Overview of VPD Surveillance Principles

Last updated: September 5, 2018

Vaccine-Preventable Diseases

Surveillance Standards

World Health Organization

Overview of VPD Surveillance Principles

OVERVIEW CONTENTS

PREFACE TO THE 2018 VPD SURVEILLANCE STANDARDS 4

1. INTRODUCTION TO VPD SURVEILLANCE 5
   - 1.1 WHAT IS VPD SURVEILLANCE? 5
   - 1.2 OBJECTIVES OF VPD SURVEILLANCE 5
   - 1.3 PRIORITIZATION OF VPDS FOR SURVEILLANCE 6
   - 1.4 RECOMMENDED STANDARDS FOR VPD SURVEILLANCE 8
   - 1.5 VPD SURVEILLANCE DESIGN CHARACTERISTICS 9
   - 1.6 INTEGRATION WITH EXISTING SURVEILLANCE SYSTEMS 10
   - 1.7 SYNDROMIC SURVEILLANCE PLATFORMS FOR VPDS 11

2. CONDUCTING VPD SURVEILLANCE 13
   - 2.1 VPD SURVEILLANCE STEPS 13
   - 2.2 CASE DETECTION 14
   - 2.3 CASE DEFINITION AND CLASSIFICATION 15
   - 2.4 CASE INVESTIGATION 15
   - 2.5 CASE MANAGEMENT 16
   - 2.6 LABORATORY TESTING 16
   - 2.7 CASE NOTIFICATION AND REPORTING 21
   - 2.8 COMMUNICATION AND FEEDBACK FOR VPD SURVEILLANCE 21
   - 2.9 LOGISTICS OF VPD SURVEILLANCE 22

3. VPD SURVEILLANCE DATA, QUALITY, AND USE 24
   - 3.1 TYPES OF SURVEILLANCE DATA 24
   - 3.2 RECOMMENDED DATA ELEMENTS 24
   - 3.3 DATA COLLECTION AND MANAGEMENT 25
   - 3.4 DATA ANALYSIS AND INTERPRETATION 26
   - 3.5 DATA VISUALIZATION 26
   - 3.6 LIMITATIONS OF INTERPRETING SURVEILLANCE DATA 29
   - 3.7 DATA TO SUPPLEMENT VPD SURVEILLANCE 29
   - 3.8 MONITORING AND EVALUATION OF VPD SURVEILLANCE 30
   - 3.9 ETHICAL ISSUES RELATED TO COLLECTING VPD SURVEILLANCE DATA 32

4. THE ROLE OF VPD SURVEILLANCE IN OUTBREAKS 33
   - 4.1 STEPS OF AN OUTBREAK INVESTIGATION 33
   - 4.2 CHANGES TO VPD SURVEILLANCE DURING OUTBREAKS 34
   - 4.3 SURVEILLANCE STAFFING DURING OUTBREAKS 35
   - 4.4 COORDINATION IN VPD OUTBREAKS 35

5. INTRODUCTION TO THE CHAPTERS ON DISEASE-SPECIFIC SURVEILLANCE STANDARDS 36

REFERENCES 37

ANNEX A. Methods used in formulating VPD surveillance standard 39

ANNEX B. Integration of VPD surveillance within existing surveillance systems 41

ANNEX C. Supplemental information to VPD surveillance 43

ANNEX D. Steps in a VPD outbreak investigation 45

Preface to the 2018 Vaccine-Preventable Diseases Surveillance Standards

This document provides World Health Organization (WHO)-recommended standards for conducting surveillance for vaccine-preventable diseases (VPDs). VPD surveillance provides vital information to help countries understand disease burden and epidemiology to inform vaccine policy and strategy.

There are several reasons WHO is updating the VPD surveillance standards at this time. WHO published the last set of surveillance standards in 2003 and included 13 VPDs, with the standards for Japanese encephalitis updated in 2008 *(1)*. Since that time, VPD control programmes have progressed, new vaccines have been introduced globally, laboratory diagnostic practices have changed, and some VPD case definitions have been modified, making the 2003 VPD surveillance standards out of date. While surveillance standards for some individual VPDs have been updated more recently, no single document compiles existing surveillance standards for most VPDs, to be used on a global scale.

The principal audiences for these surveillance standards are national Ministries of Health (MOH), particularly the Expanded Programme on Immunizations (EPI) and Communicable Disease Control programme managers and surveillance officers, as well as vaccine policy decision-makers. Other stakeholders include local and provincial health departments, WHO regional and country offices, UNICEF, the Gavi Alliance, academic institutions and non-governmental organizations.

This document provides an overview of VPD surveillance, followed by an overview of how to conduct surveillance for VPDs. These guidelines are not intended to be comprehensive for all aspects of VPDs. This document does not include step-by-step surveillance protocols, detailed laboratory methods, templates for line lists or databases, recommendations for monitoring adverse events following immunization or guidance on vaccination coverage surveys. In addition, details on routine immunization schedules will not be given here but may be found on the WHO website *(2)*.

This document is intended to provide a set of standards that countries should consider in establishing and improving existing VPD surveillance. Countries may adapt these standards based on local epidemiology, policy, disease control objectives and strategies. While the primary audiences of this document are country programme managers, it is important to recognize that standardized global surveillance data are useful for developing global vaccination policy.

Detailed methods for developing this document are described in Annex A.

1. Introduction to VPD Surveillance

1.1 WHAT IS VPD SURVEILLANCE?

Public health surveillance is the continuous and systematic collection, analysis and interpretation of health-related data needed for the planning, implementation and evaluation of public health practice *(3)*. Surveillance for VPDs is qualitatively similar to other types of disease surveillance in design *(4)*. Like other types of surveillance, VPD surveillance is vitally important for its potential to inform policy and monitor immunization programmes, including vaccine introduction, coverage and potential use for outbreak response. VPD surveillance is also able to detect changes in the epidemiology of VPDs over time due to vaccine use and other preventive measures. As the burden of a VPD is reduced, the objectives and design of the surveillance system can shift. This document provides standards for the design and implementation of VPD surveillance to meet immunization programme objectives.

Public health programmes may include surveillance for VPDs as part of a communicable disease surveillance system. Because the objectives of VPD surveillance, such as detecting outbreaks, usually overlap with other ongoing communicable disease surveillance, integration of VPD surveillance with other surveillance systems is encouraged where possible. Where VPD surveillance is integrated with national communicable disease surveillance, the surveillance team should engage EPI and other immunization stakeholders.

1.2 OBJECTIVES OF VPD SURVEILLANCE

Country programmes should outline their key objectives for each disease under surveillance as an integral part of surveillance prioritization and design. The objectives of a surveillance system should dictate its design, rather than vice versa. VPD surveillance can have several principal objectives, with common examples outlined in Table 1.

TABLE 1

VPD surveillance objectives

SURVEILLANCE OBJECTIVE	KEY CHARACTERISTICS	EXAMPLES
Monitoring disease elimination or eradication efforts	Detection of all cases; risk factors; molecular epidemiology	Polio eradication; measles and neonatal tetanus (NT) elimination
Detection of outbreaks and new pathogens	Clusters of VPD; unusual or rare strain identification	Meningococcal outbreaks; pandemic or highly virulent influenza virus
Evidence for new vaccine introduction or optimizing vaccine schedules	VPD epidemiology; trends; disease burden	Pneumococcal, rotavirus disease burden for vaccine introduction decisions; changing schedules for tetanus or pertussis vaccine
Evaluation of immunization programme performance and defining the need for supplementary immunization	Characterize gaps in immunization programme and epidemiologic patterns of cases (for example, age, geographic location)	Vaccination history of measles cases can help identify geographic areas and age groups with low vaccination coverage to inform targeting of future measles vaccine campaigns
Vaccine effectiveness, impact on disease burden, or both	Trends in VPD case counts pre- and post-vaccine introduction	Test-negative case-control studies of vaccine effectiveness
Changes in disease strains or types	Molecular or serologic characterization of cases	Seasonal influenza vaccine formulation; pneumococcal serotype replacement after pneumococcal conjugate vaccine (PCV) introduction

1.3 PRIORITIZATION OF VPDS FOR SURVEILLANCE

The Strategic Advisory Group of Experts (SAGE) on Immunization recommends surveillance for all VPDs. However, a vaccine with the proven potential to reduce morbidity and mortality should be introduced or continued even if the country does not yet do surveillance for a VPD *(5)*.

When deciding whether to undertake surveillance for a particular VPD, consider primarily whether surveillance data will inform key vaccine policy and immunization strategy decisions. Secondarily, consider the following resource questions when deciding which type of VPD surveillance to conduct:

- Can surveillance objectives be met by using the existing integrated surveillance platforms, with a minimal increase in resources? Or is disease-specific surveillance required?
- Is there sufficient technical capacity, including epidemiological staff and laboratory infrastructure? Is there adequate funding and other resources?

If there are not adequate resources to conduct high-quality surveillance that addresses the objectives of the immunization programme, reconsider the decision to do surveillance for the VPD. Poor-quality surveillance

BOX 1

Definitions of control, elimination and eradication *(6)*

Control: Reduction of disease incidence, prevalence, morbidity or mortality to a level that is acceptable as a result of deliberate efforts, but still requires continued efforts to maintain the reduction.

Elimination: Reduction to zero incidence of a specified disease in a defined geographical area as a result of deliberate efforts, but still requires continuous intervention efforts.

Eradication: Reduction to zero of the worldwide incidence of infection caused by a specific agent, the complete interruption of transmission, and the extinction of the causative agent so that it no longer exists in the environment; intervention measures are no longer needed.

can be worse than no surveillance, because it can lead to decision-making based on erroneous or incomplete data.

In some countries, limited resources and capacity might force a country to prioritize surveillance for some VPDs and not others. Box 2 lists the criteria WHO has suggested for prioritizing diseases for surveillance *(7)*. According to these criteria, many VPDs would rank highly, partially because they have a proven method of control and prevention – namely vaccination.

The objectives of a VPD surveillance system listed in Table 1 should also guide prioritization. For example, all countries should be doing surveillance for VPDs slated for global eradication or elimination, such as polio, measles and neonatal tetanus. Countries should also include VPDs that are part of regional elimination and control goals, such as rubella, Japanese encephalitis, diphtheria and yellow fever. All WHO Member States have signed on to the 2005 International Health Regulations (IHR) that include surveillance for some VPDs, such as smallpox, polio and novel influenza (Box 3). Surveillance for epidemic-prone VPDs where vaccine might be considered in response (such as yellow fever, meningitis, cholera) might also be prioritized, especially for those diseases with vaccines available in the global vaccine stockpile.

BOX 2

Criteria for prioritization of communicable disease surveillance *(7)*

The following are criteria for prioritizing communicable disease surveillance, including VPDs:

- disease burden and endemicity (natural level of disease occurrence)
- severity and case fatality ratio
- epidemic potential
- potential for emergence of virulence or changing pattern of disease
- prevention and control, and elimination potential
- social and economic impact
- international reporting regulations, such as International Health Regulations
- public perception of risk
- logistical feasibility (for example, syndromic surveillance already exists)

BOX 3

Surveillance and International Health Regulations for disease reporting

All WHO member states are obligated by the 2005 International Health Regulations to report to WHO any disease that constitutes a public health emergency of international concern. These regulations do not require a separate surveillance system or specify the use of a particular type of surveillance system. However, all member states have committed to achieve a core capacity for public health surveillance (including detection, verification and reporting) and response as part of global health security *(8)*. Of the diseases requiring mandatory immediate reporting, three are potentially vaccine preventable: smallpox, wild-type poliovirus and human influenza caused by a new subtype. Yellow fever, cholera, dengue and viral hemorrhagic fevers (such as Ebola) are diseases with vaccines that are currently licensed or under development, and are listed as potentially requiring reporting under IHR depending on the risk of serious public health impact and international spread. Therefore, IHR reporting channels must be incorporated in the VPD surveillance reporting structure where relevant.

As described in Strategic Objective 3 of the Global Vaccine Action Plan 2011–2020, it is important to consider the ability of the established VPD surveillance in a country to identify gaps and inequities in the coverage of immunization programmes. Specific VPDs that do not meet any of the criteria listed in Box 2 may also be placed under surveillance as long as there is also ongoing surveillance for other VPDs that do meet these prioritization criteria.

Usually the case for conducting surveillance for a VPD will be clear to MOHs. If the surveillance decision for any emerging or novel communicable disease or re-emerging VPD is not straightforward, one suggested method for prioritization is the Delphi method, whereby a group of public health officials, technical experts and opinion leaders are convened to score potential diseases for surveillance using a pre-determined point system for various criteria.

1.4 RECOMMENDED STANDARDS FOR VPD SURVEILLANCE

The recommended minimal standards for VPD surveillance include the design, methods and data elements necessary for achieving the specific goals of immunization programmes. Efforts should be made to meet the suggested minimal standards for whichever VPD is prioritized for surveillance. Table 2 summarizes the minimal standard by disease as detailed in the disease-specific chapters of this document. These chapters also include suggestions for enhanced surveillance standards to collect the information required to meet additional objectives. Other communicable disease surveillance systems that collect limited information on VPDs and do not address the needs of entire immunization programmes are not necessarily subject to these standards. Be sure that the data systems and database structure can accommodate the data required for the standards. Once established, a system can expand to include the enhanced approach (for example, start with subnational and expand to nationwide).

