National Collaborating Centre for Infectious Diseases

Centre de collaboration nationale des maladies infectieuses

Global Immunization Programs: A Summary and Consideration of Polio Vaccine Programs

December 2022

PREPARED BY:

By Shyama Nanayakkara, MBBS, MSc, MD

Global Immunization Programs: A Summary and Consideration of Polio Vaccine Programs

December 2022

By Shyama Nanayakkara, MBBS, MSc, MD

Contact us at:
National Collaborating Centre for Infectious Diseases
Rady Faculty of Health Sciences,
University of Manitoba
Tel: (204) 318-2591
Email: nccid@umanitoba.ca
www.nccid.ca

This is NCCID Project number 703.
ISBN: 978-1-927988-74-9
Production of this document has been made possible through a financial contribution from the Public Health Agency of Canada through funding for the National Collaborating Centre for Infectious Diseases. The views expressed herein do not necessarily represent the views of the Public Health Agency of Canada.

Table of Contents

Introduction

By providing immunity to otherwise severe diseases, vaccines reduce the risk of getting a disease and possible complications and work with the body's natural defenses to build protection. Vaccines and immunization programs stand out as one of the great discoveries of public health for the benefit of the population.

Edward Jenner is considered the founder of vaccinology after he inoculated a 13-year-old boy in 1796 with the vaccinia virus (cowpox) and demonstrated that the vaccine created immunity to smallpox. In 1798, the first smallpox vaccine was developed [1].

There are vaccines to prevent more than 20 life-threatening diseases, helping people of all ages live longer, healthier lives. Immunization currently prevents 3.5 to 5 million deaths every year from diseases like diphtheria, tetanus, pertussis, influenza and measles [2], and thus has made an enormous contribution to global health. Global vaccination coverage has dramatically improved mortality rates among children as vaccine-preventable diseases have been significantly reduced since the creation of the Expanded Program of Immunization (EPI) in 1974, and later, the formation of Gavi, the international Vaccine Alliance, in 2000 [3, 4]. International efforts to prevent tuberculosis, diphtheria, tetanus, pertussis, poliomyelitis, and measles have increased global vaccine coverage from <5% to 86% [5].

Immunization is a key component of primary health care and is considered by some a human right. [6] It is also one of the best health investments money can buy. Vaccines are also critical to the prevention and control of infectious disease outbreaks. They underpin global health security and the World Health Organization notes they will be a vital tool in the battle against antimicrobial resistance [2]. Globally, immunization is the most widely accessed and successful child health intervention in use today.

National immunization programs are responsible for the management of immunization at the country level and cover a range of functions from establishing evidence-based policies, to financing and procurement of vaccines, vaccine management and logistics, delivery of vaccination services and collection, as well as analysis and use of immunization data [7].

The focus on the health of children must expand beyond mortality to include healthy growth, development, and wellbeing. A multisectoral approach that addresses all the determinants (social, economic, cultural, political, environmental, and commercial) of child health and wellbeing resonates with the Sustainable Development Goals (SDGs) promotion of a holistic approach to global social and economic issues. In September 2015, countries ratified the Sustainable Development Goals (SDGs) to end poverty, protect the planet, and ensure prosperity for all. Immunization has a crucial role in achieving 14 of the 17 SDGs. SDG3 targets related to immunization include under-five mortality, elimination of vaccine-preventable diseases, and prevention of epidemics [8-10].

As Canada and other countries re-establish public health and health care programs following the COVID-19 pandemic, there is concern that many children and adults have missed usually scheduled vaccinations (called, "routine vaccines"), and governments and practitioners are

discussing how to initiate “catch-up” programs, in order to prevent outbreaks of vaccine-preventable diseases.

This document provides a summary of the significant progress made in immunization globally, and a history of efforts towards polio eradication. The aim of this project is to carry out a literature review to find out various strategies used by other parts of the world and provide recommendation to improve Canada immunization programs, particularly following the COVID-19 pandemic. There are lessons to be learned for Canada from the experiences of other countries in providing mass immunization programs.

We start with a look at international immunization programs in the past 50 years, and then consider the example of polio eradication efforts specifically.

International Immunization Programs

The Global Alliance for Vaccines and Immunization, now known as Gavi, is an international organization created in 2000. Despite early successes, immunization coverage had stagnated in the 1990s and life-saving vaccines were not reaching children in the poorest countries. Gavi was established to improve the distribution of and access to new and underused vaccines for children living in these countries, and to reduce the historical time lag of immunization between high- and low-income countries [7].

The United Nations Children’s Fund (UNICEF) is a founding member of all key global immunization partnerships, including Gavi, the Measles and Rubella Initiative, the Maternal and Neonatal Tetanus Elimination Initiative, the Global Polio Eradication Initiative, and the Global Vaccine Action plan [11, 12]. UNICEF plays a leading role in the collection, compilation, analysis and dissemination of data to inform sound policies, legislation and programs for promoting children’s rights and well-being, and for global monitoring of progress towards achieving the SDGs [9, 13].

As the 1974 Expanded Program of Immunization (EPI) led to substantial achievements through increasing coverage with existing vaccines and the use of the new array of life-saving vaccines, there was a call for a Decade of Vaccines in 2010 [14]. In 2012, the World Health Assembly adopted the Decade of Vaccines Global Vaccine Action Plan (GVAP) 2011-2020 as the current framework aimed at preventing millions of deaths through more equitable access to existing vaccines for people in all communities. Endorsed by the World Health Assembly in 2012, the GVAP calls on all countries to reach ≥90% national coverage with all vaccines in the country’s national immunization schedule 2020 [15].

However, there are still many impediments to vaccination compliance, including a lack of awareness regarding the importance of vaccines, missing due dates, and fear of complications from vaccinations. Despite the longstanding benefits, low immunization levels persist. Some 20 million children miss out on life-saving vaccines annually [12]. Fewer than two-thirds of all countries globally reached the GVAP 2020 target of ≥90% national coverage with Diphtheria tetanus toxoid and pertussis (DTP3) at 66% coverage and Measles-

containing-vaccine first-dose (MCV1) at 61%. There are regional differences in vaccination coverage and dropout rates, particularly for vaccines offered beyond the first year of life and need to be addressed through context-specific strategies to reach global, regional, and national immunization coverage goals [5].

