

MEASLES OUTBREAK GUIDE





World Health
Organization

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Abbreviations

AAR	after action review
AEFI	adverse events following immunization
AFP	acute flaccid paralysis
AR	attack rate
ARU	attack rates among unvaccinated persons
ARV	attack rates among vaccinated persons
BCG	bacille Calmette–Guérin (vaccine)
BeSD	behavioural and social drivers
CFR	case fatality ratio
CHW	community health worker
CIF	case investigation form
cMYP	country multi-year plan
CRS	congenital rubella syndrome
DBS	dried blood spot
DNA	deoxyribonucleic acid
EIA	enzyme immunoassay
ELISA	enzyme-linked immunosorbent assay
EPI	Expanded Programme on Immunization
EWARS	early warning and response system
FAQ	frequently asked questions
GPS	global positioning system
GMRLN	Global Measles and Rubella Laboratory Network
GVAP	Global Vaccine Action Plan
HCW	health care worker
HEPA	high-efficiency particulate air
HIV	human immunodeficiency virus
HW	health worker
IDP	internally displaced person
IEC	information, education and communication
IgA	immunoglobulin A
IgG	immunoglobulin G
IgM	immunoglobulin M
IHR	International Health Regulations
IPC	infection prevention and control
ITS	interrupted time series
IU	international unit
KAPB	knowledge, attitudes, practices and beliefs
MCV	measles-containing vaccine
M&E	monitoring and evaluation

M&RI	Measles & Rubella Initiative
MNCAH	maternal, newborn, child and adolescent health
MOH	ministry of health
MOSRP	Measles Outbreaks Strategic Response Plan 2021–2023
MOV	missed opportunity for vaccination
MRSF	Measles & Rubella Strategic Framework 2021–2020
MSF	Médecins Sans Frontières
NGO	nongovernmental organization
NHIG	normal human immunoglobulin
NNV	number needed to vaccinate
NUV	number of unvaccinated individuals
NV	number of vaccinated individuals
OCC	outbreak coordination committee
OF	oral fluid
OPV	oral polio vaccine
OR	odds ratio
ORI	outbreak response immunization
PCCS	post-campaign coverage survey
PCV	proportion of cases vaccinated
Penta	pentavalent vaccine (diphtheria + tetanus + pertussis + <i>H influenzae</i> b + hepatitis combined vaccine)
PEP	post-exposure prophylaxis
PHEIC	Public Health Emergency of International Concern
PHEOC	public health emergency operations centre
PIRI	periodic intensification of routine immunization
PPE	personal protective equipment
PPV	percentage of the population vaccinated
RCA	root cause analysis
RCCE	risk communication and community engagement
RCM	rapid convenience monitoring
RCV	rubella-containing vaccine
RI	routine immunization
RNA	ribonucleic acid
RR	risk ratio
RRT	rapid response team
RTM	real time monitoring
RT-PCR	reverse transcription polymerase chain reaction
SIA	supplementary immunization activity
SOP	standard operational procedure
SSPE	subacute sclerosing panencephalitis
TPR	test positivity rate
VE	vaccine effectiveness
VPD	vaccine-preventable disease
VPDI	vaccine-preventable disease incidence
VVM	vaccine vial monitoring
WHA	World Health Assembly
WHO	World Health Organization

Executive summary

The conclusions of the *Global Measles and Rubella Strategic Plan 2012–2020* implementation midterm review highlighted the need to update protocols for guiding surveillance and outbreak investigation and response (1). To that end, WHO and partners have developed the following guide to assist with measles outbreak management in all settings that are striving for and approaching measles elimination.

This guide is based on existing WHO documents, including:

- *Response to measles outbreaks in measles mortality reduction settings* (2);
- *Guide for clinical case management and infection prevention and control during a measles outbreak* (3);
- *WHO Surveillance standards for vaccine-preventable diseases* (4);
- *Roadmap to elimination standard measles and rubella surveillance* (5);
- *Measles vaccines: WHO position paper* (6);
- *The immunological basis for immunization: measles* (7);
- *Establishing and strengthening immunization in the second year of life (2YL)* (8);
- *Manual for the laboratory-based surveillance of measles, rubella, and congenital rubella syndrome* (9);
- *Planning and implementing high-quality supplementary immunization activities for injectable vaccines* (10); and
- Region-specific guidelines and experience with recent measles outbreaks globally (11–16).