TABLE 2

Minimal recommended surveillance standards for informing immunization programme policy of vaccine preventable diseases*

MINIMAL RECOMMENDED STANDARD FOR VPD SURVEILLANCE	NATIONWIDE, CASE-BASED WITH LABORATORY CONFIRMATION OF EVERY CASE	NATIONWIDE, AGGREGATE WITH LABORATORY CONFIRMATION OF OUTBREAKS	SENTINEL, CASE-BASED WITH LABORATORY CONFIRMATION OF EVERY CASE	OTHER (E.G. DISEASES HAVE DIFFERENT MINIMUM STANDARD OF SURVEILLANCE BASED ON CONTEXT)
Surveillance commitment in every country	Poliomyelitis, Measles	-	-	Neonatal Tetanus (no laboratory)
Surveillance commitment varies by country	Diphtheria, Rubella, Meningococcus	Hepatitis A, Hepatitis B, Mumps	Congenital rubella syndrome, *Haemophilus influenzae,* Pneumococcus, Influenza, Japanese encephalitis, Pertussis, Rotavirus, Typhoid	Cholera (event-based), HPV (surveillance not recommended), Non-neonatal tetanus (no laboratory confirmation), Varicella (no laboratory confirmation)

**This is a general categorization and the disease chapters should be referred to for specifics*

1.5 VPD SURVEILLANCE DESIGN CHARACTERISTICS

Once the objectives of surveillance are set, it is necessary to create a surveillance system design that meets the objectives. Consider the following questions to inform the system design:

- Is it necessary to capture all of the cases, or is some subset or fraction acceptable? VPDs that have elimination or eradication goals will require a system that can capture all cases.
- What level of detailed case information is necessary to inform public health action?
- Do adequate resources exist to pursue detailed information for every case, or could greater efficiency be achieved through focused surveillance in high-yield scenarios or integration with other surveillance systems?

Consider the characteristics below during the surveillance design process. These may be dependent on the existing public health system and infrastructure within a country. Although these characteristics are presented below as either/or, many surveillance systems contain a mixture of elements. For example, a system may have both passive and active elements, or be both facility- and community-based *(9)*.

AGGREGATE VS. CASE-BASED

In aggregate surveillance, only a tally of the number of cases is collected and reported from clinic admission registers, logbooks or other records. No individual level data is collected, but cases may be aggregated by subgroup such as age, sex or locality. In contrast, case-based surveillance requires the collection and reporting of detailed information on each case of a VPD. Examples of such details include age, sex, residence, vaccination status and risk factors. Individual-level data from case-based surveillance may sometimes be aggregated into summary reports.

NATIONWIDE VS. SUBNATIONAL

VPD surveillance can be nationwide or intentionally limited to a defined part of the country. Subnational surveillance might be considered if the VPD burden is confined to a certain region of the country, or if there is greater capacity to conduct high-quality surveillance in a particular geographic area. However, the cases captured through subnational surveillance might not be representative of those occurring throughout the entire country. When interpreting subnational surveillance data, always consider whether the surveillance population is representative of the larger population. For VPDs with control goals, subnational surveillance may be acceptable for determining risk factors or evaluating the impact of a vaccine. For VPDs targeted for elimination or eradication, nationwide surveillance that strives to detect all cases is essential.

POPULATION-BASED VS. SENTINEL-SITE

Population-based surveillance attempts to capture all cases in a well-defined catchment population (for example, the entire population of a country). When the catchment population is defined, you can use the total population number as the denominator to calculate VPD incidence. This makes it possible to understand of the impact of a vaccine on disease burden over time and compare VPD incidence across countries or regions. Sentinel-site surveillance refers to a system that captures cases at one or more specialized sites, such as hospitals, clinics or pharmacies. Sentinel surveillance can provide useful information about the impact of the vaccine, epidemiology and risk factors, and pathogens causing disease, such as circulating strains. Catchment populations of sentinel sites are usually hard to define and can vary over time, so it is difficult to know the total population (denominator) required to calculate disease incidence.

FACILITY-BASED VS. COMMUNITY-BASED

Facility-based surveillance usually detects more severe cases seeking care at health facilities, including outpatient clinics, doctors' offices, hospitals and emergency departments. Access to clinical diagnosis and laboratory confirmation generally make facility-based surveillance easier to conduct than community-based surveillance. Often conducted in conjunction with facility-based surveillance, community-based surveillance can potentially detect less severe VPD illness or diseases not normally captured at health facilities because they are considered a normal part of childhood (such as measles) or have an associated stigma (such as death from neonatal tetanus). For polio eradication, a community-based surveillance strategy is critical in order to detect all cases, regardless of severity,

and break chains of transmission. For community-based surveillance, additional resources are required to sensitize and follow up with community informants, and the yield of true cases can be low.

ACTIVE VS. PASSIVE

Passive case detection means that health facility staff detect and report cases, while active surveillance means that designated public health surveillance staff are directly involved in detecting cases. For example, surveillance staff may do a regular review of facility registers and have regular contact with clinicians regarding potentially missed cases. Compared to passive methods, active surveillance is more resource-intensive and expensive; it is often used for VPDs in the elimination or eradication phase, or to characterize VPD epidemiology or vaccine impact in discrete populations or sentinel sites.

CLINICAL VS. LABORATORY-BASED

The distinction between these two types of surveillance is not the involvement of a laboratory test, but rather whether case detection is initiated based on clinical diagnosis or laboratory test results. Many surveillance systems start with a clinical definition to capture suspect cases (for example, a syndrome like diarrhea or fever-rash), and then use laboratory tests to confirm cases. In laboratory-based surveillance, a laboratory result confirming a VPD case is the starting point for inclusion in surveillance *(10) (11)*. Laboratories or hospitals report these laboratory-confirmed cases to public health authorities, either as part of national disease reporting requirements or sentinel surveillance networks. A laboratory-based surveillance approach is best implemented when a majority of patients with specified signs and symptoms are laboratory tested as part of existing clinical practice. Data management systems are essential for linking lab and epidemiologic (clinic-based) data.

1.6 INTEGRATION WITH EXISTING SURVEILLANCE SYSTEMS

Integration of VPD surveillance into existing communicable disease surveillance systems, or linking one VPD surveillance system into another, has clear advantages. Integration of disease surveillance capitalizes on an economy of scale and can be less resource-intensive than starting a new disease-specific surveillance system.

VPD surveillance can be integrated into existing surveillance in three main ways:

- **Use the existing system as is.** If the existing surveillance system already captures the complement of cases and data elements from the desired population, then the system might already be sufficient to meet the standards for some VPDs as outlined in this document.
- **Add more VPDs to an existing VPD platform.** An existing VPD surveillance platform might be adapted to meet the surveillance standards for additional VPDs. An example is the adaptation of measles case definitions and testing algorithms to allow integrated surveillance with rubella.
- **Integrate surveillance activities instead of systems.** If separate VPD-specific surveillance is required, the team can integrate surveillance activities in areas of overlap between the two surveillance systems, as outlined in Box 4.

BOX 4 Practical areas where integration of VPD surveillance can occur

The following are ways to integrate VPD surveillance activities with existing surveillance efforts:

- policy, including regulations, prioritization and standards
- financing, including costing, funding and sustainability plans
- infrastructure, including facilities, equipment, supplies and maintenance
- workforce capacity, including staffing, retention plans and cross-cutting training
- field logistics, including case investigations, supervision, active surveillance visits and transport of lab samples
- laboratory, including expansion and diversification of global networks, shared procurement processes and quality management systems (for example, External Quality Assessment)
- monitoring and evaluation, including information systems and performance indicators.

See Annex B for a more detailed discussion of integrating VPD surveillance into some of the more commonly known surveillance systems such as Integrated Disease Surveillance and Response (IDSR) and Early Warning and Response Network (EWARN). Even if you cannot use the current system to meet the required standards of VPD surveillance outlined here, you can use the information generated by the existing surveillance system to triangulate the data, creating a more comprehensive picture of VPD epidemiology and disease-specific surveillance performance.

1.7 SYNDROMIC SURVEILLANCE PLATFORMS FOR VPDS

A particular type of integrated surveillance approach is syndromic surveillance. This term has several meanings and is used in many countries to detect different health threats, such as bioterrorism-related events, chronic diseases and infectious disease outbreaks *(12) (13) (14)*. In the context of VPD surveillance, syndromic surveillance refers to the use of a clinical syndrome – a constellation of symptoms and signs – as the case definition for detection of suspect cases of a VPD. Using syndromic surveillance platforms for multiple VPDs can be more efficient than doing surveillance for a single disease.

For example, acute flaccid paralysis (AFP) surveillance for polio is a type of syndromic surveillance that captures not just polio but also Guillain-Barre syndrome or other conditions that cause neurologic problems. Surveillance of fever-rash syndrome is used for measles and rubella but could also include dengue, parvovirus B19 or other viral causes *(15)*. Laboratory testing for multiple pathogens is done according to a defined algorithm to determine the final diagnosis and classify the cases to the correct VPD. Syndromic surveillance can be used for initial case detection, but laboratory confirmation should occur to increase the accuracy of the system.

The principal types of syndromic surveillance platforms for VPDs are shown in Table 3. Each syndrome has the potential to encompass multiple VPDs as well as other pathogens that might not yet be vaccine-preventable but could be in the future.

Before creating a syndromic surveillance platform for VPDs, several considerations should be taken into account. First, the sensitivity of a syndromic case definition can vary for different diseases based on the spectrum of clinical presentations. For example, rubella sometimes presents without a fever or can even be asymptomatic, so not all cases would meet the fever-rash case definition. Second, doing surveillance for multiple diseases using the same platform can dilute the focus if too many different age targets and laboratory criteria are added to accommodate the different VPDs. Third, there can be increased complexity of reporting, classification and laboratory testing if a single illness meets the syndromic case definitions for more than one VPD. Assess whether syndromic surveillance would be beneficial and feasible given these considerations.

TABLE 3

Syndromic surveillance platforms for VPDs

CLINICAL SYNDROME	VPDs	EXAMPLES OF OTHER NON-VPD CAUSES OF SYNDROME
Diarrhea (including watery and bloody)	Rotavirus Cholera	Norovirus* Shigella*
Acute jaundice	Hepatitis A,B,E Yellow Fever	Hepatitis C Leptospirosis Liver flukes
Fever-rash	Measles Rubella Varicella Dengue Typhoid Meningococcus	Scarlet fever (group A Streptococcus)* Erythema infectiosum (parvovirus B19) Roseola infantile (human herpesvirus 6) Enterovirus (echovirus, coxsackievirus) Infectious mononucleosis Kawasaki disease Chikungunya virus Zika virus
Acute flaccid paralysis (AFP)	Polio Japanese encephalitis Herpes zoster Rabies Tick-borne encephalitis	Enteroviruses (coxsackieviruses, echoviruses, enterovirus 71) West Nile Virus Guillain–Barré syndrome
Meningoencephalitis (ME)/ acute encephalitis syndrome (AES)	Meningococcus Pneumococcus *Haemophilus influenza* type B (Hib) Japanese encephalitis	West Nile virus Saint Louis Encephalitis virus
Severe acute respiratory illness (SARI)/ Influenza-like illness (ILI)	Influenza Pertussis	Respiratory syncytial virus (RSV)* Other respiratory infections
Persistent cough	Pertussis	Other respiratory infections (e.g. *Mycoplasma pneumoniae*) Tuberculosis
Meningitis/pneumonia/sepsis	Meningococcus Pneumococcus *Haemophilus influenza* type B (Hib) Typhoid Japanese encephalitis	

**Vaccines not currently available, but in late stage of development.*

2. Conducting VPD Surveillance

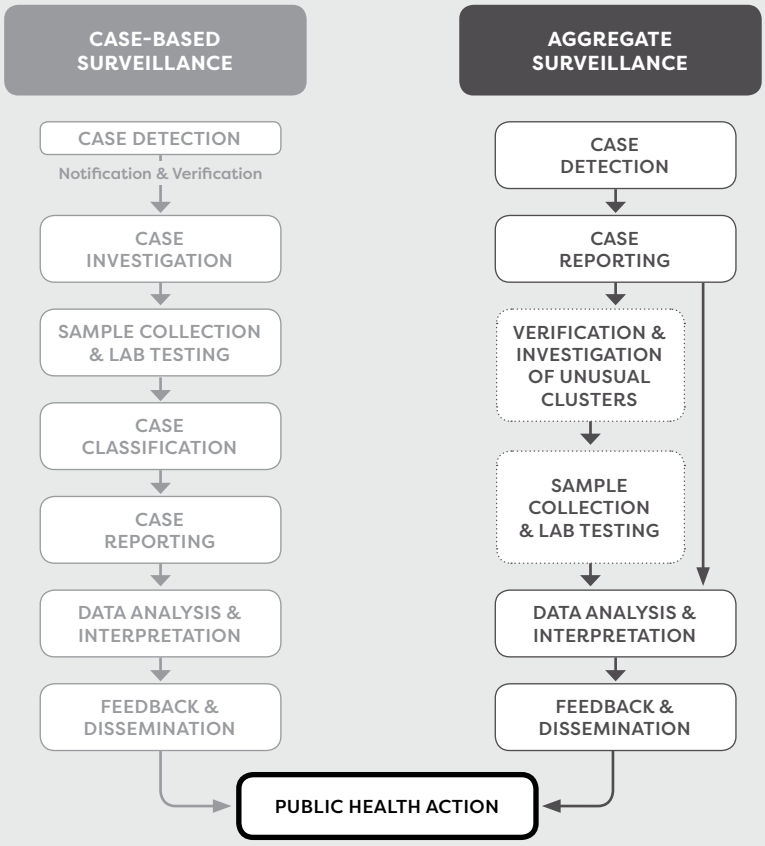
2.1 VPD SURVEILLANCE STEPS

Successful VPD surveillance requires alignment with a country's objectives, meticulous planning and ongoing attention to the daily operations at each step of surveillance. Surveillance infrastructure, including the reporting network and laboratory capacity, must first be established. For ongoing surveillance, the routine steps include:

- Case detection
- Case investigation
- Sample collection and laboratory testing
- Case classification
- Data analysis and interpretation
- Reporting
- Feedback

Figure 1 shows the VPD surveillance steps for both case-based and aggregate surveillance. Aggregate surveillance may or may not include verification and investigation of unusual clusters and sample collection and laboratory testing. These steps are in the boxes outlined with dashes in Figure 1. A discussion of the steps follows the figure.

FIGURE 1 **Steps in VPD surveillance**



2.2 CASE DETECTION

The design characteristics of the surveillance system will determine which strategy is used to detect cases. Regardless of the strategy, ensure that clinical and laboratory staff are willing and able to participate. It will also be necessary to train them to use the standardized case definitions. Develop and supply tools to educate and support clinicians in reporting cases.

Below are case detection strategies for different types of surveillance system designs.