Poliomyelitis

Poliomyelitis (Polio) is a highly contagious, vaccine preventable disease, most often seen in children under 5 years of age. Polio virus is a member of the Enterovirus genus, family Picornaviridae, a virus now classified as a species C enterovirus, a group that includes most of the Coxsackie virus. Picornaviruses are small, ether-insensitive viruses with an RNA genome. Strain Enteroviruses are transient inhabitants of the gastrointestinal tract and are stable at acidic pH. There are three poliovirus serotypes PV1, PV2, and PV3 (type 1, type 2, and type 3) [16, 17].

Humans are the only host for polioviruses. People infected with a poliovirus excrete the virus in their saliva and faeces, whether they have symptoms of the disease or not. The viruses may be passed on through contaminated water, milk or food. In the United States alone, more than 20,000 cases of paralytic polio cases were annually reported during the early 1950s [18].

Pathogenesis

Transmission of polio is person-to-person, mainly through the faecal-oral route and less frequently via contaminated water or food. The incubation period is usually 7–10 days but can range from 4–35 days. The majority (90%) of those infected with the polio virus experience no or mild symptoms and the disease usually goes unrecognized. In some cases, however, initial symptoms include fever, fatigue, headache, vomiting, stiffness in the neck, and pain in the limbs and will last for 2–10 days; there is complete recovery in almost all cases. The clinical presentation of poliomyelitis is typical flaccid paralysis. The polio enteroviruses grow mainly in the gut where infection is entirely asymptomatic. However, sometimes the virus can spread and infect other somatic tissues where it can replicate and spread further to other regions including the throat, the regional nervous system, and the central nervous system. In the central nervous system poliovirus specifically targets and destroys the motor neurons leading to the classical clinical presentation. After this prodromal phase, in a small proportion of cases the virus causes permanent paralysis, usually of the legs. The ratio of cases of inapparent infection to paralytic disease among susceptible individuals ranges from 100:1 to 1000:1 or more. Infection with the virus leads to viremia which may result in infection of central nervous system cells. The virus then attaches and enters cells via specific poliovirus receptors and the poliovirus replicates in motor neurons of the anterior horn and brain stem, resulting in cell destruction and causing the typical clinical poliomyelitis. Depending on the site of infection and paralysis, poliomyelitis can be classified as spinal, bulbar, or spino-bulbar disease [19]. Progression to

maximum paralysis is rapid (2– 4 days); paralysis is usually associated with fever and muscle pain, and rarely progresses after the temperature has returned to normal. In the central nervous system poliovirus specifically targets and destroys the motor neurons leading to the classical clinical presentation. Typically, the lower limbs are affected but infection further up the spinal cord can affect the respiratory centres leading to bulbar poliomyelitis where the victim will die unless respiration is assisted [20, 21].

Paralysis that lasts 60 days from onset is usually permanent. This can happen rapidly, within a few hours of infection. About 5 - 10% of cases die due to paralysis of the respiratory muscles. The pathogenesis of polio means that most infections are silent, so that counting cases is only an indirect measure of the presence of the virus. Thus if one country in the world has circulating poliovirus, the entire world is at risk as it can be exported by asymptomatic individuals who are impossible to identify [22].

Other causes of AFP are bacterial infections, autoimmune disorders, exposure to environmental toxins, include transverse myelitis, traumatic neuritis, other enterovirus infections and other causes of paralysis such as West Nile virus and Guillain-Barré Syndrome. Additional investigations are needed to determine the underlying cause. Sometimes no cause can be found [25, 26].

Adults who contract paralytic poliovirus as children may develop non-infectious polio syndrome 30 or more years after recovery. The post-polio syndrome is characterized by progressive muscle weakness and pain and may include breathing and swallowing difficulties from muscle atrophy [23, 24].

Laboratory Diagnosis

Polio virus is excreted via faeces from an infected person or following vaccination intermittently for one month or more. Heavy shedding of the virus occurs just prior to the onset of paralysis and during the first two weeks after initial symptoms occur [27, 28].

An important component of the polio eradication strategy was conducting surveillance for cases of acute flaccid paralysis. The WHO Global Polio Laboratory Network (GPLN) is an essential component of poliovirus surveillance. Laboratory diagnosis of poliomyelitis involves the growth and identification of polioviruses from faecal samples using cell culture techniques. Timely collection, storage and proper transport of samples are crucial for proper lab diagnosis of poliomyelitis. Two samples of stools should be collected from all cases within 14 days of the onset of paralysis. As the virus concentration decreases with time, all attempts must be made to collect stools very early in the infection, within 14 days of the onset of paralysis. As the excretion of viruses is intermittent, a minimum of two samples, collected preferably 24–48 hours apart, is recommended. The specimens are kept in a cold box between frozen ice packs at 4-8 °C to be sent to appropriate laboratories [27, 29-31].

Polio Eradication Strategies

The origins of polio eradication begin in the late 1950s. Two vaccines, live attenuated oral poliovirus vaccine (OPV) and inactivated polio vaccine (IPV) are used throughout the world to protect against polio. Albert Sabin, Hilary Kaprowski and others concluded that routine immunization with (IPV) or OPV which was very much successful in developed countries, would not interrupt poliovirus transmission where social and environmental conditions favored continuous wild poliovirus transmission. OPV costs substantially less than IPV. IPV and thus has the potential to better prevent transmission of wild viruses; OPV confers contact immunity through passive immunization of unvaccinated persons from viruses shed by vaccines; and OPV is administered in oral drops, which are easier to administer than IPV injections and easier to store and transport [32, 33].

