

Combating a resurgence of poliomyelitis through public health surveillance and vaccination

Chia Yin Chong^{1,2,3,4}*FRCPC*, Kai-Qian Kam^{1,2,3,4}*MMed (Paeds)*, Chee Fu Yung^{1,3,4}*FFPH*

ABSTRACT

Poliomyelitis, or polio, is a highly infectious disease and can result in permanent flaccid paralysis of the limbs. Singapore was certified polio-free by the World Health Organization (WHO) on 29 October 2000, together with 36 other countries in the Western Pacific Region. The last imported case of polio in Singapore was in 2006. Fortunately, polio is vaccine-preventable—the world saw the global eradication of wild poliovirus types 2 and 3 achieved in 2015 and 2019, respectively. However, in late 2022, a resurgence of paralytic polio cases from vaccine-derived poliovirus (VDPV) was detected in countries like Israel and the US (specifically, New York); VDPV was also detected during routine sewage water surveillance with no paralysis cases in London, UK. Without global eradication, there is a risk of re-infection from importation and spread of wild poliovirus or VDPV, or new emergence and circulation of VDPV. During the COVID-19 pandemic, worldwide routine childhood vaccination coverage fell by 5% to 81% in 2020–2021. Fortunately, Singapore has maintained a constantly high vaccination coverage of 96% among 1-year-old children as recorded in 2021. All countries must ensure high poliovirus vaccination coverage in their population to eradicate poliovirus globally, and appropriate interventions must be taken to rectify this if the coverage falters. In 2020, WHO approved the emergency use listing of a novel oral polio vaccine type 2 for countries experiencing circulating VDPV type 2 outbreaks. Environmental and wastewater surveillance should be implemented to allow early detection of “silent” poliovirus transmission in the population, instead of relying on clinical surveillance of acute flaccid paralysis based on case definition alone.

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INTRODUCTION

Singapore was certified poliomyelitis (polio)-free by the World Health Organization (WHO) on 29 October 2000, together with 36 other countries in the Western Pacific Region.¹ Prior to certification, there were multiple outbreaks in 1958, 1960 and 1963 with 415, 196 and 74 paralytic polio cases, respectively.^{2–4} The nationwide immunisation programme in Singapore using the oral poliovirus vaccines (OPV) led to a marked decrease in outbreaks of polio. No case of indigenous polio was reported from 1978 onwards.¹ The last imported case of polio in Singapore was in 2006 when a 2-year-old Nigerian girl presented with left lower limb paralysis and her stool was positive for wild poliovirus (WPV) type 1.⁵

In this review, we seek to provide an update on the clinical manifestations of polio, other infections that can mimic polio, and the history of poliovirus vaccination. We also describe the status of global eradication efforts since the COVID-19 pandemic and highlight key public health interventions necessary to mitigate the risk of poliovirus outbreaks globally.

Characteristics of poliovirus

“Poliomyelitis” originates from the Greek words “polio” and “myelon”, which mean “grey” and “marrow”, respectively, due to its effect on the spinal cord. It is a highly infectious disease caused by one of the three poliovirus serotypes (poliovirus types 1, 2 or 3), belonging

¹ Infectious Disease Service, Department of Paediatrics, KK Women’s and Children’s Hospital, Singapore

² Yong Loo Lin School of Medicine, National University of Singapore, Singapore

³ Duke-NUS Medical School, Singapore

⁴ Lee Kong Chian School of Medicine, Nanyang Technological University, Singapore

Correspondence: Dr Chia Yin Chong, Infectious Disease Service, Department of Pediatrics, KK Women’s and Children’s Hospital, 100 Bukit Timah Road, Singapore 229899.

Email: Chong.chia.yin@singhealth.com.sg

CLINICAL IMPACT

What is New

- Recently, in late 2022, a resurgence of paralytic poliomyelitis (polio) cases from vaccine-derived poliovirus (VDPV) was detected in countries such as Israel and the US, which have been polio-free since 1989 and 1979, respectively.
- VDPV was also detected during routine sewage water surveillance in the UK.
- During the COVID-19 pandemic, global routine childhood vaccination coverage fell by 5% to 81% in 2020–2021.