PASSIVE SURVEILLANCE

For case detection through passive surveillance, set up a network of public and private reporting sites, and sensitize health care professionals (including health workers) to case definitions and reporting procedures. For example, health workers will need to know the frequency of reporting, format of reports, deadlines for reporting and points of contact at the next reporting level. Most countries already have a passive surveillance system, but the programme may need to be strengthened to include supportive supervision of the reporting sites and verification of initial reports. Passive reporting works best when sites have a designated surveillance focal point or health information officer who is assigned to collate data and monitor for diseases that require immediate reporting. Instruct surveillance focal points to submit reports at the specified frequency (weekly or monthly) even if no cases are detected at the site. This is called "zero reporting". Zero reporting ensures the completeness of data and serves as a tool for monitoring the quality of the surveillance system even if no disease is being detected.

ACTIVE SURVEILLANCE

Diseases with eradication and elimination goals require active surveillance. The VPD surveillance programme should identify surveillance staff and managers at subnational or national levels responsible for active surveillance. Surveillance staff may also be immunization programme staff who are already engaged in related activities. Surveillance officers should establish working relations with designated health facility surveillance focal points and seek approval from health facility officials. They should also sensitize clinicians to report diseases meeting relevant case definitions. Surveillance officers should establish a schedule for conducting active surveillance visits at each assigned facility based on the likelihood of seeing specific diseases under surveillance within a specific time period. For example, if the likelihood of seeing a suspect case is high, the surveillance officer can visit weekly; if the likelihood is lower, visits can be monthly or quarterly.

During a visit, the surveillance officer should contact the surveillance focal point to obtain lists of suspect cases, visit all outpatient departments and inpatient wards where suspect cases may have been seen, and examine patient and laboratory registers for any missed cases. Officers should also visit inpatient wards to discuss specific patients exhibiting relevant signs and symptoms with unit chiefs, clinicians, head nurses and laboratory staff. The surveillance officer should alert the facility's surveillance focal point of any missed cases, and re-sensitize that person on reporting criteria. Surveillance officers should track and document active surveillance visits by completing forms and recording the officer's name and date of the visit on the registers. Suspect cases should be investigated and an appropriate laboratory specimen should be obtained for testing if within an appropriate time frame for the disease.

COMMUNITY-BASED SURVEILLANCE

Community-based surveillance involves establishing an informant network that can include traditional healers, community health workers, midwives, pharmacists and village leaders. Community informants should be sensitized to the signs and symptoms they need to report to the local health facility or surveillance focal point. They may require additional resources to fulfill reporting obligations, such as incentives or cell phone airtime. Frequently, the case definitions reported by these informants are simplified, so public health surveillance officers will need to see if the reported cases actually meet the suspect case definition used in the country.

SENTINEL-SITE SURVEILLANCE

Surveillance at sentinel sites should capture disease epidemiology, including the age group(s) affected, geographic distribution and seasonality. For the most part, sentinel sites should be chosen based on the likelihood that cases will be seen, such as reference hospitals or other large hospitals. Sentinel sites can also include other non-health facility sites such as schools or military facilities. Sites should have the clinical and laboratory capacity to confirm cases.

2.3 CASE DEFINITION AND CLASSIFICATION

A standard case definition is an agreed set of criteria used to describe if a person has a particular disease or was exposed to a particular pathogen. Case definitions are used to label a case, such as suspected, probable, confirmed. Standard definitions ensure that every case is detected and reported in the same way. Once a case meets the standard case definition for notification, it is labeled as a suspect case. Sometimes a broader syndromic case definition is used to improve the likelihood of finding cases of interest, although other similar diseases might also be detected. During case investigation, clinical criteria, laboratory testing and epidemiological information are used to confirm the case.

A suspect case definition always includes the key signs and symptoms of a VPD (such as fever-rash for measles or AFP for polio). It may also include age criteria (such as age < 15 years for AFP or age ≤ 28 days for neonatal tetanus). During outbreaks, additional criteria may be added to specify linkage to the outbreak; these criteria could include residence in a defined geographic area or a date of illness onset that is within the outbreak period.

Based on the laboratory results or epidemiological linkage, a suspect case should usually be either classified as "laboratory confirmed" or "discarded" (that is, not a case). For some VPDs, additional case classifications may be used when there is less confidence that the case is a true case. For example, those meeting the clinical criteria but without definitive laboratory test results may be classified as "clinically compatible". Epidemiological linkage is defined differently for each VPD based on its mode of transmission, but usually includes being within close proximity to a confirmed case during the infectious period.

2.4 CASE INVESTIGATION

The next step in surveillance is a detailed case investigation and sample collection. Depending on the local health system, designated public health surveillance staff may do this, or clinicians or health facility focal points may do it. For bacterial diseases under surveillance, clinicians should collect the sample, as public health staff are unlikely to collect a sample prior to the start of antibiotic treatment.

Based on national guidelines, some VPDs (such as polio, measles-rubella or neonatal tetanus) may require a detailed case investigation within a specified timeframe after receiving and verifying a case notification.
As part of the investigation, surveillance officers or clinicians complete the relevant case investigation form and collect the relevant laboratory sample. The case investigation form should be filled completely, including patient name, date of birth or age, sex, place of residence, vaccination status or date of last vaccination, date of laboratory specimen collection, signs and symptoms, and place of infection or travel history.
The goals of the case investigation usually include:

- Confirming (or discarding) the case according to established case definitions
- Determining the source of the infection
- Evaluating the extent of infection (limited to one case or a cluster of cases in the community)
- Collecting detailed information to allow appropriate epidemiologic analysis and potential response.

2.5 CASE MANAGEMENT

Case management of individuals is not an explicit objective of public health surveillance, including VPD surveillance *(3)*. VPD surveillance should not replace the routine clinical procedures for diagnosis and treatment. Treatments for most VPDs have established clinical protocols published as part of national guidance documents. If an individual with a potential VPD is detected by the surveillance system, VPD surveillance staff should refer the individual for clinical care if appropriate.

Prevention and treatment may overlap for some VPDs, with public health playing a bridging role. For example, public health may administer vitamin A to people with measles during outbreaks. As part of surveillance and response for highly infectious VPDs, clinics and hospitals should implement infection control procedures to prevent the spread of infection in health facilities and further amplification of the outbreak. For example, clinics and hospitals may isolate measles and mumps patients during the infectious period *(16)*. Lastly, for some VPDs, close contacts of cases identified through case investigations might be given prophylactic measures to prevent disease. Prophylactic measures could include antibiotics for diseases like meningococcus and diphtheria, immune globulin for hepatitis A, and vaccine for measles given within 72 hours of exposure *(17)*.

2.6 LABORATORY TESTING

If laboratory testing is required for case confirmation, this capacity must be established at national, regional or individual hospital laboratories. Laboratory staff must be hired and trained according to standardized protocols, laboratory supplies and equipment must be available and functional, and the transport and storage system for specimens must be in place. Ensure that laboratories in the surveillance system have surge capacity when designing surveillance for epidemic-prone VPDs.

Surveillance for some VPDs includes participation in global laboratory networks (see Box 5). For historic reasons, global laboratory capacity for virologic surveillance is much more established than bacteriologic surveillance. Most countries have capacity for polio and measles-rubella testing, while capacity to perform bacterial culture and other techniques may need to be established or further strengthened.

Formal laboratory accreditation is provided through global laboratory networks, but international accreditation is not mandatory for laboratory participation in VPD surveillance. Rigorous procedures for monitoring laboratory quality should be implemented. Laboratory quality assurance (QA) procedures address the testing process (for example, external quality assurance, proficiency panel testing, periodic retesting and regular site visits), while quality control (QC) procedures address the laboratory results, such as internal assay controls. Both are encouraged as part of any laboratory component of surveillance.

The principal testing methods used in VPD surveillance are outlined in Table 4. For many VPDs, more than one laboratory method can be used to confirm the diagnosis using an algorithm dictated by relative disease prevalence. The laboratory may do serial testing, in which a specimen is first tested for one pathogen (such as measles in fever-rash surveillance) and if the initial test is negative, the specimen is then tested for another pathogen (such as rubella), and so on. The order of testing may be determined by the relative prevalence of the VPDs, the existence of a vaccine for the VPD, or the public health significance of the VPDs when financial resources are constrained. Some methodologies, such as polymerase chain reaction (PCR) can be multiplexed, meaning that several pathogens could be tested simultaneously using a single specimen. For example, a nasopharyngeal swab can be tested for multiple respiratory pathogens like influenza and RSV.

TABLE 4

Principal laboratory testing methodologies used in VPD surveillance

LAB METHOD	BIOLOGICAL MECHANISM	SPECIMEN TYPE	ADVANTAGE	DISADVANTAGE	VPDS
Microscopy/ culture	Growth of pathogen on culture media; direct visualization of pathogen in infected tissues	Sterile site: blood, cerebrospinal fluid (CSF). Non-sterile site: oropharynx (OP), stool, urine	Often gold standard; less need for advanced lab technologies; high specificity (sterile sites)	Low sensitivity; low specificity in non-sterile sites; contamination or poor specimen quality; multiple step process requiring several days; affected by antimicrobial use	Diphtheria; *Haemophilus influenzae*; meningococcus; mumps; pertussis; pneumococcus; polio; yellow fever
Virus isolation on cell culture	Virus amplification in continuous cell lines	Stool; urine; throat swab; nasopharyngeal swab or aspirate; blood	Virus isolate can be used for further analysis (sequencing, virus neutralization)	Laborious; need for specialized laboratory setup; time-consuming; expensive	Poliovirus; measles virus; rubella virus; yellow fever virus; Japanese encephalitis virus; mumps virus; hepatitis A virus; influenza virus; varicella-zoster virus
Antibody detection: Enzyme-linked Immunosorbent Assay (ELISA)/Enzyme Immunoassay (EIA), Immunofluorescence	Detection of IgM antibodies to pathogens, or rise in IgG antibody titer	Blood (sera); oral fluid; CSF	High specificity for most pathogens; ease of specimen collection and testing; IgM almost always detectable at time patient seeks medical care	Not sensitive or specific for some pathogens; interpretation can be challenging (e.g. maternal antibodies present in babies); timing of exposure leading to antibody formation not always clear); false positive results due to non-specific stimulation immune system, cross reactivity or rheumatoid factor); false negative results due to competing non-specific IgG; natural variation between patients; transient or persistent IgM	Hepatitis A, B*; measles; mumps; pertussis; rubella; yellow fever; Japanese encephalitis, varicella-zoster virus
Antigen detection: Agglutination assays; immunochromatographic; ELISA/EIA, immunohistochemistry, western blot	Detection of microbial antigens in body fluids or tissues	Blood; CSF; stool; tissues	Can be a rapid test	Lower sensitivity; can be difficult to interpret (e.g. visual inspection for agglutination)	*Haemophilus influenzae*, Hepatitis B; influenza; meningococcus, pneumococcus; rotavirus; rubella; varicella-zoster virus

TABLE 4

Principal laboratory testing methodologies used in VPD surveillance

LAB METHOD	BIOLOGICAL MECHANISM	SPECIMEN TYPE	ADVANTAGE	DISADVANTAGE	VPDS
Nucleic acid testing: polymerase chain reaction (PCR) (including genotyping, serotyping, antiviral susceptibility testing)	Detection and/or characterization of nucleic acid (DNA/RNA) of infecting pathogen in the body	Blood; CSF; OP; stool; tissues; lesions; saliva; amniotic fluid	Small amounts of nucleic acids detectable; highly sensitive; viable organism not needed; less affected by antimicrobial use; multiplexing possible	Can have lower specificity (false positives); cannot distinguish infection from colonization; requires more sophisticated laboratory and technologies	Diphtheria; *Haemophilus influenzae*; hepatitis B; influenza; measles; meningococcus, pertussis; pneumococcus; polio; rubella; yellow fever
Functional assays: virus neutralization, hemagglutination-inhibition, complement fixation, agglutination, antiviral susceptibility testing	Detection of specific activities resulting from binding of specific antibodies to viral antigens; detection of antiviral antibodies by blocking virus-induced haem-agglutination; ability of antiviral antibodies to fix complement, preventing lysis of indicator erythrocytes		Neutralization correlates well with protection from virus infection; standard against which other serologic assays are measured	Cumbersome; expensive	Poliovirus; measles; Japanese encephalitis; mumps; rubella; varicella-zoster virus; hepatitis A; hepatitis B; influenza, yellow fever, rotavirus

** Hepatitis B antibody detection alone cannot distinguish between infection and immunity.*

Laboratories sometimes do further characterization of VPD pathogens beyond the diagnostic testing outlined in Table 4. Serotyping or genotyping gives more specific information on the type or strain of the infecting pathogen, which can be important in informing programme strategy such as monitoring elimination of polio and measles viral strain. These methods can also inform choices of vaccine formulations, as when deciding among seasonal influenza vaccines or pneumococcal conjugate vaccines.

Lastly, consider whether specimens will be discarded or maintained in a laboratory. This depends on resources, available freezer space and potential future use of specimens for strain or serotype testing or other purpose. For polio, stored specimens have the potential to threaten eradication efforts, and it requires substantial resources to discard specimens from the biorepository with polio containment in mind. Moreover, there are ethical issues in the long-term storage of bio-specimens that must be considered, such as protection of personal information and sharing of biologic materials internationally *(18)*.