The first IPV was produced by Salk using virus grown on monkey kidney cells and inactivated with formalin. In 1954, the inactivated vaccine was tested in a placebo-controlled trial, which enrolled 1.6 million children in Canada, Finland and the United States [20]. The licensure of the inactivated poliomyelitis vaccine for nonexperimental national use followed immediately after the April 12, 1955 [34]. Dr. Albert Sabin's live attenuated poliovirus vaccine had undergone a few successful field tests and had reached the stage when large trials were indicated. Such trials were recommended by the WHO Expert Committee on Poliomyelitis in July of 1957. But in the United States, the Salk vaccine was proving to be successful, reducing the incidence of poliomyelitis to several thousand cases per year. Leaders of the National Foundation were therefore satisfied and not interested in supporting a trial of the Sabin oral vaccine, nor was the United States Public Health Service [35]. At a time when most of the United States' efforts concerned the introduction of Salk-type vaccines, WHO initiated studies that set standards and permitted the large-scale trials of Sabin and other attenuated vaccines. Independent expert review validated studies in countries such as the U.S.S.R. which helped lead to the adoption of Sabin vaccines for worldwide usage [36].

From 1955 IPV was used extensively in the US and polio incidence declined by more than 95 per cent. However, in 1962, when oral poliovirus vaccine (OPV) became available, the national policy was shifted to its exclusive use. By 1985, polio incidence had decreased sharply in most countries and the number of countries reporting cases of poliomyelitis in the Americas had decreased from 19 to 11 [18].

Sabin's oral vaccine quickly won acceptance around the world because of its low cost, ease of administration in drops or on sugar cubes, ability to spread to unvaccinated contacts, inducement of a strong immune response in the gut, and political acceptability (it was produced and endorsed by both democratic and communist countries). The oral vaccine was also welcomed as an alternative to Salk's competing inactivated polio vaccine, which had encountered suspicion because some early lots of commercial vaccine had been contaminated with live poliovirus. The WHO adopted a policy of the exclusive use of OPV in developing countries [20, 35, 37].

Global Polio Eradication Initiative (GPEI)

Inspired by the previous success of smallpox eradication, the Global Polio Eradication Initiative (GPEI), was launched in 1988 and aimed for completion by 2000. The strategy was developed to eliminate and to eventually eradicate poliovirus infection from the world, using intensive and persistent immunization programs in every country. It is spearheaded by national governments, the World Health Organization (WHO), Rotary International, the US Centers for Disease Control and Prevention (CDC) and UNICEF [21, 36-40]. Polio has been eradicated from most countries, however there is still a risk of polio in some parts of the world. Since the global polio eradication initiative was first adopted by the World Health Assembly in 1988, most of the global progress toward polio eradication has been highlighted by the achievements of the Americas and the Western Pacific Region. In the South-East Asia Region (SEAR) of the WHO, paralytic poliomyelitis has decreased from 25,711 cases in 1988 to 3,304 cases in 1995, representing an 87% reduction. Polio was eradicated in six of the ten member countries by 1995 [18, 20, 41-43].

National Immunization Day (NID)

Based on the initial proposals of Albert Sabin, a National Immunization Day (NID) was introduced. As Sabin noted, "the interruption of polio transmission could be achieved if the OPV was applied simultaneously to many children, particularly those under 5 years of age, in a very short period, preferably in 1 day or 1 week." NIDs are nationwide mass campaigns to deliver supplemental doses of oral poliovirus vaccine to interrupt the circulation of wild polioviruses. One of the critical strategies of WHO for global poliomyelitis eradication is to implement NID in all countries with widespread poliovirus transmission [7, 20, 21, 44-46]. [47]

NID in Sri Lanka

The last virologically confirmed case of polio was detected in Sri Lanka in 1993. Still, there were cases neighboring country India, and there was a civil war in the country which disturbed most of the immunization programs in the north part of the country, and eradication was not completed [47].

In 1997 I worked as a Medical Office of Health (MOH) in Sri Lanka in a municipality with a population of 100,000. I coordinated a pilot project for NID. I was able to get great help from the local authorities, non-governmental organizations (NGOs) including the Rotary Club and other small organization in the area. After public awareness program and with the help of the nearly 100 volunteers there were 20 vaccination centers. All children under the age of 5 were given a single dose of OPV in one day.

The National Immunization Day was considered very successful, achieving 85% coverage and NID was later implemented countrywide in over 200 MOH areas. – Shyama Nanayakkara, MD.

Vaccine-associated Paralytic Poliomyelitis

Because Sabin-derived polioviruses can replicate for prolonged periods in individuals or in communities and potentially reestablish endemic and epidemic transmission, strategies for the elimination of all polioviruses, including the attenuated Sabin vaccine viruses emanating from the OPV needed to be developed and implemented to achieve polio eradication [37, 42, 48]. The risks of paralytic poliomyelitis occurring in the post-certification era fall into two major categories: risks related to the continued use of the OPV and risks associated with the unsafe handling of wild polioviruses. Both categories have three main risks, all of which are being increasingly understood and most of which are now quantifiable. The risks that arise from the continued use of OPV are vaccine-associated paralytic poliomyelitis (VAPP), circulating vaccine-derived poliovirus cVDPVs, and immunodeficient long-term excretion of vaccine-derived polioviruses (iVDPVs) [49]. VAPP is caused by a VDPV that has regained neurovirulence during replication in the gut. Cessation of the OPV was considered necessary to eradicate poliomyelitis, since the vaccine strains produce cases of VAPP and cVDPV [42, 48, 50].

NID in Zambia

"On Zambia's polio day (NID) in July 1997, 8000 vaccination points were set up around the country, each staffed by 1 nurse and 2 volunteer workers, who worked from thatched huts built for the day, churches, health centers, and house-to-house to reach the target of 2.1 million children. With about half of Zambia's 10 million people living in rural communities poorly served by roads and without main electricity, it was a particular challenge to maintain the cold chain. The cold chain began at Lusaka airport with the arrival of 5.4 million doses of frozen vaccine from Copenhagen, Denmark. The vaccines were then stored in freezers at a central location in Lusaka until they were eventually trucked out to the regional and district centers. The Flying Doctor Service and air force were used, as well as ox and carts, to get vaccines to hard-to-reach communities. The vaccines arrived at such sites on the NID packed in ice carried over the shoulders of the nurses who delivered them. The NID was deemed successful by the minister of health the morning after it occurred even though some districts ran short of vaccines. Two annual NIDs will continue if polio is present in that part of Africa" [46]

Although the year 2000 goal was not met, tremendous progress was made toward the interruption of wild poliovirus transmission. By 2000 mass immunization campaigns reached as many as 450 million children per year and 134 million children in a single day. The number of reported cases has declined from 35,251 to 7,088 cases during that time span. Because surveillance has improved the decline in cases occurring is significantly greater. By 2002, three WHO Regions (the Americas, Western Pacific and European Regions) had been certified polio-free [44, 51, 52].