Clinical Implications

- Poliovirus vaccination programme is critical, and the novel oral poliovirus vaccine 2 may boost global eradication efforts.
- Environmental and wastewater surveillance may facilitate early detection of “silent” poliovirus transmission.

to the *Enterovirus* genus and *Picornaviridae* family.⁶ Poliovirus can survive in the environment (soil and water) for months at 4°C, but viral infectivity can be reduced by heating. Poliovirus is resistant to common detergents and lipid solvents, but can be inactivated by formaldehyde, heat or chlorine.^{6,7}

Humans are the only reservoir for poliovirus, and it can be transmitted from a symptomatic or asymptomatic carrier via the faecal-oral or oral-oral route. Transmission can also occur through close contact via oral exposure to cough or sneeze droplets. The faecal-oral route is more common in areas with poor sanitation, especially among the non-immune population. Poliovirus is most contagious from 7–10 days before and after the onset of symptoms.⁸ Immunocompetent infected persons can shed poliovirus in the pharynx and stools for around 2 and 4 weeks, respectively.⁸ In contrast, immune-compromised persons can shed the virus for a longer period of time, with a median length of excretion of 1.3 years.⁹ The development of mucosal immune responses in the form of immunoglobulin A is associated with a decrease in viral replication, shedding and risk of transmission.^{10,11} Hence, persons with deficiencies in mucosal immune responses are at higher risk of prolonged poliovirus shedding and viral transmission.^{10,11}

Clinical presentation of poliomyelitis

The poliovirus enters through the oral route and multiplies in the oropharynx, tonsils, cervical lymph nodes and gastrointestinal tract. In the gastrointestinal tract, the virus can invade lymphoid tissue; it may enter the bloodstream to infect the central nervous system, causing the destruction of motor neurons.

Poliovirus can lead to one of the following disease manifestations: (1) asymptomatic infection; (2) abortive polio or minor illness; (3) non-paralytic polio or aseptic meningitis; or (4) paralytic polio, which is the most severe presentation. Table 1 summarises the characteristics of each disease manifestation.^{6,7,12–19} Paralytic polio is extremely rare and seen in <1% of poliovirus infections. Therefore, the detection of a single case of polio will suggest wider unknown transmission in the population. Patients can present with severe back, neck and muscle pain associated with involvement of the spinal, mixed spinal-bulbar or bulbar paralysis. Bulbar polio has the highest mortality due to the involvement of the brainstem neurons. Involvement of the respiratory muscles can also lead to death. Poliomyelitis can also occur where patients present with confusion and seizures with upper motor neuron signs, which are indistinguishable from other viral encephalitis.¹⁷ Sensory involvement never occurs in polio.

In children and rarely in adults, paralytic spinal polio can present classically with a biphasic course. This course is an initial period of minor illness followed by a brief symptom-free period of up to 10 days and subsequent rapid onset of acute flaccid paralysis (AFP) with asymmetrical paralysis, loss of deep tendon reflexes, fever, headache, neck stiffness and cerebrospinal fluid (CSF) pleocytosis.^{13,14} Recovery may occur in some patients. In around 50% of the survivors of paralytic polio, a non-infectious post-polio syndrome (PPS) can occur 8–71 years later.⁷ A new gradual onset of muscle weakness, pain and fatigue can occur in the same muscles that were affected during the course of paralytic spinal polio. Previously unaffected limb muscle groups can also be involved in PPS.

Other infectious aetiologies of AFP

AFP is a clinical syndrome characterised by an acute onset of flaccid limb weakness of <4 weeks, which can also involve the respiratory and/or swallowing muscles. Progression to maximum severity can occur within days to weeks. Other infectious aetiologies of AFP that have been described include non-polio enterovirus D68 and A71, flavivirus and human herpesvirus. Table 2 summarises the characteristics of other infections

