or severe acute illness (with or without fever) in a patient is considered a precaution to vaccination, although persons with minor illness may be vaccinated.

Since IPV contains trace amounts of streptomycin, neomycin, and polymyxin B, there is a possibility of allergic reactions in persons sensitive to these antibiotics. Persons with allergies that are not anaphylactic, such as skin contact sensitivity, may be vaccinated.

Contraindications to combination vaccines that contain IPV include the contraindications to the individual component vaccines (e.g., DTaP, hepatitis B), but specific ingredients might differ.

## Pregnancy

Pregnancy is a precaution to IPV vaccination. Although no adverse effects of IPV vaccine have been documented among pregnant women or their fetuses, vaccination of pregnant women should be avoided on theoretical grounds. However, if a pregnant woman is at increased risk for infection and requires immediate protection against polio, IPV vaccine can be administered in accordance with the recommended schedule for adults.

## Vaccine Safety

In pre-licensure trials of enhanced-potency IPV, local reactions were mild and transient. Participants reported induration (18%), pain (13%), and erythema (3.2%) within 48 hours after vaccination. Systemic reactions reported were fever (38% reported temperature  $\geq 39^{\circ}\text{C}$ ), irritability, sleepiness, fussiness and crying. Study participants received DTP at the same time as IPV and therefore these systemic reactions could not be attributed to a specific vaccine. However, the frequency and severity of these reactions were comparable to that reported when DTP is given alone.

### Poliovirus Vaccine Contraindications and Precautions (IPV)

- Contraindication
  - Severe allergic reaction to a vaccine component or following a prior dose of vaccine
- Precaution
  - Moderate or severe acute illness
  - Pregnancy, unless at increased risk and requiring immediate protection against polio

### Poliovirus Vaccine Safety

#### IPV

- Local reactions mild and transient
- Induration, pain, erythema
  - 3.2%-18%
- Fever ( $39^{\circ}\text{C}$ )
  - 38%

#### OPV

- VAPP occurs very rarely

No increased risks for serious adverse events have been observed in countries relying on all-IPV schedules. After the expanded use of IPV in the United States, a review of the Vaccine Adverse Events Reporting System from 1991 through 1998 did not show an increase in the reporting rate for poliovirus vaccine-associated adverse events with the increased use of IPV. In addition, the distribution of symptoms grouping was comparable for IPV and OPV.

VAPP occurs very rarely after administration of OPV vaccine. The mechanism of VAPP is believed to be a mutation, or reversion, of the attenuated vaccine poliovirus to a more neurotropic form. Reversion is believed to occur in almost all vaccine recipients, but it only rarely results in paralytic disease. The paralysis that results is identical to that caused by wild poliovirus. IPV vaccine does not contain live virus, so it cannot cause VAPP.

The risk of VAPP is 7 to 21 times higher for the first dose than for any other dose in the series. VAPP is more likely to occur in persons age 18 years or older than in children, and it is almost 7,000 times higher for persons with certain types of immunodeficiencies, particularly B-lymphocyte disorders (e.g., agammaglobulinemia and hypogammaglobulinemia), which reduce the synthesis of immune globulins.

VDPVs are genetically divergent forms of vaccine strains. VDPVs develop through prolonged replication of vaccine strains contained in OPV in an immunodeficient individual or in a community with poor vaccination coverage and have re-acquired the neurovirulence and transmissibility of wild poliovirus. The risks of paralysis and manifestations of paralysis caused by VDPVs are similar to those of wild poliovirus of the same serotype. Outbreaks of circulating VDPVs have been responsible for more than 1,200 cases of paralytic polio during 2000–2019 and have exceeded the wild poliovirus case count since 2017.

## Vaccine Storage and Handling

IPV vaccine should be maintained at refrigerator temperature between 2°C and 8°C (36°F and 46°F). Manufacturer package inserts contain additional information. For complete information on best practices and recommendations, please refer to CDC's *Vaccine Storage and Handling Toolkit*, [www.cdc.gov/vaccines/hcp/admin/storage/toolkit/storage-handling-toolkit.pdf](http://www.cdc.gov/vaccines/hcp/admin/storage/toolkit/storage-handling-toolkit.pdf).

## Surveillance and Reporting of Poliomyelitis

For information on guidance for state and local health department staff who are involved in surveillance activities for vaccine-preventable diseases, please consult the *Manual for the Surveillance of Vaccine-Preventable Diseases*, [www.cdc.gov/vaccines/pubs/surv-manual/chapters.html](http://www.cdc.gov/vaccines/pubs/surv-manual/chapters.html).

## Acknowledgements

The editors would like to acknowledge Valerie Morelli and Ginger Redmon for their contributions to this chapter.

## Selected References

- CDC. International notes certification of poliomyelitis elimination– the Americas, 1994. *MMWR* 1994;43(39):720 –2.
- CDC. Immunization schedules. Atlanta: CDC; 2020. [www.cdc.gov/vaccines/schedules/hcp/index.html](http://www.cdc.gov/vaccines/schedules/hcp/index.html). Accessed August 29, 2020.
- CDC. Poliomyelitis prevention in the United States: updated recommendations of the Advisory Committee on Immunization Practices (ACIP). *MMWR* 2000;49(RR-5):1–22.
- CDC. Updated recommendations of the Advisory Committee on Immunization Practices (ACIP) regarding routine poliovirus vaccination. *MMWR* 2009;58(30):829–30.
- Chard A, Datta S, Tallis G, et al. Progress toward polio eradication - worldwide, January 2018-March 2020. *MMWR* 2020;69(25)784–9.
- DeVries A, Harper J, Murray A, et al. Vaccine-derived poliomyelitis 12 years after infection in Minnesota. *N Engl J Med* 2011;364(24):2316–23.
- Food and Drug Administration. Prescribing information (package insert). IPOL (poliovirus vaccine inactivated). Silver Spring, MD: U.S. Department of Health and Human Services, Food and Drug Administration; 2019. <https://www.fda.gov/media/75695/download>. Accessed October 13, 2020.
- Global Polio Eradication Initiative. Global wild and circulating vaccine-derived poliovirus cases, 2018-2019 (data as of 24 August 2020). [polioeradication.org/polio-today/polio-now/this-week](http://polioeradication.org/polio-today/polio-now/this-week). Accessed August 28, 2020.
- Prevots D, Sutter R, Strebel P, et al. Completeness of reporting for paralytic polio, United States, 1980 through 1991. *Arch Pediatr Adolesc Med* 1994;148(5):479–85.
- Sutter R, Kew O, Cochi S, et al. Poliovirus vaccine—live. In Plotkin S, Orenstein W, Offit P, eds. *Plotkin’s Vaccines*. 7th ed. Philadelphia, PA: Elsevier;2018:866–917.
- Vidor E. Poliovirus vaccine—inactivated. In Plotkin S, Orenstein W, Offit P, eds. *Plotkin’s Vaccines*. 7th ed. Philadelphia, PA: Elsevier;2018:841–865.

## NOTES