Investigators recognized that two factors could potentially reduce the effectiveness of OPV programs and that these factors needed special attention. Oral polio vaccine is more heat sensitive than IPV and must be preserved at 0-8° Celsius or lower, almost to the time of administration. This required the development and operation of a cold chain for vaccine distribution, which has been achieved. Also, unlike IPV, OPV can cause vaccine-associated paralysis (VAP). Studies show, however, that this occurs so infrequently that OPV is a very safe product by any pharmaceutical standards [17, 53]. The marked progress has been achieved through widespread use of oral poliovirus vaccines (OPVs), most commonly trivalent OPV (tOPV), which contains types 1, 2, and 3 live, attenuated polioviruses and has been a mainstay of efforts to prevent polio since the early 1960s. However, attenuated polioviruses in OPV can undergo genetic changes during replication, and in communities with low vaccination coverage, can result in vaccine-derived polioviruses (VDPVs) that can cause paralytic polio indistinguishable from the disease caused by WPVs [38, 43, 49].

At the present time, reducing the numbers of VAPP cases through reducing OPV coverage is not an option. OPV contains weakened viruses that can replicate, some of them may be excreted by the vaccinated child and transmitted to other people – particularly in areas with poor sanitation. In high-risk populations free of wild poliovirus transmission, sub-optimal immunization rates increase the risks of poliomyelitis outbreaks caused by both wild polioviruses from the remaining endemic countries, and from circulating vaccine-derived polioviruses (cVDPV) with transmission and neurovirulence characteristics of wild polioviruses. Continued high coverage with OPV is necessary to prevent poliomyelitis caused by viruses derived from WPVs [42, 43].

From the three serotypes exist for polio: poliovirus type 1, poliovirus type 2 and poliovirus type 3, wild type 2 (WPV2) is considered eradicated as the last naturally occurring case was detected in India in 1999. Wild type 3 (WPV3) appears to be on the verge of eradication, with no cases reported since November of 2012, the longest period that a WPV3 has not been isolated. In addition, indigenous WPV type 2 was last detected in Northern India in 1999 and WPV type 3 poliovirus was last reported from Nigeria in November 2012 [32, 54].

The Polio Eradication & Endgame Strategic Plan 2013-2018 provides a framework for interruption of wild poliovirus transmission in remaining endemic regions and lays out a plan for the new polio end game, which includes the withdrawal of Sabin strains, starting with type 2, and the introduction of inactivated poliovirus vaccine, for risk mitigation purposes. As a key component of the plan, it will be necessary to stop oral polio vaccine (OPV) use globally to achieve eradication, because the attenuated viruses in the vaccine rarely can cause polio [18, 55, 56]. In April 2016, therefore, the GPEI entered the post-OPV2 cessation era. The World Health Assembly endorsed the phased withdrawal of OPV and introduction of inactivated poliovirus vaccine (IPV) into childhood routine immunization schedules. Type 2 OPV was withdrawn through a globally synchronized and switched from trivalent OPV (all three types) to bivalent OPV (types 1 and 3) [43, 57, 58]. Ultimately, the world must cease using all OPV after the eradication of polioviruses, to avoid the transmission of vaccine-related polioviruses and ensure that polio is eradicated. Switching from tOPV to bOPV is not without risks. The primary risk is the reemergence of outbreaks

involving type 2 circulating vaccine-derived polioviruses [57]. In communities where lots of people have been vaccinated against polio, transmission is limited, and the virus quickly dies out. But in communities with low vaccine coverage, the weakened virus may continue to circulate for many months, gradually accumulating mutations that enable it to cause paralysis once more.

The initiative to eradicate polio from the Americas was launched in May 1985, with the goal of interrupting transmission of the disease by the end of 1990. Five of the six WHO regions, representing over 90% of the world's population, are now free of wild polioviruses. Given this achievement, GPEI is focusing efforts on two goals: interrupting persistent WPV1 transmission and stopping all current outbreaks of cVDPV2. In 2019, circulating WPV was endemic in only one region of the world, Afghanistan and Pakistan [59-62].

The GPEI, a public–private partnership, announced a US$5.1 billion campaign to achieve a polio-free world by 2025 [42]. The updated GPEI Polio Eradication Strategy 2022-2026 includes expanded use of the type 2 novel oral poliovirus vaccine (nOPV2) to avoid new emergences of cVDPV2 during outbreak responses. The new strategy deploys other tactics, such as increased national accountability, and focused investments for overcoming the remaining barriers to eradication, including program disruptions and setbacks caused by the COVID-19 pandemic [61]. To prevent these outbreaks of polio variants, it's imperative that every child is reached with the vaccine.

Children receive IPV which prevents paralysis but does not prevent transmission of the virus. Therefore, so-called silent outbreaks can occur in countries that use the injectable vaccine. This is when the virus spreads from child to child but does not cause paralysis.

Community-based vaccination campaigns should be sensitively conducted in vaccine-hesitant communities. It is very much important to maintain cold chain storage is when it comes to reaching remote communities with vaccines e.g., making sure the vaccines aren't wasted when electricity is lost [53, 56].