BOX 5

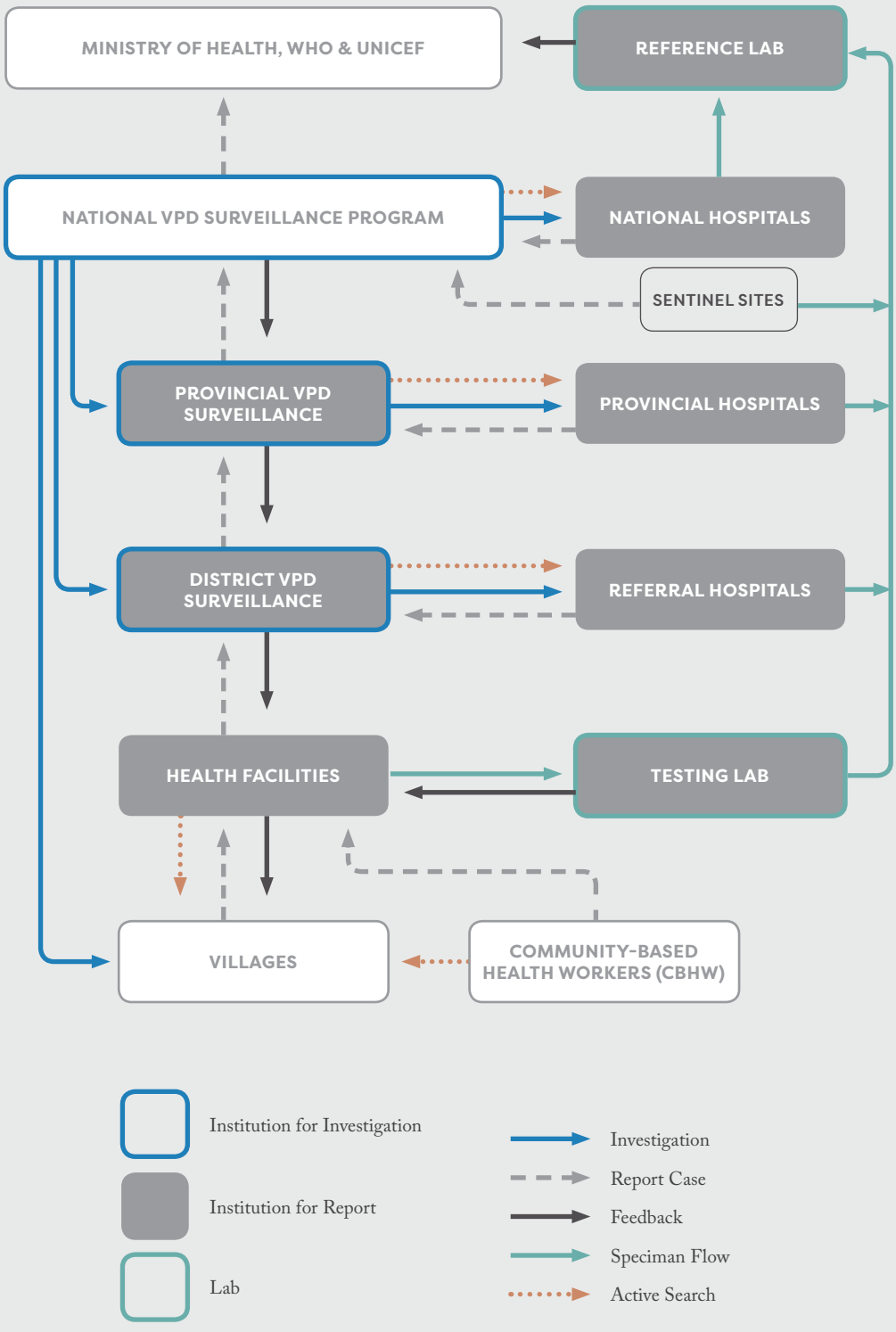
WHO global laboratory surveillance networks

WHO coordinates global laboratory networks to support surveillance for several VPDs, including polio, measles-rubella, yellow fever, Japanese encephalitis, rotavirus and invasive bacterial diseases (IBD) (19)(20). Global laboratory networks provide confidence in data used in eradication and elimination programmes, allow for valid comparison of VPD epidemiology and incidence across countries, and provide confidence in surveillance data used in vaccine policy decisions both nationally and globally. Most global laboratory surveillance networks have a tiered approach based on the structuring of the Global Polio Laboratory Network established in the late 1980s. National laboratories are trained to test for the VPD and are supported by regional reference laboratories for confirmatory testing and quality assurance/quality control. A few global specialized laboratories perform selective advanced testing such as molecular typing.

Being part of a global VPD laboratory network provides several advantages. The first is standardization of laboratory testing and diagnostic criteria. Second, laboratory networks provide a set of uniform criteria to evaluate the accuracy and proficiency of laboratory testing, emphasizing routine ongoing quality assurance and quality control. Third, laboratory networks allow for efficiency in combining results of surveillance from multiple countries and streamline reporting to WHO and other stakeholders. Though some countries have bacterial laboratories as part of sentinel surveillance networks like IBD, no bacterial laboratory networks exist for diseases such as diphtheria and pertussis. Further support is needed to develop bacterial laboratory capacity and make widespread accurate confirmation of these diseases a reality.

FIGURE 2

VPD surveillance information and specimen flow



2.7 CASE NOTIFICATION AND REPORTING

Notification is the process whereby the informant (clinician or health care worker) informs the public health system that there is a suspect case. Reporting is the process whereby a lower-level surveillance unit informs the next level of suspect and confirmed cases at a regular reporting frequency.

Notification of communicable diseases, including VPDs, occurs at a set frequency based on national guidelines. Immediate notification can occur by phone, SMS (text), email or paper from health facility or community informants to public health authorities. Immediate or near-immediate notification is usually required for outbreak-prone VPDs and other VPDs requiring timely public health action, such as polio, measles or diphtheria (to access diphtheria antitoxin quickly). Verification of cases with immediate notification is required and usually occurs prior to or as part of the case investigation process. Verification includes contacting the health facility to determine that initial reports meet suspect case definitions.

Weekly or monthly reporting is usually required for all VPDs to assess trends, seasonality and geographic distribution. Weekly or monthly reporting usually occurs as part of routine paper or electronic reporting from designated sites, and typically also includes zero reporting when there is no disease. Public health authorities should verify that the reported VPD cases meet the standard case definitions and assess whether an outbreak investigation is required for observed increases in reported cases.

Most countries send the Joint Reporting Form (JRF) to WHO for global annual reporting of most VPDs, so WHO can evaluate progress towards disease control targets and EPI programme impact. For diseases with global eradication and elimination goals such as polio and measles, case-based data is also reported regularly to WHO. Some VPDs might require immediate global reporting to WHO as mandated by the International Health Regulations.

2.8 COMMUNICATION AND FEEDBACK FOR VPD SURVEILLANCE

An essential component of VPD surveillance is that data are analysed and communicated for timely public health action and larger decisions on vaccine policy and strategy. Communication between the different levels of the surveillance system is essential, and a detailed plan that addresses the "who, what, where, when and how" should be included as part of national surveillance protocols. Frequent communication and regular feedback should flow both up and down the surveillance chain between informants, surveillance officers, supervisors and laboratory personnel. Cases of some VPDs such as polio and measles must be reported up the chain immediately via phone or text messaging to trigger timely investigation and response by public health staff. Laboratory results and feedback on surveillance reporting should be shared back to informants and reporting units via direct communication, surveillance bulletins and database linkage through the use of unique identifiers. Results of surveillance monitoring and evaluation should be shared regularly among the surveillance staff and stakeholders in surveillance or data review meetings.

It is also important to consider communications with external surveillance stakeholders. Timely communications should occur across district and national borders for diseases of epidemic potential, and to international authorities for diseases of global importance (for example, polio and measles reporting to WHO). Regularly sharing surveillance findings and programme achievements to external stakeholders is also a critical component of VPD surveillance. Broader dissemination of surveillance data to the public health community as part of scientific publications can also be used to better understand disease epidemiology and vaccine characteristics, which can be used to make changes to vaccine policy.

2.9 LOGISTICS OF VPD SURVEILLANCE

Making a VPD surveillance system run effectively requires consideration and attention to several key logistical components, both in setting up and maintaining surveillance. These logistical components are described below.

STAFFING

VPD surveillance requires adequate staffing to generate and interpret quality data. Most surveillance systems will need the following staff, although some duties might be covered by the same individual: supervisors, surveillance officers, facility surveillance focal points for case detection, laboratory personnel, and data managers or data analysts. Roles and responsibilities for each staff member, including supervisory structure, should be defined in advance to facilitate a well functioning surveillance team. Training of staff is essential at the beginning of surveillance, as well as periodic refresher training to ensure a sensitive system and accurate data. Moreover, clinicians should be sensitized to case definitions and reporting procedures so they can coordinate with surveillance staff to capture potential VPD cases. Ideally, students entering the medical or nursing fields should be educated on the importance of surveillance as well as their role in surveillance, case definitions for diseases under surveillance and the reporting structure. It should be clear who is responsible for investigating cases, collecting samples and conducting active surveillance visits.

SURVEILLANCE MATERIALS

Data collection tools, including paper forms or electronic forms on devices such as mobile phones, must be available in sufficient quantities at all times. Specimen collection supplies should be available at the sites of case detection and may include blood drawing equipment, blood or stool collection tubes, throat swabs and transport media, or kits for cerebrospinal fluid collection. Ice packs and cold boxes will be needed for transport of some types of specimens. Laboratories require reagents, supplies and equipment for routine testing of specimens from surveillance, and any additional supplies that may be needed during outbreaks. Give careful attention to the ordering of laboratory reagents and supplies to avoid stockouts.

TRANSPORT

Establish a plan for transportation of surveillance staff and laboratory specimens, and ensure adequate funding for implementation. For example, allocate fuel money for case investigations and transporting specimens to national or regional reference laboratories. Dedicated cars, trucks or motorcycles may be required for surveillance activities and supervision. Alternatively, you may need to establish access to a car or truck shared with other MOH units. It is best to establish standard transport mechanisms and protocols for virologic and bacteriologic sample transport that follow local biosafety regulations.

INFORMATION AND COMMUNICATIONS TECHNOLOGY

Communication between staff and supervisors can be facilitated through the use of dedicated mobile phones or provision of airtime. Data reporting and analysis will require computers and internet access. Gaps in any of these components can result in a weakening of the surveillance system and compromise the ability of the surveillance system to meet its objectives.

SUPERVISION AND MONITORING

At each level, case reports should be reviewed and unusual reports verified before sending to the next level. Field visits by supervisors are recommended for not only quality assurance, but to support and acknowledge the important role of the field teams and to build team cohesion and commitment *(4)*. Sites that are silent for reporting or not meeting surveillance performance indicator targets should be prioritized for supportive supervision. Supportive supervision can be integrated across multiple VPDs and broader communicable disease surveillance.

FUNDING

High-quality surveillance requires sufficient and sustained financial resources for adequate staffing, materials and implementation of activities. Surveillance that is underfunded will likely suffer in quality and completeness. For most longitudinal VPD surveillance, develop a detailed multi-year budget with dedicated funding for implementation, with line items for supervision visits, data harmonization meetings and production of monthly surveillance bulletins. Lastly, for outbreak-prone VPDs, funding should be set aside for rapid mobilization of outbreak investigations and response.

BOX 6

Key components of a VPD surveillance system

An effective VPD surveillance system must have the following components in place:

- health facility and community level surveillance officers and points of contact
- district and national level surveillance staff, managers and administrative support
- training materials and job aides outlining reporting procedures, case definitions and other information
- reporting tools such as case investigation forms, active surveillance logs, mobile devices and airtime
- computer hardware and software for data entry and management (district and national level)
- specimen collection, field processing and cold storage supplies such as ice packs and refrigerators
- courier service to transport specimens to testing laboratory
- laboratory testing supplies, reagents and tools for linking test results to epidemiological data
- transportation resources (vehicles and fuel) for supervisory staff to get to reporting sites
- data managers and analysts (district and national level)
- data visualization and dashboard tools
- data dissemination plan and materials (epidemiologic reports and bulletins, workshops, etc.)
- monitoring and evaluation tools to assess and improve surveillance quality.

3. VPD Surveillance Data, Quality, and Use

At the heart of successful VPD surveillance lies high quality data, including linkage between laboratory and epidemiologic data. In this section, we briefly describe the main data-related considerations pertaining to VPD surveillance. These issues should be considered from the beginning of discussions around establishing or upgrading VPD surveillance.

3.1 TYPES OF SURVEILLANCE DATA

In general, VPD surveillance data falls into two main categories:

- **Individual-level (case-based) data** and outbreak-response line list data, which includes individual-level information for a defined subset of variables.
- **Aggregate data** (such as weekly facility reports of total numbers of cases by age and sex) and summary report data (such as aggregate numbers of cases reported by area during an outbreak).

3.2 RECOMMENDED DATA ELEMENTS

Each disease-specific chapter in these guidelines recommends a set of data elements to be captured in the reporting tools for surveillance of that VPD. This section discusses recommendations for data elements across all VPDs.

For case-based data, it is critical that each case have a unique identifier other than name, such as an ID number. Names are often not unique, and are therefore not adequate for linking clinical data with laboratory testing results. Some VPDs have additional recommended data elements based on their particular epidemiology (for example, birth-related information for neonatal tetanus). Be sure to include data elements that allow for follow up at the local level, such as the name of surveillance officer doing the investigation, contact information for the case and name of the reporting facility. This is not elaborated in the disease-specific chapters but should be included on investigation forms.

For surveillance systems that intend to calculate disease incidence, plan to collect data for the population as a whole, such as total population and age-stratified population size (live births, surviving infants, less than 15 population size).

Limit data collection to only those data elements that are absolutely required. Exclude any data elements without a clear analysis objective and those that will not impact the public health response. Each additional data element adds to the data collection burden, which can negatively impact reporting, reduce data quality and compromise the primary objectives of the surveillance system.

3.3 DATA COLLECTION AND MANAGEMENT

There are multiple methods for data collection, entry and management *(21)*. Data are generally collected using paper forms or mobile devices such as mobile phones or tablets. If collection is paper-based, an additional step to enter data into a computer database is required. Mobile collection devices can be connected to the central database or work offline, in which case data will need to be synchronized at a later stage.

When planning the establishment of a new surveillance programme, it is critical to define how data will be collected and how data will flow through the surveillance system, including between people and computer databases and applications.

Whether data are entered on a mobile device or are copied from a paper-based form into a computer, electronic data entry forms should match the case reporting form and only allow for the entry of valid values. For example, the field used to enter the patient's age should only allow numbers within a certain range to be entered. Free and open-ended text fields should be avoided whenever possible. Additional data validation procedures to compare information collected in different variables should also be built in the information system. For example, date of birth should always be earlier than the date of onset of the disease. Require all data elements on an investigation form to be filled in. If something is not known, it is better to write in "unknown" rather than leaving it missing. It is preferable to have data quality checks that can be run on demand or when data entry is completed and used on a regular basis to evaluate and improve data quality.