Table 1. Summary of clinical manifestations of poliovirus infection^{6,7,12-19}

Clinical manifestation	Frequency	Presenting symptoms/signs	Diagnosis	Prognosis
Asymptomatic infection	75–95% of infection	Asymptomatic or minor malaise.	Detected through isolation or polymerase chain reaction (PCR) of poliovirus from faeces or oropharynx, or through serology testing during poliovirus epidemic or outbreaks, as symptoms/presentation are not specific to poliovirus infection.	Complete recovery without complications
Abortive polio/ minor illness	4–24% of infection	Transient illness with nonspecific symptoms including fever, malaise, drowsiness, nausea, anorexia, vomiting, constipation, headache and sore throat; normal neurological examination.	Detected through isolation or PCR of poliovirus from faeces or oropharynx.	High mortality for bulbar polio or spinal-bulbar polio involving the medulla, leading to cardio-respiratory compromise and death; high mortality for polioencephalitis.
Nonparalytic polio/ aseptic meningitis	1–4% of infection	Symptoms are similar to abortive polio but with the addition of meningeal irritation, neck stiffness, severe headache and pain over the limbs, back and neck that develop 1–2 days later. The illness lasts for up to 2 weeks.	CSF biochemical markers are similar to those found in viral meningitis. CSF can have increased leucocytes with a high ratio of polymorphonuclear cells to lymphocytes during early disease. CSF total protein can also be elevated at an average of 40–50mg/dL. CSF glucose level is usually normal. Unlike other viral causes of aseptic meningitis, poliovirus is rarely isolated from CSF.	Permanent weakness in two-thirds of patients. Complete recovery is less likely if presenting symptoms of paralysis are severe.
Paralytic polio	<1% of infection	<u>Spinal paralytic polio</u> Initial period of minor illness followed by a brief symptom-free period of up to 10 days and subsequent rapid onset of acute flaccid paralysis (AFP), loss of deep tendon reflexes, paraesthesia, fever, headache, neck stiffness and cerebrospinal fluid (CSF) pleocytosis. Lower motor neuron signs appear with classical asymmetrical distribution of flaccid paralysis. Lower limbs are more commonly affected than upper limbs. Sensory involvement is very rare. <u>Bulbar paralytic polio</u> Paralysis of cranial nerves especially the ninth and tenth cranial nerves innervating the soft palate and pharynx, without limb weakness. Patients can present with dysphagia, dyspnoea and pooling of saliva. <u>Polioencephalitis</u> Agitation, confusion, disturbances of consciousness, seizures, autonomic dysfunction and upper motor neuron signs.		
Post-polio syndrome (PPS)	Around 50% of survivors of paralytic polio	A non-infectious syndrome can occur in survivors of paralytic polio from 8–71 years later. New gradual onset of muscle weakness, pain and fatigue can occur in the same muscles that were affected during the course of paralytic polio, or previously unaffected limb muscle groups can also be involved in PPS.	No specific test for diagnosis. Most experts have validated the diagnostic criteria by Halstead et al.¹⁹ PPS is a diagnosis of exclusion and all potential medical or surgical causes must be excluded before diagnosis of PPS is made.	Varied prognosis. In some cases, affected persons are not severely handicapped and symptoms stabilised over time. In severe cases, PPS can lead to skeletal deformities, affecting a person's ability to perform simple tasks of daily living.

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that can lead to AFP.^{20–26} As poliovirus is only one of the causes of AFP, and there are other infections and immune-mediated syndromes that can mimic polio, WHO uses a screening case definition for surveillance of AFP to evaluate polio outbreaks.¹² This definition includes any case of AFP in children aged <15 years old, or a person of any age where polio is suspected. Clinical vigilance in notifying health authorities early about patients who fulfil the AFP case definition is important, as part of efforts to eradicate polio.

Diagnosis of poliomyelitis

Poliovirus can be detected by isolating the virus in cell culture from isolates of stool, throat swabs, blood, CSF or by polymerase chain reaction (PCR).^{8,12} Viral culture or PCR from stool isolate is the most sensitive diagnostic method given the prolonged stool viral shedding. Isolation of the virus is also more common in pharyngeal specimens than blood or CSF. Viral isolates can subsequently undergo genome sequencing to aid in the identification of the poliovirus serotype, and differentiate between wild-type and vaccine (Sabin)-derived infection. Two samples of stool collected at least 24 hours apart within 2 weeks of symptom onset can further increase the sensitivity of the tests.²⁷ In the absence of isolates, paired acute and convalescent blood serum (with a 4-fold increase in titre during the convalescent phase) for neutralising antibodies against the three poliovirus serotypes can diagnose polio in the presence of clinical symptoms and/or epidemiological risk factors for polio. However, serologic tests cannot differentiate between wild-type and vaccine-derived polio.