Although IPV is an effective vaccine and valuable in countries with zero incidence of polio, it is better used as a precaution since it does not trigger the same immune response as OPV and therefore is not as effective in stopping active poliovirus transmission. OPV induces mucosal immunity in the intestine, the primary site where poliovirus replicates – in this way, the vaccine prevents shedding of the virus into the environment and can limit or stop person-to-person transmission. This is critical in communities with poor water and sanitation, where people are more likely to be exposed to water-borne pathogens [42, 43].

About 90% of children vaccinated with IPV are still prone to shedding the virus after being given OPV. This means that IPV alone would probably not be enough to eradicate circulating OPV-derived viruses. It is recommended that children receive a dose of IPV first, followed by a booster of OPV. This will reduce the shedding of OPV-derived virus in stool, which is better than giving a dose of OPV first and a second booster of OPV [38, 63].

In November 2020, nOPV2 received a recommendation for use under WHO's Emergency Use Listing (EUL) procedure to be able to roll it out rapidly. The nOPV2 which has been

modified to be more genetically stable than the Sabin strain and less likely to cause vaccine-derived virus. As of October 2021, nOPV2 has been rolled out, in eight countries [50, 61].

Low vaccine coverage has to be boosted by vaccine supply and engaging the trust of communities to overcome misinformation and raise awareness of the need for the vaccine, which can mean bringing in community and religious leaders.

Polio Virus Surveillance

The main strategy recommended by the WHO for PV surveillance is the investigation of acute flaccid paralysis (AFP) cases in children, which is a sensitive marker for poliomyelitis. Although paralysis is a rare outcome of WPV (and circulating) infections (<1%) [27], AFP surveillance has been the proven means of tracing WPV transmission [42, 61].

In May 1985, the Pan American Health Organization proposed the goal of the interruption of wild poliovirus transmission in the Western Hemisphere. An important component of the polio eradication strategy was conducting surveillance for cases of acute flaccid paralysis [64, 65]. Surveillance for poliovirus relies on two things: the detection, reporting and stool testing of AFP in children or paralysis in any person who is suspected of being infected with poliomyelitis; and a laboratory that can positively identify poliovirus and distinguish wild polio from vaccine-derived disease. Though polio is increasingly rare and difficult to differentiate clinically from other diseases, cases of suspected paralytic illness, including other forms of acute flaccid paralysis such as Guillain-Barré syndrome and transverse myelitis, should be fully investigated. Detection and investigation of cases of AFP includes standardized virological analysis of two faecal samples of the patient and/or sometimes those from contacts. Active surveillance visits to priority health facilities are used to assure all children under 15 years of age with AFP are detected, followed by stool specimen collection and testing for poliovirus in WHO-accredited polio laboratories. To increase the probability of detecting wild poliovirus, if present, in a community, investigators also attempted to collect stool specimens from at least 5 children(contacts) living in the same house or neighborhood as the index AFP case [65-67].

AFP surveillance is also a key strategy used by the GPEI to measure progress towards reaching the global eradication goal. Global certification of eradication requires a minimum of at least three years after the last detection of wild poliovirus globally in conditions of high-quality surveillance. Several studies have demonstrated the significance of AFP surveillance [59, 65, 66, 68-71].

Surveillance for poliovirus relies on two things: the detection, reporting and stool testing of AFP in children or paralysis in any person who is suspected of being infected with poliomyelitis; and a laboratory that can positively identify poliovirus and distinguish wild polio from vaccine-derived disease. Nationwide AFP surveillance is the WHO gold standard for detecting cases of poliomyelitis [38, 59]. The standard approach recommended by WHO for polio surveillance is the detection and investigation of cases of acute flaccid paralysis (AFP), which includes standardized virological analysis of two faecal samples of the patient, and/or sometimes those from contacts [65, 67].

Surveillance indicators of program performance, especially those relating to the completion and timeliness of case investigations, were established, and incorporated as an integral part of the surveillance system. By the end of 1989, after the system had been computerized (Polio Eradication Surveillance System), analysis of data could be performed at various levels of the health system. The information gained from the analysis of these data has been used to adjust program strategies [18, 65].

AFP surveillance is enhanced by environmental surveillance for poliovirus (testing of sewage water at selected sites). Environmental surveillance can be used to trace enteroviruses shed from human stool using a sewer network that is independent of symptomatic or asymptomatic infection. The virus is excreted into the faeces and shed into the environment. Environmental poliovirus surveillance (ENV) means monitoring of poliovirus transmission in human populations by examining environmental specimens supposedly contaminated by human faeces. The World Health Organization has included ENV in the new Strategic Plan of the Global Polio Eradication Initiative for years 2010–2012 to be increasingly used in PV surveillance, supplementing AFP surveillance [39, 65-67, 70-72].

Current Status

After two decades of maintaining polio-free status, the WHO Western Pacific Region (WPR) reported an emergence of polio outbreaks of type 1 and type 2 cVDPVs in the Philippines and Malaysia during 2019–2020. This highlighted the potential risk of cVDPV outbreaks in high-risk areas and/or communities in the WPR [50]

As of 2019, wild poliovirus type 1 affects only two countries in the world Pakistan and Afghanistan [73].

In 2020, COVID-19 disrupted routine immunizations, resulting in more than 80 million children being at an increased risk of vaccine-preventable diseases, including polio.

In May 2022, the health authorities in Mozambique declared an outbreak of wild poliovirus type 1 after confirming that a child in the country's north-eastern Tete province was the second case in southern Africa this year, following an outbreak in Malawi in mid-February [74]. The sharp rise wild polio cases in Pakistan and the detection of one case each in Malawi and Mozambique in recent past continued risks of poliovirus and the urgency required to permanently interrupt transmission in both Afghanistan and Pakistan[62].

In June 2022, the US Centers for Disease Control and Prevention (CDC) were coordinating with New York State health authorities concerning a confirmed case of polio type 2 VDPV. Public health experts are working to understand how and where the individual was infected. The patient, aged 20 years old, was hospitalized in June [75-77]. The CDC urges everyone who is not fully vaccinated to complete the polio vaccination series as soon as possible.