One of the most frequent data collection mistakes occurs during the process of creating a new and unique case ID, a critical element to retrieve, update or link cases with other data sources. For example, if two health workers separately collect data on two mobile devices working offline, case IDs generated on these two devices should be different to avoid duplicate records when synchronizing the devices with the central database. One solution could be to incorporate a unique device ID as part of each case ID. Similarly, if each district in a given country records cases using incremental numbers as case IDs, these will result in duplicate records when collated in the central database. Also, do not assign more than one case ID to the same individual. Plan to have the case ID follow the patient and the patient's medical record and samples throughout the health facility and outside of it. Examples of unique identifiers and their use are provided in WHO and other UN guidance documents *(22)*.

More broadly, review data quality with all staff involved in surveillance activities at both the local and central level to identify gaps in the processes, data outliers (such as an unusual increase in reported cases) and ways to resolve these issues. Data quality can improve only when data managers work together with all surveillance staff.

When choosing database software, consider stability (online tools are unreliable when the internet connection is unstable) and reliability or fidelity, such as making it easy for the user to copy and paste data may lead to more unintended errors. The choice of software should be driven by local technical capacity and preference. However, it is generally not recommended to use spreadsheet software to record cases, as these will generally display data in different ways on different computers, leading to problems when data are reported and collated.

3.4 DATA ANALYSIS AND INTERPRETATION

Analysis of VPD surveillance data can range in complexity from frequencies of cases to sophisticated regression analyses. Simple case counts often provide useful information. For VPDs in the eradication and elimination phases, a single case can indicate an outbreak and signal a gap in the immunization programme. For endemic VPDs, the trend of cases going up or down can provide a broad signal on the impact of a vaccine programme. Stratifying VPD case counts by person, place and time can provide insights into disproportionate burden in certain subgroups, and inform vaccine policy and strategy decisions, such as the need for booster vaccination or campaigns in particular groups or regions *(21)*.

Analysis and interpretation of longitudinal data can provide feedback on the impact of vaccine introduction, such as a decrease in disease burden *(23)*. For longitudinal data, case counts alone might appear to be the result of changes in disease epidemiology, but in fact are artifacts of changes to the surveillance system (increased confirmatory laboratory testing), health system (a change in reimbursement policy for hospital admission, or change from primarily a public to private insurance system) or surveillance population (increases over time or mass movement). Therefore, annualized incidence calculations, in which a denominator population is defined, are a better measure of temporal trends in VPD burden than case counts, because incidence data reflect changes to the catchment population size. Annualized age-specific incidence is defined as the number of new cases per population (of a specific age group) at risk during a given year. The denominator is the sum of the cumulative time that the at-risk population is under surveillance (often referred to as person-time). In outbreaks and seasonal diseases (those that do not occur during an entire calendar year), it is common to calculate attack rates (number of cases in the population in a discrete time period) rather than annualized incidence. When comparing percentages of cases positive for a disease over time, the number of specimens tested can be used as the denominator.

3.5 DATA VISUALIZATION

Visualizing surveillance data can improve data interpretation and use. Tables often summarize an abundance of numerical data most efficiently, allowing for detailed comparison of data based on multiple variables. Graphs provide a visual display of quantitative information that can more easily highlight interpretation of the main epidemiological findings related to person, place, and time (Figure 3). Surveillance data are frequently visualized as epidemiologic curves ("epi-curve"), histograms, lines graphs of incidence and spot maps of cases. Bar graphs and maps can depict important epidemiologic aspects of VPDs such as disease occurrence by age, vaccination status, and genotype or serotype.

Figures 3a, b, c, d and e are examples of data visualizations.

FIGURE 3a

Reported number of measles cases, vaccination coverage, and supplementary immunization activities

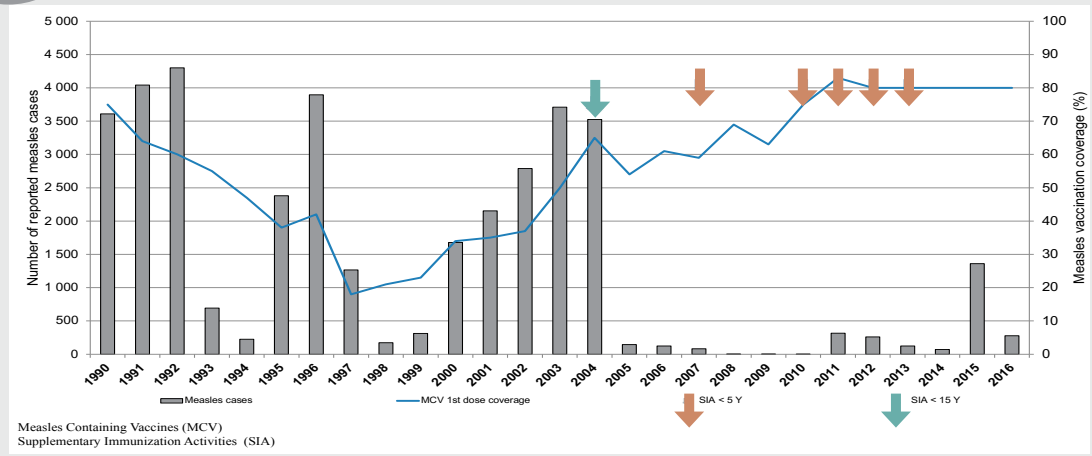


FIGURE 3b

Epi-curve of cases by confirmation status

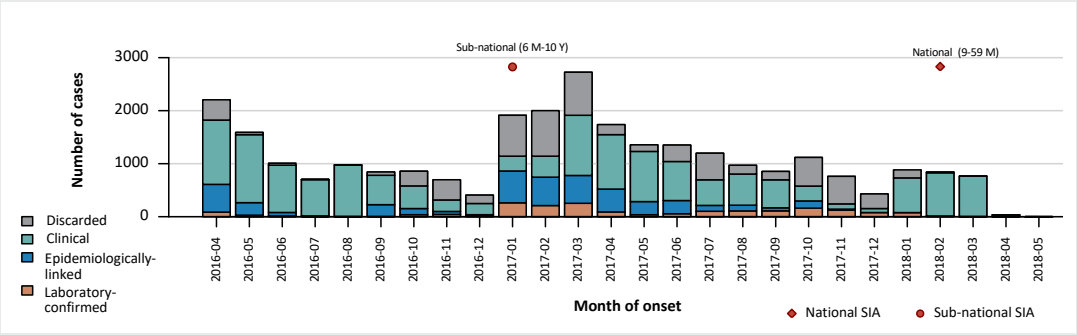


FIGURE 3c

Age distribution, incidence and vaccination status by age group

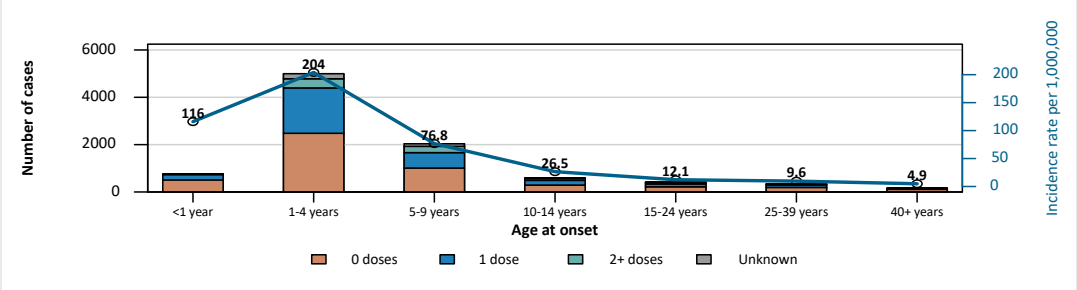


FIGURE 3d

Map showing case distribution

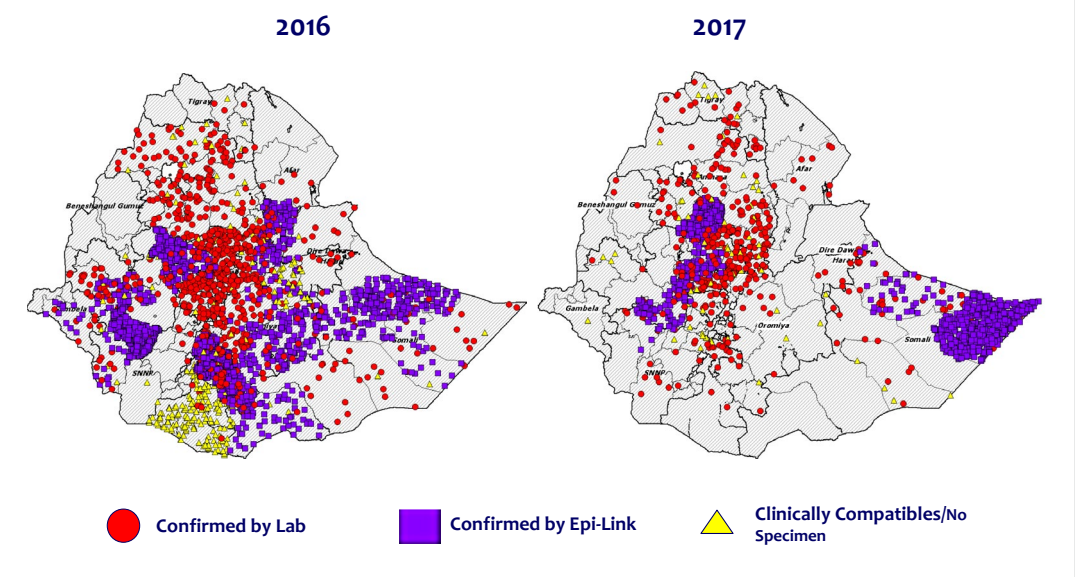
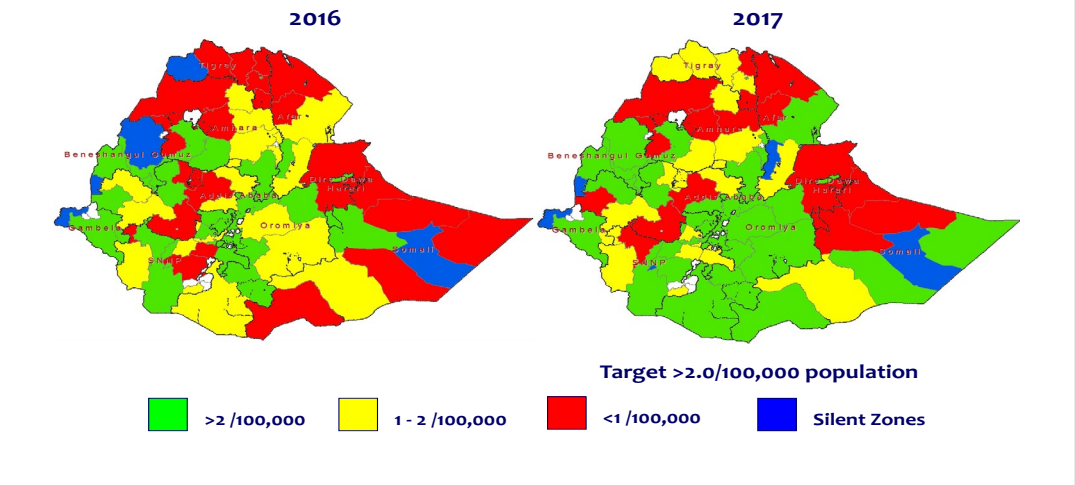


FIGURE 3e

Surveillance indicator mapped to the subnational level



Surveillance indicator mapped to the subnational level allows one to quickly see the chronic problem areas. This figure shows the non-measles discard rate by subnational area for 2016 and 2017.

3.6 LIMITATIONS OF INTERPRETING SURVEILLANCE DATA

When analysing surveillance data, consider missing data, the generalizability of the data allowed by the surveillance design, and other sources of error. For example, cases captured through subnational or sentinel-site surveillance might not be representative of the entire country. If facility-based surveillance is used, cases will be restricted to those seeking care. Health care-seeking behavior may vary across sociodemographic subgroups of the population. In other cases, the case definitions or laboratory testing may introduce systematic error by excluding cases from specific subgroups or with certain clinical presentations.

Of note, VPD surveillance that relies on detection of clinical signs and symptoms will not capture asymptomatic infections. For diseases with substantial asymptomatic infection like polio, rubella and hepatitis, this limitation should be considered when interpreting surveillance data to understand true disease burden and transmission dynamics. To detect "silent" disease circulation, use other methods such as environmental surveillance or serosurveys (see Annex C).

Random fluctuations in disease incidence occur over time in a population, so care should be taken not to over-interpret small changes in disease burden *(2)*.

For example, epidemic cycles of pertussis have been occurring every two to five years (typically three to four years), even after the introduction of effective vaccination programmes and high vaccination coverage *(24)*.

When reviewing trends in VPD surveillance data over time, consider any changes in components of the surveillance system that may have occurred. Examples of this include changes to the case definition, reporting network, clinical practice, health care utilization, laboratory testing or the health care system *(25)*. Changes in longitudinal surveillance systems that coincide with vaccine introduction are especially problematic as they can lead to misinterpretation of vaccine effectiveness or impact *(26)*.

Missing data for key variables such as age and vaccination status can result in further challenges with epidemiologic interpretation of surveillance data. If a significant proportion of the data are missing, findings will be limited in terms of generalizability. Missing data variables may occur more often among particular subgroups (such as lower socioeconomic status), which may also be less likely to be vaccinated. Such potential sources of bias must be considered and reported.

3.7 DATA TO SUPPLEMENT VPD SURVEILLANCE

Several other sources of data can provide supplemental information about VPDs that may be useful as adjuncts to VPD surveillance data in defining the public health burden. These other surveillance data sources include administrative data, vital statistics, health information systems, serosurveys, environmental and entomological surveillance, and carriage studies. These are described in more detail in Annex C. Data triangulation may also be used for integrating data from existing sources to address relevant questions and overcome the limitations associated with any one data source.