Management of poliomyelitis

Currently, there is no antiviral medication for the treatment of polio. A capsid inhibitor, pocapavir, had completed a phase 1 trial and was shown to be safe and effective in improving viral clearance in immunocompromised persons.²⁸ However, there was a concern about emerging viral resistance in a group of study patients in the isolation facility.²⁸ The study was not able to accurately conclude if pocapavir had led to viral resistance directly. More studies are required to evaluate if pocapavir can indeed lead to drug resistance in immunocompromised persons and if proven so, other drug combinations may be required to overcome the resistance.

For persons who suffer from paralytic polio, various supportive management strategies including mechanical ventilation, pain management with analgesia, neurorehabilitation and use of orthotic devices have been deployed to maximise recovery and improve outcomes.

History of poliovirus vaccinations

Historically, the first available polio vaccine was the inactivated poliovirus vaccine (IPV), which was created in the 1950s and licensed in 1955. IPV was available as the trivalent form containing the three poliovirus (PV) serotypes PV1, PV2 and PV3. OPV was initially available as a monovalent form in 1961, followed by the trivalent form (tOPV) in 1963.¹² Both IPV and OPV provide substantial immunity and protection against polio, but only OPV provides intestinal immunity, while IPV provides some nasopharyngeal immunity.²⁹ OPV contains live Sabin poliovirus strains, which are derived from WPV strains attenuated by multiple passages in non-human cell culture, hence reducing neurovirulence and transmissibility.³⁰ While the attenuated PV did not cause disease, it replicated sufficiently to induce protective immunity. However, vaccine-derived poliovirus (VDPV) can undergo genetic changes during replication, such as in reversing the mutations in the viral genome that conferred the attenuation phenotype, and/or acquiring new mutations with enhanced neurovirulence.^{31,32} Since the VDPV in OPV can shed for several weeks in the oropharyngeal secretions and stools post-vaccination, the transmission of these viruses from a vaccinated person can lead to vaccine-derived paralytic polio (VDPP). VDPP is clinically identical to the paralysis caused by wild poliovirus but is a rare adverse event of OPV on its recipients and particularly, unvaccinated contacts.

The national immunisation schedule in Singapore had an all-OPV schedule comprising 6 doses of tOPV until June 2013. This was replaced with a sequential IPV-OPV schedule comprising the recommendation for 4 IPV doses given at ages 3, 4 and 5 months, with a booster dose at 18 months. A fifth dose of tOPV at 10–11 years old (primary school level 5) was recommended. The tOPV dose at 6–7 years old (primary school level 1) was discontinued at the end of 2013.

WPV type 2 virus has not been detected since 1999 and was declared to be eradicated in September 2015.¹² Consequently, WHO removed serotype 2 from tOPV in a global synchronised switch and replaced it with the bivalent OPV (bOPV) containing types 1 and 3 Sabin viruses. This became the only globally available OPV from May 2016. Monovalent OPV containing serotype 2 is only stockpiled for emergency or outbreak use.

Global eradication of WPV type 3 was declared on 24 October 2019.¹² Since 2020 when bOPV was no longer available, the national immunisation schedule in Singapore changed to an all-IPV schedule using the

Table 2. Summary of other infectious aetiologies that can lead to polio-like illness²⁰⁻²⁶