A series of setbacks have occurred in the battle to rid the world of polio, resulting in polio spreading back into areas where it had been previously eliminated. To date, each time this

has occurred, the outbreak has been contained through enhanced vaccination, but the battle is not yet over [37]. Authorities are working to provide protective measures, such as vaccination services to prevent the spread of polio to under- and unvaccinated individuals.

In Afghanistan, access has improved across the country, but accessing every child through house-to-house vaccination remains a challenge in some areas [73].

Following the discovery of type 2 vaccine-derived poliovirus in sewage in north and east London, the Joint Committee on Vaccination and Immunization (JCVI) has advised that a targeted inactivated polio vaccine (IPV) booster dose should be offered to all children between the ages of 1 and 9 in all London boroughs [78].

Polio Eradication in Canada

Canada has had few polio cases since widespread vaccination in the 1950s and 1960s, with the last recorded case of wild poliovirus infection in 1977. The vaccine programs switched from OPV to IPV exclusively in 1995/1996 after Canada was certified polio-free in 1994. Canada uses the inactivated poliovirus vaccine, which prevents disease, rather than the oral live attenuated-virus vaccine, which also prevents carriage. This means most Canadians are protected from getting the disease but can circulate the virus because they lack gut immunity. Again, there are populations in Canada with low coverage of the polio vaccine, and rates of polio uptake are not in the 80% range needed for herd protection [38, 63, 79].

To ensure polio-free children, the Public Health Agency of Canada, in collaboration with the Canadian Pediatric Society, conducts an active surveillance to investigate all AFP in children under the age of 15. From 2015 to 2019, a total of 220 AFP cases were reported in Canada. An average of 44 cases were reported annually, with an average incidence rate of 0.7 cases per 100,000 population (0.5-1.2). There is a limitation to this data as most of the surveillance systems are not received from provinces and territories in real time, nor are most cases reported at the national level linked with laboratory and epidemiological data [80].

As there is still a risk of polio in some areas of the world, the PHAC recommends that travelers get vaccinated against polio when going to countries where there is a risk of ongoing transmission.

Every two years in Canada, the Childhood National Immunization Coverage Survey (CNICS) collects information on national immunization coverage for vaccines administered to children and pregnant women. The report needs to be submitted to the World Health Organization and the Pan-American Health Organization with estimates of national vaccine coverage for childhood vaccines. Based on the 2019 CNICS, by two years of age, 92% of children in Canada received the recommended doses of polio vaccine. The goal is 95% [81].

As there is dramatical reductions in the incidences of vaccine-preventable diseases in recent but may have changed how parents perceive child vaccines. Childhood vaccination efforts in Canada have been negatively impacted by parents' vaccine hesitancy based on their knowledge, attitudes, and beliefs (KAB) about vaccinations [82, 83].

References

1. *A brief history of vaccination*. 2020, The Immunisation Advisory Centre.
2. *Vaccines and immunization*. 2022: World Health OrganizationVaccines and immunization.
3. Mantel, C. and T. Cherian, *New immunization strategies: adapting to global challenges.* Bundesgesundheitsblatt Gesundheitsforschung Gesundheitsschutz, 2020. **63**(1): p. 25-31.
4. Bustreo, F., J.-M. Okwo-Bele, and L. Kamara, *World Health Organization perspectives on the contribution of the Global Alliance for Vaccines and Immunization on reducing child mortality.* Archives of Disease in Childhood, 2015. **100**(Suppl 1): p. S34-S37.
5. Peck, M., et al., *Global Routine Vaccination Coverage, 2018.* MMWR Morb Mortal Wkly Rep, 2019. **68**(42): p. 937-942.
6. Blanchet, k., *How the principle of universal access to vaccines should be considered a human right.* 2021: The Geneva Centre of Humanitarian Studies.
7. Cherian, T. and C. Mantel, *National immunization programmes.* Bundesgesundheitsblatt - Gesundheitsforschung - Gesundheitsschutz, 2020. **63**(1): p. 16-24.
8. Decouttere, C., K. De Boeck, and N. Vandaele, *Advancing sustainable development goals through immunization: a literature review.* Global Health, 2021. **17**(1): p. 95.
9. UNICEF, *UNICEF and the Sustainable Development Goals*. 2022.
10. Coll-Seck, A., et al., *Framing an agenda for children thriving in the SDG era: a WHO-UNICEF-Lancet Commission on Child Health and Wellbeing.* Lancet, 2019. **393**(10167): p. 109-112.
11. Burton, A., Monasch, R., Lautenbach, B., Gacic-Dobo, M., Neill, M., Karimov, R., Wolfson, L., Jones, G., & Birmingham, M. , *WHO and UNICEF estimates of national infant immunization coverage: methods and processes.* Bulletin of the World Health Organization, 2009. **87**(7535–541).
12. UNICEF, *Eradicating polio*. 2022, United Nation Childre's Fund.
13. Murray, C. and H. Newby, *Data Resource Profile: United Nations Children's Fund (UNICEF).* International Journal of Epidemiology, 2012. **41**(6): p. 1595-1601.
14. Moxon, E.R., et al., *A call to action for the new decade of vaccines.* Lancet, 2011. **378**(9788): p. 298-302.
15. MacDonald, N., et al., *Global vaccine action plan lessons learned I: Recommendations for the next decade.* Vaccine, 2020. **38**(33): p. 5364-5371.
16. Dowdle, W.R. and M.E. Birmingham, *The biologic principles of poliovirus eradication.* J Infect Dis, 1997. **175 Suppl 1**: p. S286-92.
17. Minor, P.D., *Poliovirus biology.* Structure, 1996. **4**(7): p. 775-8.
18. De Quadros, C.A., et al., *Polio Eradication From the Western Hemisphere.* Annual Review of Public Health, 1992. **13**(1): p. 239-252.
19. Kidd, D., A.J. Williams, and R.S. Howard, *Poliomyelitis.* Postgrad Med J, 1996. **72**(853): p. 641-7.
20. Baicus, A., *History of polio vaccination.* World Journal of Virology, 2012. **1**(4): p. 108.
21. De Quadros, C., *History and prospects for viral disease eradication.* Medical Microbiology and Immunology, 2002. **191**(2): p. 75-81.
22. Minor, P., *The polio endgame.* Human Vaccines & Immunotherapeutics, 2014. **10**(7): p. i-iii.
23. Wendebourg, M.J., et al., *Spinal cord gray matter atrophy is associated with functional decline in post-polio syndrome.* Eur J Neurol, 2022. **29**(5): p. 1435-1445.
24. Duncan, A. and Z. Batliwalla, *Growing older with post-polio syndrome: Social and quality-of-life implications.* SAGE Open Med, 2018. **6**: p. 2050312118793563.
25. Molinero, M.R., et al., *Epidemiology of childhood Guillain-Barre syndrome as a cause of acute flaccid paralysis in Honduras: 1989-1999.* Journal of Child Neurology, 2003. **18**(11): p. 741-747.
26. National Department of Health, S.A., *EPI Diseases Surveillance Guideline*. 2015.