3.8 MONITORING AND EVALUATION OF VPD SURVEILLANCE

Monitoring and evaluation is an integral component of all VPD surveillance and should occur at multiple steps in the surveillance process (Box 7). The overall objective of monitoring and evaluation is to assure the integrity of the surveillance system while improving its utility, efficiency and validity *(21)*. It also addresses suboptimal performance and leads to better use of resources. In general, monitoring refers to routine and continuous tracking of the implementation and performance of surveillance, whereas evaluation refers to periodic assessment of the relevance, effectiveness and impact of surveillance *(27)*.

The use of surveillance performance indicators gives structure to the monitoring and evaluation process. Indicators are variables that can be measured repeatedly and in a standardized way to assess a surveillance system's performance *(27)*. Indicators should be simple, sensitive and easy-to-calculate variables that can be applied uniformly across surveillance sites, detect problems in the surveillance system and help to identify where the problem lies. Some VPDs have recommended performance indicators that are described in the relevant disease-specific chapters. The performance indicators for VPDs with eradication, elimination or control goals are regularly monitored at the subnational, national and global levels. Country surveillance programmes can also define their own performance indicators for different steps in the surveillance system. Common indicators include completeness and timeliness of case detection, case investigation, laboratory testing and reporting.

Evaluations of VPD surveillance should be done regularly, ideally every year. Evaluations should combine desk reviews of existing data with field visits to laboratories and sites of case ascertainment. The surveillance evaluation can be done separately or in conjunction with an evaluation of the immunization programme (for example, EPI review or post-introduction evaluation) *(28)*. The advantage of the latter is that the surveillance evaluation more directly links VPD outcomes to the EPI programme itself, such as coverage data. A potential disadvantage is that a combined evaluation might require a different set of experts who focus on different sets of data and sites, leading to an inefficient or incomplete evaluation.

Evaluating a surveillance system according to a set of key attributes is a useful approach (see Table 5) *(29)*. Examples of tools that can be used to conduct a surveillance review can be found at http://www.who.int/immunization/documents/WHO_IVB_17.17/en/. Additional performance indictors to monitor the function of a surveillance system can include the proportion of local health facilities submitting reports on time to the district and higher levels, proportion of suspect cases with a completed investigation, and the proportion of districts that report laboratory data for VPDs under surveillance.

BOX 7 Key aspects of monitoring and evaluation of VPD surveillance

- Monitoring and evaluation should be employed in all aspects of surveillance, including the clinical, laboratory and data components.
- Baseline data will be critical to assess changes identified by monitoring and evaluation.
- Monitoring data should be easily collected through the system itself.
- Standardized methods should be used for monitoring and evaluation; the use of indicators is encouraged.
- Monitoring and evaluation data needs to be used to give feedback to surveillance managers and officers.
- Feedback from monitoring and evaluation data should be acted on in a timely and appropriate way.

TABLE 5

Key attributes of a surveillance system to be evaluated *(29)*

ATTRIBUTE	OBJECTIVE	EXAMPLE OF PERFORMANCE INDICATOR
SIMPLICITY	Simple as possible in structure and ease of operation	Amount and type of data necessary to establish that the health-related event has occurred
FLEXIBILITY	Can adapt to changing information needs or operating conditions quickly and easily	Retrospective evaluation of how system adapted to new demand
DATA QUALITY	Completeness and validity of data	Percentage of unknown or missing responses for key data variables
ACCEPTABILITY	Willingness of people and organizations to participate in surveillance	Completeness of report forms
SENSITIVITY	A high proportion of cases of a disease or outbreaks detected	The percentage of cases in a population captured by surveillance
PREDICTIVE VALUE POSITIVE	A high proportion of reported cases that actually have the health-related event under surveillance	Evaluation of the "false positive" rate of cases detected in surveillance
REPRESENTATIVENESS	Accurately describes health-related events over time and its distribution in the population by place and person.	Comparing the characteristics (such as age, sex, and geographic location) of reported events to all such actual events
TIMELINESS	Rapid transition between steps in a public health surveillance system	The time interval linking any two of these steps
STABILITY	A reliable and available surveillance system in place	The number of unscheduled outages and down times for the system's computer

3.9 ETHICAL ISSUES RELATED TO COLLECTING VPD SURVEILLANCE DATA

In most societies, surveillance of infectious diseases, including VPDs, has been considered to be something that serves the common good. As such, the primary benefit of conducting surveillance is for the community as a whole. While individuals can and should benefit from surveillance, the summed value of surveillance might be greater than that realized by its individuals. As a mandated activity for society that is usually understood to present minimal risk to individuals, informed consent is usually not required from individuals participating in surveillance. Surveillance data can usually be published without collecting informed consent so long as data were collected and anonymity maintained with the intent of adhering to the objectives and principles of surveillance, rather than research.

While VPD surveillance might be viewed as a public health activity, surveillance programmes must adhere rigorously to ethical principles protecting individual rights. Individuals should not be harmed physically, legally, socially, economically or psychologically. Some diseases, including VPDs such as viral hepatitis and HPV, can lead to stigmatization of individuals by their family or community. Confidentiality should be maintained to the greatest extent possible when conducting VPD surveillance. Only de-identified data should be reported, and cross-tabulations in data summaries should not allow an individual to be identified.

Public health investigations of a few VPDs, such as polio and measles, require the sharing and use of personally identifiable information to investigate contacts, prevent further transmission or identify reservoirs of viral circulation. Recently, patient protection regulations have been put in place in some countries to prevent the disclosure of a patient's medical information without explicit consent, but surveillance is frequently considered an exception. If it is not, MOHs need to work with legislative bodies to ensure that case investigations and sharing of surveillance information can continue, both within the public health systems and with the international community.

4. The Role of VPD Surveillance in Outbreaks

For many VPDs, one of the objectives of surveillance is to detect and respond to disease outbreaks and epidemics. For most diseases, an outbreak is defined as an increase in the number of cases over the normally expected number; for some diseases like polio and measles, an outbreak investigation is often initiated upon detection of a single case *(4) (21)*. Surveillance plays an important role in both outbreak detection and response. Ongoing VPD surveillance can detect an increase in VPD cases, which upon further investigation might be classified as an outbreak. Surveillance data should allow characterization of the initial outbreak in terms of person, place and time to guide an effective response.

In cases where VPD surveillance is not established, surveillance can be set up after an outbreak has been identified. For example, if a VPD outbreak is detected through other methods (such as rumours in the community) in an area without pre-existing VPD surveillance, then surveillance might rapidly be established in the outbreak area to further characterize the outbreak and guide the response. Surveillance can also measure the impact of the public health response to the outbreak.

4.1 STEPS OF AN OUTBREAK INVESTIGATION

If a VPD outbreak is identified, an investigation should be conducted by surveillance officers or other public health officials, or both. The investigation of outbreaks of disease, including VPDs, is often broken down into the following series of steps *(4) (30)*:

1. Verify the diagnosis and confirm the existence of an outbreak.
2. Establish an outbreak case definition (or modify existing one used in VPD surveillance).
3. Conduct case-finding and data collection.
4. Describe the outbreak.
5. Generate and test hypothesis regarding the source and cause of outbreak (for example, failure to vaccinate versus vaccine failure).
6. Implement control and prevention measures (vaccination for VPDs among other public health interventions).
7. Analyse lessons learned and communicate findings.
8. Strengthen VPD surveillance and the immunization programme, and potentially change vaccine policy.

The steps in a VPD outbreak investigation are described in more detail in Annex D.

4.2 CHANGES TO VPD SURVEILLANCE DURING OUTBREAKS

In the setting of an outbreak, existing VPD surveillance might be modified in several ways, as described below.

- The objectives might shift from measuring disease burden or vaccine impact to providing data for implementation and evaluation of immediate disease control measures.
- The mode of case-finding might shift from passive to active. This may mean that instead of waiting for health facilities to report cases, surveillance officers will contact facilities and other sources of case detection, or require case tallies from them on a regular basis, often daily. Surveillance officers might also go the community to find unreported cases.
- The surveillance case definition might be modified in an outbreak setting. The localization of the outbreak in place and time might lead inclusion of these components in the case definition.
- For some VPDs, once the outbreak is laboratory-confirmed, case confirmation may shift to epidemiologically linked for greater efficiency *(31)*.
- The role of the laboratory in surveillance might change from that of confirming all cases to confirmation of cases in new geographic or epidemiologic groups and characterizing the pathogen in order to assist the response (for example, antimicrobial resistance testing for bacteria, genotyping for polio, strain testing for influenza). If a backlog of specimen testing exists, testing recently collected samples will provide more timely information for the response. Close communication between surveillance and laboratory staff is necessary.
- A list of cases might be required during the outbreak to efficiently track individual cases and better define the epidemiology (generate epidemic curves).
- Case investigations and data elements collected can change during an outbreak. A special emphasis on obtaining vaccination status of cases is important, to distinguish vaccine failure from lack of vaccination. There might be an emphasis on risk factors of interest for the outbreak (for example, specific water sources for cholera and typhoid). In addition, for VPDs that spread person to person, information on contacts will become important during outbreaks, particularly if measures to prevent disease in contacts are instituted (such as antibiotic prophylaxis for meningococcal meningitis and diphtheria).
- The frequency of reporting might increase to daily during an outbreak. Sometimes a zero-reporting approach will be taken in an outbreak, if not already being done, to assure that facilities are actively seeking new cases every day.
- Situational reports (or "sitreps") are often used to give regular, structured information about the status of the investigation and response. More requests for information from media sources are likely, and communication messages to a non-technical audience need to be considered.

4.3 SURVEILLANCE STAFFING DURING OUTBREAKS

Not only can the internal components of the surveillance system change during an outbreak, but the staffing, supervision and stakeholders may change as well. When setting up surveillance for outbreak-prone VPDs, consider the surge capacity needed during outbreaks. The role that existing VPD surveillance staff play during outbreak investigation and response depends on the setting. In some countries, a separate team will handle the outbreak investigation (for example, the communicable disease unit of the MOH). In other countries, the surveillance staff will also investigate the outbreak. The outbreak investigation often requires supplemental staff, such as staff from the disease control department or other MOH departments, rapid response teams or public health trainees. Surveillance staff will likely need to do different and expanded activities when there is an outbreak. VPD surveillance laboratories must also be prepared for a potential surge in the number or types of tests that need to be done during outbreaks. It is important to note that large outbreaks may negatively impact ongoing surveillance for other diseases, and should be considered when interpreting the data from other surveillance systems.

4.4 COORDINATION IN VPD OUTBREAKS

A VPD outbreak requires coordination between the departments of disease control, the laboratory and the EPI programme. This collaboration takes on a particular importance when enhanced or supplemental vaccination is part of the outbreak response. It has become more common to use Emergency Operation Centers or Interagency Coordinating Committees in order to manage the diverse activities related to an outbreak at a central level *(32)*. These can bring in emergency response and command staff experienced in logistics, coordination and communication of large-event responses, skills not necessarily found among EPI and disease control personnel.

Committees might be formed with stakeholders from different sectors involved in the response or affected by the outbreak. These committees will likely include representatives from the MOH, in addition to non-governmental organizations (NGOs) and assistance organizations, government officials, communications specialists, representatives from affected communities and civil society groups. In addition, outbreak response committees at the local level often play an important role in facilitating the outbreak response on the ground.

5. Introduction to the Chapters on Disease-Specific Surveillance Standards

Each VPD-specific chapter outlines the particular details of setting up and implementing surveillance for that disease. As much as possible, the chapters use the terminology and concepts discussed in this overview. Each disease-specific chapter is broken down into the following sections:

- Disease and vaccine characteristics
- Rationale and objectives of surveillance
- Type of surveillance recommended
- Case definition and final classification
- Case investigation
- Specimens collection
- Laboratory testing
- Data collection, reporting and use
- Surveillance performance indicators
- Clinical case management
- Contact tracing and management
- Surveillance, investigation and response in outbreak settings
- Special considerations
- References

The methods and process used to develop these VPD surveillance standards are described in Annex A. For each VPD, a group of subject matter experts was consulted so as to include the most up-to-date approaches to surveillance.