Organism	Route of transmission	Reservoir	Incubation	Clinical symptoms and conditions
Non-polio enterovirus	Faecal-oral, respiratory droplet	Humans	2 to 10 days	Enterovirus D68 Wide range of presentations from asymptomatic to mild or severe respiratory tract symptoms such as fever, cough, runny nose, sore throat, breathlessness and wheezing. Conditions related to enterovirus D68 infections include pharyngitis, severe pneumonia and respiratory failure. Acute flaccid paralysis (AFP) can occur with sudden onset of limb weakness in one or more limbs, or involvement of respiratory or bulbar muscles.
• D68				Enterovirus A71 Causes a wide range of conditions such as hand, foot and mouth disease (fever, ulcers in posterior pharynx and rashes over hands and feet), aseptic meningitis and/or encephalitis (fever, headache, neck stiffness, drowsiness and confusion), myocarditis (fever, chest pain, vomiting, loss of cardiac output and arrhythmia) and AFP.
• A71				Asymptomatic or mild to severe disease. Symptoms include cough, runny nose, sore throat, fever and rash. Severe conditions include sepsis-like presentation, meningoencephalitis and AFP. Respiratory failure, loss of tendon reflexes and cranial nerve involvement have been reported.
Human parechovirus	Respiratory droplet, faecal-oral, contact	Humans	Unknown but thought to be 2 to 14 days	
Flavivirus	Japanese encephalitis virus Bites from infected <i>Culex</i> mosquitoes in rural areas in Southeast Asia, Pacific islands and the Far East	Japanese encephalitis virus Pigs, wild birds, <i>Culex</i> mosquitoes	Japanese encephalitis 4 to 15 days	Japanese encephalitis virus Asymptomatic to symptoms of fever, nausea, vomiting, diarrhoea and myalgia lasting several days. Less than 0.1% develop encephalitis with altered mental status, agitation, confusion, seizure and psychosis. Cases of AFP with extrapyramidal symptoms of dystonic, choreoathetoid movements have been reported.
• Japanese encephalitis virus	WNV Bites from infected <i>Culex</i> mosquitoes in Europe, sub-Saharan and North Africa, and the Middle East; blood transfusions, organ transplants, vertical transmission through placenta and breastmilk transmission	WNV Birds and <i>Culex</i> mosquitoes	WNV 2 to 14 days	WNV More than 50% present with headache, generalised weakness, morbilliform rash (at the time of defervescence), fever and myalgia. Less than 1% have meningism, altered mental state, AFP with marked progression over 48 hours without sensory abnormalities, extrapyramidal symptoms, and features of parkinsonism.
• West Nile Virus (WNV)	TBE Saliva of infected tick, intake of unpasteurised milk products from viraemic livestock, blood transfusion, breastfeeding	TBE Ticks and less frequently through viraemic animals	TBE 4 to 28 days	TBE Biphasic disease occurs in 72–87% of patients with 2–10 days of illness in the first stage and a 1–21 days symptom-free interval that progresses to the second stage. Symptoms in the first stage include fever, fatigue, malaise, headache and myalgia. During the second stage, presentation ranges from mild meningitis to severe encephalitis. Myelitis and AFP involving respiratory muscles can occur. Severe disease in children younger than 3 years is rare.
• Tick-borne encephalitis virus (TBE)				

Table 2. Summary of other infectious aetiologies that can lead to polio-like illness^{20,26} (Cont'd)