27. Hull, B.P. and W.R. Dowdle, *Poliovirus surveillance: building the global Polio Laboratory Network.* J Infect Dis, 1997. **175 Suppl 1**: p. S113-6.
28. Alexander, J.P., H.E. Gary, and M.A. Pallansch, *Duration of poliovirus excretion and fts implications for acute flaccid paralysis surveillance: A review of the literature.* Journal of Infectious Diseases, 1997. **175**: p. S176-S182.
29. Saraswathy, T.S., et al., *Laboratory acute flaccid paralysis surveillance in Malaysia: a decade of commitment to the WHO global polio eradication initiative.* Southeast Asian J Trop Med Public Health, 2004. **35**(2): p. 421-4.
30. Baicus, A., et al., *The maintaining of the active laboratory-based surveillance of the acute flaccid paralysis (AFP) cases in Romania in the framework of the strategic plan of the global polio eradication initiative.* Roum Arch Microbiol Immunol, 2007. **66**(1-2): p. 44-50.
31. Jasem, J.A., et al., *An epidemiological analysis of acute flaccid paralysis and its surveillance system in Iraq, 1997-2011.* BMC Infect Dis, 2014. **14**: p. 448.
32. Bandyopadhyay, A.S., et al., *Polio vaccination: past, present and future.* Future Microbiology, 2015. **10**(5): p. 791-808.
33. Sabin, A.B., *Paralytic Consequences of Poliomyelitis Infection in Different Parts of the World and in Different Population Groups.* American Journal of Public Health and the Nations Health, 1951. **41**(10): p. 1215-1230.
34. Monto, A.S., *Francis Field Trial of Inactivated Poliomyelitis Vaccine: Background and Lessons for Today.* Epidemiologic Reviews, 1999. **21**(1): p. 7-23.
35. Hampton, L., *Albert Sabin and the Coalition to Eliminate Polio From the Americas.* American Journal of Public Health, 2009. **99**(1): p. 34-44.
36. Magrath, D. and P. Reeve, *On the Role of the World Health Organization in the Development of Sabin Vaccines.* Biologicals : journal of the International Association of Biological Standardization., 1993. **21**(4): p. 345-348.
37. John, T.J., *The golden jubilee of vaccination against poliomyelitis.* The Indian journal of medical research., 2004. **119**(1): p. 1-17.
38. Booth, T., et al., *The polio eradication endgame: Why immunization and continued surveillance is critical.* Canada Communicable Disease Report, 2015. **41**(10): p. 233-240.
39. Hovi, T., et al., *Role of environmental poliovirus surveillance in global polio eradication and beyond.* Epidemiology and Infection, 2012. **140**(1): p. 1-13.
40. Centers for Disease, C. and Prevention, *Certification of poliomyelitis eradication--the Americas, 1994.* MMWR Morb Mortal Wkly Rep, 1994. **43**(39): p. 720-2.
41. Andrus, J.K., et al., *Polio Eradication in the World Health Organization South-East Asia Region by the Year 2000: Midway Assessment of Progress and Future Challenges.* Journal of Infectious Diseases, 1997. **175**(Supplement 1): p. S89-S96.
42. Bahl, S., et al., *Global Polio Eradication – Way Ahead.* The Indian Journal of Pediatrics, 2018. **85**(2): p. 124-131.
43. Orenstein, W.A., *Eradicating Polio: How the World's Pediatricians Can Help Stop This Crippling Illness Forever.* Pediatrics, 2015. **135**(1): p. e20143163.
44. Birmingham, M.E., et al., *National Immunization Days: State of the Art.* Journal of Infectious Diseases, 1997. **175**(Supplement 1): p. S183-S188.
45. Bilous, J., et al., *The Experience of Countries in the Western Pacific Region in Conducting National Immunization Days for Poliomyelitis Eradication.* Journal of Infectious Diseases, 1997. **175**(Supplement 1): p. S194-S197.
46. Carlisle, D., *National immunisation day.* Afr Health, 1997. **20**(1): p. 10-1.
47. O'Connor, P.M., et al., *Update on Polio Eradication in the World Health Organization South-East Asia Region, 2013.* Journal of Infectious Diseases, 2014. **210**: p. S216-S224.
48. Stern, A., et al., *The Evolutionary Pathway to Virulence of an RNA Virus.* Cell, 2017. **169**(1): p. 35-46.e19.