References

1. *World Health Organization. WHO-recommended standards for surveillance of selected vaccine-preventable diseases. Geneva: World Health Organization; 2008 (*http://apps.who.int/iris/bitstream/10665/68334/1/WHO_V-B_03.01_eng.pdf*).*
2. *World Health Organization. WHO recommendations for routine immunization–summary tables. In: Immunization, vaccines and biologicals [website]. Geneva: World Health Organization; 2017 (*http://www.who.int/immunization/policy/immunization_tables/en/*).*
3. *World Health Organization. WHO health topics: public health surveillance. Geneva: World Health Organization; 2014 (*http://www.who.int/topics/public_health_surveillance/en/*).*
4. *Gregg MB. Field epidemiology. Oxford, New York: Oxford University Press; 2008.*
5. *World Health Organization. Public Health Emergency Operations Centre Network (EOC-NET). Geneva: World Health Organization; 2017 (*http://www.who.int/ihr/eoc_net/en/*).*
6. *Dowdle WR. The principles of disease elimination and eradication. Bull World Health Organ. 76 Suppl 2:22-5; 1998 (*https://www.ncbi.nlm.nih.gov/pmc/articles/PMC2305684/*).*
7. *World Health Organization. Setting priorities in communicable disease surveillance. Geneva: World Health Organization; 2006. (*http://www.who.int/csr/resources/publications/surveillance/WHO_CDS_EPR_LYO_2006_3.pdf?ua=1*).*
8. *World Health Organization. International Health Regulations. Geneva: World Health Organization; 2005 (*http://www.who.int/topics/international_health_regulations/en/*).*
9. *Murray J, Agocs M, Serhan F, Singh S, Deloria-Knoll M, O'Brien K, et al. Global invasive bacterial vaccine-preventable diseases surveillance – 2008-2014. Morb Mortal Wkly Rep. 2014;63(49):1159-1162. (*https://www.cdc.gov/mmwr/preview/mmwrhtml/mm6349a4.htm*).*
10. *Tate JE, Haynes A, Payne DC, Cortese MM, Lopman BA, Patel MM, Parashar UD et al. Trends in national rotavirus activity before and after introduction of rotavirus vaccine into the national immunization program in the United States, 2000 to 2012. Ped Infect Dis J. 2013; 32(7):741–4. doi: 10.1097/INF.0b013e31828d639c.*
11. *von Gottberg A, de Gouveia L, Tempia S, Quan V, Meiring S, von Mollendorf C. Effects of vaccination on invasive pneumococcal disease in South Africa. N Engl J Med 2014; 371(20):1889-1899. doi: 10.1056/NEJMoa1401914 NEJM. 2014.*
12. *Henning KJ. Overview of syndromic surveillance: what is syndromic surveillance? Morb Mortal Wkly Rep. 2004;53(Suppl):5–11.*
13. *May L, Chretien JP, Pavlin JA. Beyond traditional surveillance: applying syndromic surveillance to developing settings – opportunities and challenges. BMC Public Health. 2009;9:242. doi: 10.1186/1471-2458-9-242.*
14. *Pavlin J. Syndromic surveillance for infectious diseases. In: M'ikanatha NM, Lynfield R, Van Beneden CA, de Valk H, editors. Infectious disease surveillance, second edition. Hoboken: John Wiley & Sons; 2013. doi: 10.1002/9781118543504.ch38*
15. *World Health Organization. Framework for verifying elimination of measles and rubella. Wkly Epidemiol Rec. 2013;88(9):89-99 (*http://www.who.int/wer/2013/wer8809.pdf*).*
16. *McLean HQ, Fiebelkorn AP, Temte JL, Wallace GS. Prevention of measles, rubella, congenital rubella syndrome, and mumps, 2013: summary recommendations of the Advisory Committee on Immunization Practices (ACIP). Morb Mortal Wkly Rep. 2013;62(RR-04):1-34 (*https://www.cdc.gov/mmwr/preview/mmwrhtml/rr6204a1.htm*).*
17. *Cohn AC, MacNeil JR, Clark TA, Ortega-Sanchez IR, Briere EZ, Meissner HC et al. Prevention and control of meningococcal disease: recommendations of the Advisory Committee on Immunization Practices (ACIP). Morb Mortal Wkly Rep. 2013;62(RR-02):1–28. (*https://www.cdc.gov/mmWr/preview/mmwrhtml/rr6202a1.htm*).*
18. *World Health Organization. Guidance for managing ethical issues in infectious disease outbreaks. Geneva: World Health Organization; 2016 (*http://apps.who.int/iris/bitstream/10665/250580/1/9789241549837-eng.pdf*).*
19. *Mulders MN, Serhan F, Goodson JL, Icenogle J, Johnson BW, Rota P. Expansion of surveillance for vaccine-preventable diseases: building on the Global Polio Laboratory Network and the Global Measles and Rubella Laboratory Network Platforms. J Infect Dis. 2017;216(Supp 1):S324–S330 (*https://academic.oup.com/jid/article-lookup/doi/10.1093/infdis/jix077*).*
20. *Agocs MM, Serhan F, Yen C, Mwenda JM, de Oliveira LH, Teleb N et al. WHO global rotavirus surveillance network: a strategic review of the first 5 years, 2008-2012. Morb Mortal Wkly Rep. 2017;63(29):634-637 (*https://www.cdc.gov/MMWr/preview/mmwrhtml/mm6329a5.htm*).*
21. *Teutsch SM, Churchill RE. Principles and practice of public health surveillance. Oxford, New York: Oxford University Press; 2000.*
22. *UNAIDS. Considerations and guidance for countries adopting national health identifiers. Geneva: UNAIDS/PEPFAR; 2014 (*http://www.unaids.org/sites/default/files/media_asset/JC2640_nationalhealthidentifiers_en.pdf*).*

23. *Tate JE, Haynes A, Payne DC, Cortese MM, Lopman BA, Patel MM, Parashar UD. Trends in national rotavirus activity before and after introduction of rotavirus vaccine into the national immunization program in the United States, 2000 to 2012. Pediatr Infect Dis J. 2013:32(7):741–4. doi: 10.1097/INF.0b013e31828d639c.*

24. *World Health Organization. Report from the SAGE Working Group on Pertussis vaccines, 26–27 August 2014 meeting. Geneva: World Health Organization; 2014 (*http://www.who.int/immunization/sage/meetings/2015/april/1_Pertussis_report_final.pdf?ua=1*).*

25. *Zanella RC, Bokermann S, Andrade AL, Flannery B, Brandileone MC. Changes in serotype distribution of Haemophilus influenzae meningitis isolates identified through laboratory-based surveillance following routine childhood vaccination against H. influenzae type b in Brazil. Vaccine; 2011 Nov 8;29(48):8937–42. doi: 10.1016/j.vaccine.2011.09.0532011.*

26. *Hanquet G, Lernout T, Vergison A, Verhaegen J, Kissling E, Tuerlinckx, D et al. Impact of conjugate 7-valent vaccination in Belgium: addressing methodological challenges. Vaccine. 2011 Apr 5;29(16):2856-64. doi: 10.1016/j.vaccine.2011.02.016.*

27. *World Health Organization. Communicable disease surveillance and response systems: guide to monitoring and evaluating. Geneva: World Health Organization; 2006 (*http://www.who.int/csr/resources/publications/surveillance/WHO_CDS_EPR_LYO_2006_2.pdf*).*

28. *World Health Organization. Guide for comprehensive immunization programme reviews including vaccine post-introduction evaluations. Geneva: World Health Organization; 2017 (*http://www.who.int/immunization/documents/WHO_IVB_17.17/en/*).*

29. *German RR, Lee LM, Horan JM, Milstein RL, Pertowski CA, Waller MN. Updated guidelines for evaluating public health surveillance systems: recommendations from the Guidelines Working Group. Morb Mortal Wkly Rep. 2001;50(RR-13):1–35 (*https://www.cdc.gov/mmwr/preview/mmwrhtml/rr5013a1.htm*).*

30. *Centers for Disease Control and Prevention. Principles of epidemiology in public health practice, third edition: an introduction to applied epidemiology and biostatistics. Atlanta, USA: Centers for Disease Control and Prevention; 2011 (*https://www.cdc.gov/ophss/csels/dsepd/ss1978/index.html*).*

31. *Lipsitch M, Hayden FG, Cowling BJ, Leung GM. How to maintain surveillance for novel influenza A H1N1 when there are too many cases to count. Lancet. 2009;374(9696):1209-11.*

32. *World Health Organization. Vaccine position papers. Geneva: World Health Organization; 2017 (*http://www.who.int/immunization/documents/positionpapers/en/*).*

Annex A

METHODS USED IN FORMULATING VPD SURVEILLANCE STANDARDS

To determine the structure of these updated surveillance standards, an in-person consultation of VPD surveillance experts was held at WHO in Geneva on March 14 and 15, 2017. One of the issues discussed was the list of VPDs to include in the revised surveillance standards, as the number of VPDs had grown since 2003. After discussion, the participants agreed that the VPDs for inclusion in these surveillance standards should meet the following criteria:

- vaccine available, recommended by SAGE and used by country programmes
- currently or projected to be in use in greater than 10% of national immunization programmes (20+ countries) within next 5 years
- surveillance informs vaccine use, EPI programme or vaccine policy.

In the future, vaccines for more diseases will be developed and introduced into countries. It is expected that more VPDs will meet the above criteria for inclusion and the surveillance standards will be updated as such to include them. Such updates will be vetted by subject matter experts on surveillance for the new vaccine and follow the same review process as outlined below.

The components of the surveillance standards for each VPD were determined by review of the 2003 surveillance standards, and input from VPD surveillance experts during the consultation. It was recognized that not all components would be applicable to all VPDs. The main components of the surveillance standards are listed below.

- Clinical/epidemiological description and vaccine characteristics
- Rationale and objectives of surveillance
- Case definitions and case classification
- Approaches to surveillance including
  - » Types of surveillance
  - » Case investigation
  - » Contact management
  - » Reporting
  - » Specimen collection
- Laboratory testing
- Data collection
- Data analysis and use for decision-making
- Clinical case management
- Evaluation of surveillance
- Outbreak response
- Special considerations for that VPD
- References

For each included VPD, we did a review of existing surveillance standards, guidance, recommendations and published literature. From this review, we abstracted existing data to fill each section of the surveillance standards. After abstraction, we used one of three approaches to complete the surveillance standards, depending on the available information.

1. Information abstracted from existing documentation was sufficient to complete nearly all components of the surveillance standards. Required criteria for VPDs in this category were as follows:
   a. WHO guidance document(s) exists
   b. WHO guidance documents were created after 2013 or deemed to be unchanged by the VPD focal point at WHO headquarters
   c. The majority of the surveillance criteria had been defined in existing documentation.

2. Data abstraction from existing documentation was sufficient to complete the majority of the components, although information for a few key components was considered to be lacking. In this case, subject matter experts were consulted, and a consensus was developed on the resolution.

3. Data abstraction from existing documentation was insufficient to complete most of the components, or available information for key components was conflicting. In this situation, a working group was convened to develop and approve the surveillance standards. If an existing SAGE working group for a VPD already existed that has at least three members knowledgeable on surveillance and could address the unresolved surveillance components, then such a group was engaged. If no working group for a VPD existed, then an international group of experts was formed for the purposes of addressing these surveillance standards.

For all VPDs, the surveillance standards were reviewed by VPD-specific experts at WHO headquarters.

The revised surveillance standards are available in print or online. The standards will be updated to include new VPD chapters and as new disease-specific information becomes available. These changes will be reflected in the online version.

Annex B

INTEGRATION OF VPD SURVEILLANCE WITHIN EXISTING SURVEILLANCE SYSTEMS

A country may have several other types of surveillance that can be adapted to include VPD surveillance, or provide supplemental and complementary data.

Integrated Disease Surveillance and Response (IDSR). The concept of IDSR was first introduced in Africa in the early 2000s and has matured since then, with the majority of AFRO countries now having implemented some aspects of IDSR *(1)*. Surveillance for many diseases consists of similar, essential components (such as case detection, data collection and analysis, reporting and public health action), and often involves the same types of stakeholders in a country (such as MOH and WHO). Given this, the core concept of IDSR is to build platforms that integrate surveillance and response for multiple diseases, thereby promoting an economy of scale in conducting surveillance. Diseases considered for IDSR include those with epidemic potential and those deemed to have public health importance. Some VPDs are already included as priority disease for IDSR.

Because IDSR is usually coordinated through communicable disease control programmes, it is essential that EPI managers be involved in both the design and reporting structure of IDSR for VPDs so that the objectives of surveillance as it relates to the vaccine programme are incorporated. Moreover, because IDSR's main objective is to detect and control diseases, some data elements relevant to a vaccination programme might not be included, such as vaccination status and risk factors. Finally, the IDSR guidelines allow for laboratory testing and case-based investigation; however, this is variably implemented, with many countries choosing to conduct aggregate surveillance with laboratory confirmation only in the case of outbreaks. This needs to be considered when coordinating with and using data from the IDSR platform.

Early Warning and Response Network (EWARN). Normal public health practice, including surveillance, can be disrupted during humanitarian emergencies. As part of the public health response to such situations, special surveillance called EWARN can be rapidly set up *(2)*. EWARN usually focuses on the most severe epidemic-prone diseases, such as cholera and measles, and its focus is to detect outbreaks in most settings. In some countries, EWARN is considered similar to the IDSR platform described above. The network part of EWARN refers to the way information on potential outbreaks can come from multiple sources, including clinicians, laboratory personnel and community health workers. While providing useful information about some VPDs in humanitarian crises, EWARN is not a VPD surveillance system per se, and is often temporary during the time of crisis. An EWARN system in conjunction with regular VPD surveillance, however, can provide useful data on VPDs, especially those that tend to ignite into outbreaks during humanitarian crises, to inform a country's vaccine policy and lead to an immunization response.

Event-based surveillance (EBS). Event-based surveillance is a more unstructured type of surveillance intended primarily to detect outbreaks, as opposed to more traditional "indicator-based" surveillance that focuses on detection and reporting of cases of specific diseases. EBS can garner information from news reports, rumours, internet blogs, social media and other informal sources. Information on public health events of potential significance are communicated via a hotline, Internet site, or in person to public health authorities, who then investigate the reported event. A slightly more structured form of EBS is called community-based surveillance (CBS). CBS proposes using volunteers living or working in a community, such as community health workers or Red Cross workers, to monitor and detect unusual events at the community level, which would often be missed by formal public health surveillance systems *(3)*. Detected events are then triaged by a supervisor and, if determined to be of legitimate public health concern, reported to public health authorities for further investigation. CBS would be most relevant for early detection of VPD outbreaks based on syndromic criteria or mortality, rather than a strategy for more specific case-based or long-term surveillance *(4) (5)*.

REFERENCES FOR ANNEX B

1. *World Health Organization and Centers for Disease Control and Prevention. Technical guidelines for integrated disease surveillance and response in the African region, 2nd edition. Brazzaville, Republic of Congo and Atlanta, USA; 2010 (*http://www.afro.who.int/sites/default/files/2017-06/IDSR-Technical-Guidelines_Final_2010_0.pdf*).*
2. *World Health Organization. Outbreak surveillance and response in humanitarian emergencies: WHO guidelines for EWARN implementation. Geneva: World Health Organization; 2012 (*http://apps.who.int/iris/bitstream/10665/70812/1/WHO_HSE_GAR_DCE_2012_1_eng.pdf*).*
3. *International Federation of Red Cross and Red Crescent Societies. Community-based surveillance: guiding principles. Geneva: International Federation of Red Cross and Red Crescent Societies; 2017 (*http://media.ifrc.org/ifrc/wp-content/uploads/sites/5/2018/03/CommunityBasedSurveillance_Global-LR.pdf*).*
4. *Meyers DJ, Ozonoff A, Baruwal A, Pande S, Harsha A, Sharma R, et al. Combining healthcare-based and participatory approaches to surveillance: trends in diarrheal and respiratory conditions collected by a mobile phone system by community health workers in rural Nepal. PLOS One. 2016; 11(4): e0152738 (*https://doi.org/10.1371/journal.pone.0152738*).*
5. *Gurav YK, Chadha MS, Tandale BV, Potdar VA, Pawar SD, Shil P, et al. Influenza A(H1N1) outbreak detected in inter-seasonal months during the surveillance of influenza-like illness in Pune, India, 2012–2015. Epidemiol Infect. 2017;145(9):1898-1909. doi: 10.1017/S0950268817000553.*

Annex C

SUPPLEMENTAL INFORMATION TO VPD SURVEILLANCE

Several other sources of data or surveillance can provide supplemental information about VPDs that may be useful as adjuncts to VPD surveillance in defining the public health burden.