Organism	Route of transmission	Reservoir	Incubation	Clinical symptoms and conditions
Human herpesvirus	<u>HSV</u>	Humans	<u>HSV</u>	<u>HSV</u>
• Herpes simplex virus (HSV)	Mucosal, oral or genital contact		2 to 12 days	Majority are asymptomatic or have mild symptoms. Other more significant symptoms include fever, myalgia, lymphadenopathy or headache. Vesicles can erupt around the site of infection (genitals, rectum or mouth) and develop into painful ulcers. Recurrent HSV infection can occur. In HSV-associated neurological manifestations, aseptic meningitis, transverse myelitis (appearing as AFP) and encephalitis (fever, confusion and seizures) can occur.
• Varicella zoster virus (VZV)	<u>VZV</u>		<u>VZV</u>	<u>VZV</u>
• Cytomegalovirus (CMV)	Direct contact, respiratory secretion, inhalation of viral aerosol from skin lesions		10 to 21 days	Prodrome of fever and malaise occur 1–2 days before the onset of generalised pruritic rash starting from the truncal area and spreading to peripheries and face. Primary or reactivation VZV infection can also lead to a range of neurological conditions such as cerebellitis, meningoencephalitis and myelitis. AFP can be one of the presenting symptoms.
• Epstein-Barr virus (EBV)	<u>CMV and EBV</u>		<u>CMV</u>	<u>CMV</u>
	Oral secretions, direct contact with infectious body fluids		3 to 12 weeks	Some are asymptomatic or have mild symptoms (fever, sore throat, fatigue and lymphadenopathy). Other symptoms include mononucleosis or hepatitis. Neurological manifestations such as encephalitis, multifocal neuropathy and polyradiculopathy (appearing as AFP) can occur, especially in immunocompromised persons.
			<u>EBV</u>	<u>EBV</u>
			4 to 6 weeks	Spectrum of illness including mild to severe symptoms. Can present with infectious mononucleosis (severe fatigue, sore throat, fever, headache, myalgia, lymphadenopathy and hepatosplenomegaly). Neurological manifestations include meningoencephalitis, transverse myelitis, Guillain-Barré syndrome (appearing as AFP) and cerebellitis.
<i>Clostridium botulinum</i>	Ingestion of spores from food (food-borne botulism); honey ingestion or environmental exposure (e.g. soil) to spores (infant botulism); contamination of wound from spores (wound botulism); inhalation of <i>C. botulinum</i> spores	Soil, aquatic sediments, intestinal tracts of birds, animals, fish and agricultural products (e.g. honey and vegetables)	<u>Food-borne botulism</u> 12 to 36 hours <u>Infant botulism</u> 3 to 30 days <u>Wound botulism</u> 4 to 14 days <u>Inhalation</u> 12 hours to 5 days	Acute, bilateral cranial neuropathy and symmetrical descending weakness (appearing as AFP). Key features include absence of fever, symmetrical neurological involvement, normal mental status, normal heart rate or bradycardia without hypotension and absence of sensory involvement. Infants with botulism can present with constipation, drooling, feeding difficulties, weak cry and hypotonia.
<i>Borrelia burgdorferi</i> and <i>Borrelia mayonii</i> (Lyme disease)	Ixodid tick species in parts of North America, Europe and Asia	White foot mouse, rodents, squirrels, chipmunks and shrews	3 to 32 days	<u>Early presentation</u> Fever, chills, headache, myalgia, arthralgia, lymphadenopathy. Erythema migrans (red, circular or oval patch of rash that expands into a bullseye, warm to touch but rarely itchy or painful) may appear at the site of the tick bite. <u>Late presentation</u> Secondary annular lesion, malar rash, migratory pain in joints and bone, osteomyelitis, atrioventricular nodal block and myopericarditis. Neurological manifestations include meningitis, cranial neuritis, myelitis (appears as AFP), cerebellar ataxia and facial palsy.

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5-in-1 vaccine (DTaP-IPV-Hib: against diphtheria, tetanus, acellular pertussis, inactivated polio and *Haemophilus influenzae* type b) or the 6-in-1 vaccine (DTaP-IPV-Hib-HepB: 5-in-1 and against hepatitis B) given at age 2, 4 and 6 months (schedule revised from 3, 4 and 5 months since 1 November 2020) followed by the fourth dose of 5-in-1 vaccine at 18 months. The fifth dose of IPV at age 10–11 years is given as a combined tetanus, diphtheria, pertussis, polio and IPV vaccine, i.e. Tdap-IPV (Adacel-Polio or Boostrix-Polio), to supplement waning immunity over time. The waning immunity effect was seen in a study from Sri Lanka whereby PV3 seropositivity was reduced to 75% among 15-year-old children despite 5 doses of OPV.³³ In another study, protective antibodies against all three serotypes persisted for at least 18 years after the administration of the last dose of OPV or IPV, with a longer duration of immunity against PV3 provided by IPV as compared to OPV.³⁴ The last seroprevalence study in Singapore conducted from 2008–2010 showed that approximately 92.3% of children aged 1–17 years had antibodies against poliovirus.³⁵

In Singapore, the infant vaccination rate (3 completed doses) for polio was 96.5% in 2018 and fairly stable (96.3–96.9%) from 2014–2018. However, the first booster dose completion in 2-year-olds decreased from 90–91% in 2014–2017 to 89.3% in 2018.³⁶ The lowest reported first booster uptake was 83% in 2003, after which it hovered at 87–91% in 2004–2010.¹ The first booster completion rates showed a worrying trend for uptake of dose at age 18 months. In addition, the booster dose uptake at 10–11 years old (primary school level 5) decreased from 97.4% in 2016–2017 to 95.2% in 2018.³⁶ Reassuringly, a local review of vaccination records extracted in November 2020–December 2021 from SingHealth polyclinics showed an improvement in vaccine uptake by 10.8% (an increase from 65.9 to 76.7%) of children at 6 months old and 2.1% (from 58.9 to 61.0%) at 12 months old after the revision from 3, 4 and 5 months to 2, 4 and 6 months.³⁷ Another study showed that during the COVID-19 pandemic from January–April 2020, there was a 0.4–10.3% drop in 5-in-1 vaccine uptake compared to January–April 2019.³⁸ After the “circuit breaker” period from 7 April–1 June 2022, routine childhood vaccinations reverted to levels from pre-COVID-19 pandemic, reflecting a temporary postponement in vaccination due to the pandemic.³⁹