49. Hampton, L.M., et al., *Cessation of Trivalent Oral Poliovirus Vaccine and Introduction of Inactivated Poliovirus Vaccine — Worldwide, 2016.* MMWR. Morbidity and Mortality Weekly Report, 2016. **65**(35): p. 934-938.
50. Kitamura, K. and H. Shimizu, *Outbreaks of Circulating Vaccine-Derived Poliovirus in the World Health Organization Western Pacific Region, 2000-2021.* Jpn J Infect Dis, 2022. **75**(5): p. 431-444.
51. Aylward, B. and R. Tangermann, *The global polio eradication initiative: Lessons learned and prospects for success.* Vaccine., 2011. **29**: p. D80-D85.
52. Dowdle, W.R., et al., *Polio eradication: the OPV paradox.* Reviews in Medical Virology, 2003. **13**(5): p. 277-291.
53. Daniell, H., V. Rai, and Y. Xiao, *Cold chain and virus-free oral polio booster vaccine made in lettuce chloroplasts confers protection against all three poliovirus serotypes.* Plant Biotechnol J, 2019. **17**(7): p. 1357-1368.
54. Sutter, R.W., et al., *The New Polio Eradication End Game: Rationale and Supporting Evidence.* Journal of Infectious Diseases, 2014. **210**(suppl 1): p. S434-S438.
55. Patel, M., L. Menning, and P. Bhatnagar, *Polio Eradication and Endgame Plan - Victory within Grasp.* Indian pediatrics : journal of the Indian Academy of Pediatrics., 2016. **53 Suppl 1**: p. S28-S32.
56. Menning, L., et al., *Communications, Immunization, and Polio Vaccines: Lessons From a Global Perspective on Generating Political Will, Informing Decision-Making and Planning, and Engaging Local Support.* The Journal of Infectious Diseases, 2017. **216**(suppl_1): p. S24-S32.
57. Ramirez Gonzalez, A., et al., *Implementing the Synchronized Global Switch from Trivalent to Bivalent Oral Polio Vaccines—Lessons Learned From the Global Perspective.* The Journal of Infectious Diseases, 2017. **216**(suppl_1): p. S183-S192.
58. Garon, J., et al., *Polio endgame: the global switch from tOPV to bOPV.* Expert review of vaccines., 2016. **15**(6): p. 693-708.
59. Bao, J., et al., *Polio – The old foe and new challenges: An update for clinicians.* Journal of Paediatrics and Child Health, 2020. **56**(10): p. 1527-1532.
60. Wassilak, S.G.F., et al., *Progress Toward Global Interruption of Wild Poliovirus Transmission, 2010-2013, and Tackling the Challenges to Complete Eradication.* Journal of Infectious Diseases, 2014. **210**(suppl 1): p. S5-S15.
61. Bigouette, J.P., et al., *Progress Toward Polio Eradication — Worldwide, January 2019–June 2021.* MMWR. Morbidity and Mortality Weekly Report, 2021. **70**(34): p. 1129-1135.
62. Kitamura, K. and H. Shimizu, *Outbreaks of Circulating Vaccine-derived Poliovirus in the World Health Organization Western Pacific Region, 2000-2021.* Jpn J Infect Dis, 2022.
63. Jafari, H., et al., *Polio eradication. Efficacy of inactivated poliovirus vaccine in India.* Science, 2014. **345**(6199): p. 922-5.
64. De Quadros, C.A., et al., *Eradication of Wild Poliovirus from the Americas: Acute Flaccid Paralysis Surveillance, 1988-1995.* Journal of Infectious Diseases, 1997. **175**(Supplement 1): p. S37-S42.
65. Zaidi, S.S.Z., et al., *Poliovirus Laboratory Based Surveillance: An Overview.* Poliovirus: Methods and Protocols, 2016. **1387**: p. 11-18.
66. Tangermann, R.H., et al., *The critical role of acute flaccid paralysis surveillance in the Global Polio Eradication Initiative.* International Health, 2017. **9**(3): p. 156-163.
67. Dietz, V., et al., *Predictors of Poliomyelitis Case Confirmation at Initial Clinical Evaluation: Implications for Poliomyelitis Eradication in the Americas.* International Journal of Epidemiology, 1992. **21**(4): p. 800-806.
68. Suresh, S., S. Forgie, and J. Robinson, *Non-polio Enterovirus idetection with acute flaccid paralysis: A systematic review.* Journal of Medical Virology, 2018. **90**(1): p. 3-7.
69. Roberts, J.A., et al., *Australian National Enterovirus Reference Laboratory annual report, 2015.* Communicable Diseases Intelligence, 2020. **44**.

70. Coulliette-Salmond, A.D., et al., *Haiti Poliovirus Environmental Surveillance.* The American Journal of Tropical Medicine and Hygiene, 2019. **101**(6): p. 1240-1248.
71. Ivanova, O.E., et al., *Environmental Surveillance for Poliovirus and Other Enteroviruses: Long-Term Experience in Moscow, Russian Federation, 2004–2017.* Viruses, 2019. **11**(5): p. 424.
72. Ozawa, H., H. Yoshida, and S. Usuku, *Environmental Surveillance Can Dynamically Track Ecological Changes in Enteroviruses.* Applied and Environmental Microbiology, 2019. **85**(24).
73. Bagcchi, S., *Polio vaccination in Afghanistan.* Lancet Microbe, 2022. **3**(1): p. e10.
74. *Wild poliovirus case in Malawi reinforces need to continue eradication efforts.* Bull World Health Organ, 2022. **100**(6): p. 362-363.
75. Tanne, J.H., *Polio emergency declared in New York State over virus found in wastewater.* BMJ, 2022. **378**: p. o2211.
76. Larkin, H., *What All Physicians Need to Know About the Polio Resurgence in New York State.* JAMA, 2022.
77. Graham, F., *Daily briefing: Polio outbreaks in New York, London and Jerusalem.* Nature, 2022.
78. Mahase, E., *Polio: What do we know about the polioviruses detected in the UK?* BMJ, 2022. **377**: p. o1578.
79. Brown, C., *Canada not immune to spread of polio.* Canadian Medical Association Journal, 2014. **186**(10): p. 738-738.
80. PHAC, *Surveillance of acute flaccid paralysis*. 2018: Public Health Agency of Canada.
81. *Childhood National Immunization Coverage Survey (CNICS)*. 2019.
82. Hajizadeh, M., *Socioeconomic inequalities in child vaccination in low/middle-income countries: what accounts for the differences?* J Epidemiol Community Health, 2018. **72**(8): p. 719-725.
83. Carpiano, R.M., et al., *Socioeconomic status differences in parental immunization attitudes and child immunization in Canada: Findings from the 2013 Childhood National Immunization Coverage Survey (CNICS).* Preventive Medicine, 2019. **123**: p. 278-287.