Serosurveillance. Serologic surveys of a population can provide data on disease burden and population immunity. For some VPDs, surveillance for acute illness is unlikely to provide accurate estimates of disease burden or vaccine impact because the clinical disease manifests many years after the acute infection, as with hepatitis B. For measles, in contrast, the presence of IgG antibodies in the sera can indicate either past infection or vaccination, thereby providing a representation of population immunity rather than disease burden alone *(1)*. Tetanus provides a third scenario whereby immunity does not result from natural infection, so presence of antibodies serves as an indicator of tetanus population immunity through vaccination *(2)*. To increase the efficiency of serosurveys, a single serum sample can be evaluated for population immunity for multiple VPDs, as well as tested for prevalence of non-VPD diseases; work to evaluate multiplex assay platforms for evaluating multiple VPDs simultaneously, such as the multiplex bead assay, is ongoing *(2)*. Serosurveys have limitations, however, such as the waning of immunity over time, the inexact correlation between antibodies and disease exposure or vaccination, and lack of information on the timing and severity of illness. Therefore, they are most often used to provide supplemental information to VPD surveillance systems *(3)*.

Secondary data sources, such as administrative data, vital statistics, death certificates/registries, and health information systems. An enhanced focus on the use of routinely collected data has been identified by WHO as a key component of strengthened health systems in developing countries *(4)*. The primary interest in health information systems (HIS) or other administrative databases that are based on International Classification of Diseases (ICD) coding of health care visits is for clinical care. However, such data can also be used to assess disease trends, usually at large-scale population level. Countries with widespread and functional electronic medical records and discharge data have used data in this way, to estimate, for example, the burden of seasonal influenza- or rotavirus-related deaths *(5) (6) (7)*. In many countries, however, administrative data is not collected using a standardized approach. Moreover, diagnostic criteria and completeness of records can vary substantially by region and by institution *(8)*. In some places, vital registration statistics might also provide some data on causes of death, including from VPDs.

Environmental surveillance. Environmental surveillance seeks to detect pathogens in the environment rather than from clinical samples from people. For example, sampling for poliovirus in sewage is part of the endgame strategy for polio eradication *(9)*. Because the majority of poliovirus infections in humans are asymptomatic, environmental surveillance can expand the sensitivity of acute flaccid paralysis surveillance in documenting residual poliovirus circulation in endemic countries. Moreover, environmental surveillance can provide early evidence of importations in countries at high risk of reinfection with poliovirus, help document the elimination of vaccine-related strains after removal of bivalent oral polio vaccine (bOPV), and eventually complete OPV cessation. Monitoring the presence of *Vibrio cholerae* in specific environmental water sources may help with early detection of cholera transmission in some areas to identify the sources or vehicles for infection *(10)*.

Entomological surveillance. Entomological surveillance assesses the prevalence of pathogens, including VPDs, in insect vectors. For yellow fever, many infections are asymptomatic, and surveillance for clinical symptoms like fever and jaundice with laboratory confirmation can delay recognition and characterization of a yellow fever outbreak. Surveillance can be supplemented by entomological surveys for the presence of competent vector populations in the community, such as *Aedes* mosquitoes *(11)*. These surveys can define communities as being at risk for an outbreak, leading to a supplemental vaccination campaign or larvicide implementation, or both. Entomological surveillance has also been proposed as playing an important role for dengue, as it allows for the earliest detection of the pathogen prior to human infection if done on a routine basis *(12)*.

Carriage studies. For some bacterial VPDs, studies of carriage in the upper respiratory tract can provide information about the persistence of the bacteria in the population and identify potential risk groups. For example, after successful introduction of Hib vaccine in Alaskan infants, detection of residual colonization of older children, along with disease surveillance data, suggested ineffectiveness of the vaccine in use *(13)*. Pneumococcal carriage studies provide useful information on serotype distribution that can inform vaccine product choices, as well as serotype replacement after vaccine introduction *(14)*. Meningococcal carriage has been used to anticipate outbreaks and identify risk groups *(15)*.

REFERENCES FOR ANNEX C

1. *Lowther SA, Curriero FC, Kalish BT, Shields TM, Monze M, Moss WJ. Population immunity to measles virus and the effect of HIV-1 infection after a mass measles vaccination campaign in Lusaka, Zambia: a cross-sectional survey. Lancet. 2009;373:1025–32. doi: 10.1016/S0140-6736(09)60142-2.*
2. *Scobie HM, Patel M, Martin D, Mkocha H, Njenga SM, Odiere MR, et al. Tetanus immunity gaps in children 5–14 years and men ≥ 15 years of age revealed by integrated disease serosurveillance in Kenya, Tanzania, and Mozambique. Am J Trop Med Hyg. 2017;96(2):415–20. doi: 10.4269/ajtmh.16-0452.*
3. *MacNeil A, Lee C, Dietz V. Issues and considerations in the use of serologic biomarkers for classifying vaccination history in household surveys. Vaccine. 2014;32:4893-900. doi: 10.1016/j.vaccine.2014.07.005.*
4. *World Health Organization. Everybody's business: strengthening health systems to improve health outcomes. Geneva: World Health Organization; 2007 (*http://www.who.int/healthsystems/strategy/everybodys_business.pdf*).*
5. *Thompson WW, Comanor L, Shay DK. Epidemiology of seasonal influenza: use of surveillance data and statistical models to estimate the burden of disease. J Infect Dis. 2006;194 Suppl 2:S82-91. doi: 10.1086/507558.*
6. *Grijalva CG, Moore MR, Griffin MR. Assessing the effect of pneumococcal conjugate vaccines: what is the value of routinely collected surveillance data? Lancet Infect Dis. 2011;11(10):724-6. doi: 10.1016/S1473-3099(11)70143-8.*
7. *Richardson V, Parashar U, Patel M. Childhood diarrhea deaths after rotavirus vaccination in Mexico. N Engl J Med 2011;365:772–3. doi: 10.1056/NEJMc1100062.*
8. *Sharma V, Rana SS, Bhasin DK. Extra-pancreatic necrosis alone: Contours of an emerging entity. J Gastroenterol Hepatol. 2016;31:1414–21. doi:10.1111/jgh.13384.*
9. *Global Polio Eradication Initiative. Polio eradication and endgame strategic plan 2013–2018. Geneva: World Health Organization; 2013 (*http://polioeradication.org/wp-content/uploads/2016/07/PEESP_CH5_EN_US.pdf*).*
10. *World Health Organization. Global Task Force on Cholera Control (GTFCC) Surveillance Working Group, World Health Organization. Interim guidance document on cholera surveillance. Geneva: World Health Organization; 2017 (*http://www.who.int/cholera/task_force/GTFCC-Guidance-cholera-surveillance.pdf?ua=1*).*
11. *World Health Organization. Rapid field entomological assessment during yellow fever outbreaks in Africa. Geneva: World Health Organization; 2014 (*http://apps.who.int/iris/bitstream/10665/112785/1/WHO_HSE_PED_CED_2014.3_eng.pdf?ua=1*).*
12. *World Health Organization. Dengue haemorrhagic fever: diagnosis, treatment, prevention and control. Geneva: World Health Organization; 1997 (*http://www.who.int/csr/resources/publications/dengue/Denguepublication/en/*).*
13. *Galil K, Singleton R, Levine OS, Fitzgerald MA, Bulkow L, Getty M, et al. Reemergence of invasive Haemophilus influenzae type b disease in a well-vaccinated population in remote Alaska. J Infect Dis. 1999;179(1):101-6. doi: 10.1086/314569.*
14. *Satzke C, Turner P, Virolainen-Julkunen A, Adrian PV, Antonio M, Hare KM, et al. Standard method for detecting upper respiratory carriage of Streptococcus pneumoniae: updated recommendations from the World Health Organization Pneumococcal Carriage Working Group. Vaccine. 2013;32(1):165–79. doi: 10.1016/j.vaccine.2013.08.062.*
15. *Borrow R, Alarcón P, Carlos J, Caugant DA, Christensen H, Debbag R, et al. The Global Meningococcal Initiative: global epidemiology, the impact of vaccines on meningococcal disease and the importance of herd protection. Expert Rev Vaccines. 2017;16(4):313–28. doi: 10.1080/14760584.2017.1258308.*

Annex D

STEPS IN A VPD OUTBREAK INVESTIGATION

1. **Verify the diagnosis and confirm the existence of an outbreak.** The first step is to verify the diagnosis, normally done by laboratory confirmation, so as to guide the appropriate response. Sometimes confirmatory testing in a national or regional reference laboratory is required to verify a local laboratory's test results. Laboratory confirmation has been critical to characterizing mixed outbreaks, such as the co-circulation of measles and rubella resulting in large increases in fever-rash case reporting. Before labelling an increase in cases as an outbreak, investigators must rule out other causes for increased reporting of VPDs, such as changes in case definition or reporting practices, laboratory testing, health utilization or population migration. For ongoing VPD surveillance, baseline rates or counts of cases from similar time periods in previous years might be available, so a true increase over the expected can be identified. Some diseases have clear outbreak thresholds (such as 10 cases per 100,000 people per week for meningococcus).
2. **Establish an outbreak case definition**. It is important to form a case definition early in the outbreak investigation. A working case definition will be needed for case-finding and classifying cases in order to describe the outbreak. In an outbreak investigation, the main components of the case definition will be the same as those described for VPD surveillance. For outbreaks of VPDs, especially those detected by VPD surveillance, a case definition already will have been established. However, in the setting of an outbreak, the definition might be modified from that used in surveillance – for example, adding a time or place component.
3. **Case finding and data collection**. After confirmation of an outbreak, identify additional cases through either passive reporting from health facilities, active surveillance (visiting facilities to find unreported cases) or a combination of the two. Sometimes public health officials ask clinicians or even the public to report possible cases. If the outbreak was detected through routine VPD surveillance in a restricted population, further case finding during the outbreak might be expanded to include new populations such as different areas or age groups. Regardless of how case finding is instituted, a common set of data elements is usually collected in the outbreak setting. For VPDs, vaccination status will always be an essential data element, both in terms of defining risk and guiding intervention strategies.
4. **Describe the outbreak**. Analyse case data during an outbreak early and often, even as data on new cases is still being collected. Early descriptions of the outbreak can accelerate identification of the outbreak source, characterize populations at risk and the risk of ongoing transmission, and assist early planning of the response. The most accepted way of describing the epidemiology of an outbreak is in terms of time, place and person. For VPDs, a localization of cases can highlight localized deficiencies in the immunization system (shown with a spot map), and dictate the geographic parameters of immunization campaigns. Knowing who is getting the disease also gives insight into the cause and exposure risk during an outbreak. For VPDs, the age of affected persons often reflects the vaccination status of the population. For example, pertussis outbreaks can occur in school-age children whose immunity waned after their infant vaccination series.
5. **Hypothesis generation and testing**. After basic data analysis, the next step is to develop a hypothesis about what might be causing the outbreak. For some VPDs, such as cholera or typhoid, the source of infection might be unknown, and studies such as case-control studies might be done to identify the source. However, for many VPDs, the source is not in question, but rather the main question is whether the outbreak represents vaccine failure or a lack of vaccination. Investigations should focus on answering this question. In some cases, an unusual distribution of VPD cases, in terms of geography or demography, can lead to hypotheses about the immunization programme, which might lead to further investigations. In a recent outbreak of measles in Micronesia, an excess of cases in vaccinated young adults suggested inefficiencies in the vaccine supply chain over a decade ago *(1)*.

6. **Implement control and prevention measures**. Although this step often occurs at the end of the series of steps of an outbreak investigation, in practice, prevention and control practices are usually implemented much earlier in the process. VPDs are unique in that the vaccine itself is often used as a key preventive component in controlling outbreaks. Vaccination requires a unique set of logistical and personnel requirements when compared with other outbreak responses. Many VPDs will implement other measures besides vaccination to control the outbreak, such as hand washing campaigns and safe water provision.

7. **Analyse lessons learnt and communicate of findings**. The results of outbreak investigations should be summarized in a final report. This should also include lessons learned during the outbreak investigation and response to improve future investigations and response. This can take the form of an oral briefing or written report, which should always include recommendations for the prevention of further cases. Dissemination of findings should go to all stakeholders, especially the MOH if they are not writing the reports. Sometimes an outbreak investigation can be written up more formally for publication, for purposes of training and general scientific knowledge.

8. **Maintain and strengthen VPD surveillance, immunization programme, and potentially change vaccine policies**. Regardless of whether the outbreak was detected in an area with VPD surveillance in place, or whether surveillance was established in the setting of an outbreak, that surveillance should be maintained for some time after the outbreak to ensure successful resolution of the outbreak and vaccination efforts, if part of the response. Often in the course of an outbreak, defects in surveillance are revealed, leading to strengthening of surveillance in the post-outbreak period. Additionally, findings from the outbreak investigation should be used to strengthen immunization programmes, and can sometimes be used to inform vaccination policies.

REFERENCES FOR ANNEX D

1. *Hales CM, Johnson E, Helgenberger L, Papania MJ, Larzelere M, Gopalani SV. Measles outbreak associated with low vaccine effectiveness among adults in Pohnpei State, Federated States of Micronesia, 2014. Open Forum Infect Dis. 2016; 3(2): ofw064. doi: 10.1093/ofid/ofw06.*