In 2020, WHO approved the emergency use listing of a novel OPV type 2 (nOPV2) vaccine for countries experiencing circulating VDPV type 2 (cVDPV2) outbreaks.⁴⁰ The vaccine is a modified version of type 2 monovalent OPV that showed comparable protection

against poliovirus in clinical trials while being more genetically stable and did not revert to virulence.^{41–43} Currently, the nOPV2 vaccine is only deployed in cVDPV2 outbreaks and not for routine use globally. Available safety data on the first 65 million doses of nOPV2 use for outbreak response showed that there were no safety concerns.¹²

Re-emergence of poliovirus and public health response

In 1988, WHO established the Global Polio Eradication Initiative with the aim of achieving polio eradication by the year 2000.^{12,44} The last cases of WPV type 2 were reported in 1999 in India, and WPV type 3 in 2012 in Nigeria.¹² Despite most countries being certified polio-free, polio was declared a Public Health Emergency of International Concern by WHO in 2014 with outbreaks in certain countries.¹² In the absence of global eradication, the risk of re-infection from the importation of wild or VDPV from another country or emergence and circulation of VDPV remains.

In 2015, WPV type 2 was officially declared to be eradicated. The following year, there was a global switch from tOPV to bOPV (type 1 and type 3 only) to remove the risk associated with the ongoing use of live-attenuated type 2 vaccine. To address a potential gap in immunity to type 2, one dose of IPV was recommended to coincide with the switch. Unfortunately, the process encountered challenges leading to the emergence of type 2 immunity gaps. In addition, poorly coordinated outbreak responses using monovalent OPV type 2 vaccine inadvertently resulted in the emergence of more VDPV2, especially in areas of low coverage. These issues were further exacerbated by the emergence of SARS-CoV-2 and subsequent COVID-19 pandemic, resulting in disruptions and suspension of supplementary immunisation activity in 2020. In 2021, six WPV type 1 cases were reported in only 2 endemic countries, Afghanistan and Pakistan.⁴⁵

Relatively recently, Jerusalem, Israel and New York, US reported one case of paralytic polio each in March and July 2022, respectively.^{46,47} The case in Jerusalem was an unvaccinated child, 3 years and 9 months old, with AFP presenting in February 2022 from whom VDPV type 3 was detected in the stools.⁴⁶ The case in New York was a young unvaccinated adult who developed AFP and had VDPV type 2 in his stools.⁴⁷ Prior to his illness, wastewater surveillance in his county and a neighbouring county had detected VDPV 25 days before and 41 days after his onset of illness. He presented with 5 days of low-grade fever, neck stiffness, back and abdominal pain, constipation and 2 days of

AFP. He was unvaccinated and had attended a large gathering 8 days before his illness with no international travel. The polio vaccination uptake in his county had been low at 67.0% in July 2020, which decreased to 60.3% in August 2022, with uptake as low as 37.3% in some areas.⁴⁷ In contrast, the national IPV uptake by 24-month-old children was 92.7% among infants born in 2017–2018.⁴⁸ In London, UK, sewage and wastewater surveillance also detected VDPV2 from February 2022, with no cases of paralytic polio.⁴⁹

As of 5 October 2022, 33 countries were reported to be affected by poliovirus (Table 3).^{50,51} These countries had previously stopped local transmission of WPV but now have re-infection or re-emergence of WPV or VDPV. Not surprisingly, VDPV type 2 is the predominant type of poliovirus with WPV type 1 also detected in Malawi and Mozambique. Four countries—Malawi, Mozambique, Yemen and Israel—are affected by more than one virus type. Nigeria, Yemen and the Democratic Republic of the Congo account for the majority of clinical polio cases reported. Therefore, the recent reports of VDPV in New York and London were not unique or new. However, VDPV occurrence across the world may be an indicator of a worrying trend in the global polio eradication effort and a wake-up call for all countries.

To mitigate the risks of transmission and outbreaks, there are a number of key public health interventions all countries will need to focus on regardless of their polio-free status. First, maintaining high vaccination coverage in the population is critical. Global routine childhood vaccination coverage has fallen by 5%—from 86% to 81%—for 3-dose completion of diphtheria-tetanus-pertussis vaccination during the COVID-19 pandemic.⁵² Transiting out of the COVID-19 pandemic, the ongoing political instability around the world, and the associated increase in global migration are world events that will inevitably facilitate the poliovirus' movement. Since the withdrawal of tOPV, it is essential that IPV coverage improves to ensure that children are protected against the clinical manifestation of paralytic polio. There is a need to invest in and maintain surveillance systems to enable the early detection of “silent” poliovirus transmission in the population as demonstrated by the events in Israel, the UK and the US. To augment ongoing AFP surveillance, environmental surveillance systems with genomic sequencing capabilities are essential. Such systems need to be working well to ensure cases of polio—and more importantly, “silent” transmissions—in the population are detected quickly to inform public health response. Finally, the recent development and

Table 3. Poliomyelitis in non-endemic countries by type of virus and number of cases reported in 2021/2022 (as of 5 October 2022)^{50,51}

Non-endemic country affected by poliovirus	Type of virus	No. of case(s)	
		2022	2021
Algeria	VDPV2	1	0
Benin	VDPV2	6	3
Burkina Faso	VDPV2	0	2
Cameroon	VDPV2	0	3
Central African Republic	VDPV2	0	0
Chad	VDPV2	18	0
Côte d'Ivoire	VDPV2	0	0
Democratic Republic of the Congo	VDPV2	120	28
Djibouti	VDPV2	0	0
Egypt	VDPV2	0	0
Eritrea	VDPV2	1	0
Ethiopia	VDPV2	0	10
Gambia	VDPV2	0	9
Ghana	VDPV2	2	0
Guinea	VDPV2	0	6
Guinea Bissau	VDPV2	0	3
Israel	VDPV3/ VDPV2	1 (VDPV3)	0
Liberia	VDPV2	0	3
Madagascar	VDPV2	8	13
Malawi	VDPV1/ WPV1	2 (VDPV1)	1 (WPV1)
Mauritania	VDPV2	0	0
Mozambique	WPV1/ VDPV2	1 (WPV1)	2
Niger	VDPV2	10	18
Nigeria	VDPV2	33	415
Senegal	VDPV2	0	17
Sierra Leone	VDPV2	0	5
Somalia	VDPV2	3	1
Togo	VDPV2	1	0
Uganda	VDPV2	0	0
Ukraine	VDPV2	1	2
United Kingdom	VDPV2	0	0
United States of America	VDPV2	1	0
Yemen	VDPV2/ VDPV1	139	66 (n=3VDPV1)

VDPV: vaccine-derived poliovirus; WPV: wild poliovirus
Superscript numbers: Refer to REFERENCES

emergency licensing of nOPV2 vaccine is much-welcomed news. The nOPV2 vaccine is genetically more stable and hence, less likely to result in the loss of key attenuation mutations.^{41,53} Population acceptance and appropriate implementation of nOPV2 will minimise the risk of future seeding events.

CONCLUSION

The potential for clinical disease with significant mortality and morbidity remains for polio in light of the absence of antiviral treatment options. The poliovirus vaccination programme has been critically important to date, and the development of nOPV2 is a much-needed boost to global eradication efforts. Polio has not disappeared as evidenced by the recent resurgence of paralytic polio cases in Israel, the US and other countries, as well as the detection of VDPV in wastewater in London relatively recently. All countries must ensure high poliovirus vaccination coverage in their population, and appropriate interventions must be taken to rectify this if coverage falters. Surveillance systems, including those for the environment and wastewater should be implemented to allow early detection of “silent” poliovirus transmission in the population, instead of relying on AFP surveillance alone.

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