This guide also draws on the standard operating procedures (SOPs) to apply for measles outbreak response support from the Measles & Rubella Initiative Outbreak Response Fund (17) and includes a section on measles outbreak recovery so that contributing factors and potential root causes are identified and addressed systematically after a measles outbreak. This guide does not aim to be a comprehensive guide on measles elimination or routine immunization (RI) more broadly.

Note: Recommendations on rubella outbreak management provided in this guide are consistent with existing rubella outbreak response recommendations and are included only as they pertain to measles outbreaks.

1 Introduction

Core capacities in outbreak preparedness and response are required of all signatory countries of the International Health Regulations (IHR 2005). Systems for measles outbreak preparedness and response rely on many of the 19 technical areas of the IHR, including but not limited to surveillance and laboratory systems, medical countermeasures, risk communication and immunization coverage.

The measles-rubella goal for the 2021–2030 period is to achieve and sustain the regional measles and rubella elimination goals (18). Outbreak preparedness and timely response is a core component of the global measles elimination strategy and is embedded in the Immunization Agenda 2030 (IA2030). The seven strategic priorities are:

- 1 primary health care and universal health coverage;
- 2 commitment and demand;
- 3 coverage and equity;
- 4 life-course and integration;
- 5 outbreaks and emergencies;
- 6 supply and sustainability; and
- 7 research and innovation.

The Measles Outbreaks Strategic Response Plan 2021–2023 (MOSRP) (19) supports the achievement of the strategic priorities of the post-2020 Measles and Rubella Strategic Framework (MRSF 2021–2030) (20). The primary goal of the MOSRP is that countries prevent, prepare for, respond to and recover from measles outbreaks with support from WHO and partners. This guide provides measles outbreak stakeholders with comprehensive operational recommendations for preparedness, readiness, response and recovery.

1.1 Target audience and purpose of this document

The target audience of this guide are health authorities, at all levels, and immunization partners. The purpose is to support countries in measles outbreak preparedness, early detection, response and recovery. This document provides guidance on:

- preparedness for measles outbreaks;
- detection, verification, investigation and response to measles outbreaks, including vaccination strategies; and
- development of recovery plans, including post-outbreak health systems strengthening.

1.2 Public health importance

During the pre-vaccine era, major measles epidemics occurred approximately every 2 to 3 years and an estimated 165 million cases of measles with more than 6 million estimated measles deaths occurred globally each year; and by 15 years of age more than 95% of individuals had serological evidence of previous infection by measles virus (21,22). Measles is preventable and can be eliminated through strategic

Table 1. Objectives of this guide: summary

readiness and preparedness	outbreak response	recovery
<p>Preparedness</p> <ul style="list-style-type: none"> • Ensure systems are established to enable a rapid, effective response to measles outbreaks. 	<p>Coordination</p> <ul style="list-style-type: none"> • To strengthen the health and immunization systems to sustainably contribute to reduction in morbidity and mortality from measles and improve health status of the outbreak-affected population. 	<p>Recovery</p> <ul style="list-style-type: none"> • To strengthen the health and immunization systems to sustainably contribute to reduction in morbidity and mortality from measles and improve health status of the outbreak-affected population.
<p>Detection</p> <ul style="list-style-type: none"> • Detect and confirm measles cases to ensure proper case management and enable implementation of appropriate public health strategies to control further transmission. 	<p>Determine the risk of spread</p> <ul style="list-style-type: none"> • Determine the risk of a large outbreak with high morbidity and mortality, as well as the risk of further transmission and potential for geographic spread both in the affected and neighbouring areas. 	
<p>Investigation</p> <ul style="list-style-type: none"> • Determine the cause and extent of measles outbreaks. • Identify potential measles contacts to target those at particular risk of disease for intervention. • Determine the source of infection, including who infected the individual and whether the infection was imported, importation-related or endemic. • Identify populations and areas with low coverage and at higher risk of outbreaks that require enhanced vaccination efforts, and determine the reason for each measles case. 	<p>Outbreak response immunization</p> <ul style="list-style-type: none"> • Reduce the extent and duration of the outbreak and interrupt transmission. 	
<p>Outbreak response</p> <ul style="list-style-type: none"> • Interrupt measles virus transmission. • Reduce measles morbidity, mortality, complications and sequelae. • Identify root causes so that immunity gaps and/or system weaknesses can be addressed to reduce the risk of future outbreaks. 	<p>Clinical case management</p> <ul style="list-style-type: none"> • Reduce measles morbidity and mortality through early adequate clinical management. 	
	<p>Infection prevention and control</p> <ul style="list-style-type: none"> • Prevent health worker infections, reduce transmission in health care settings, and reduce the risk of spread to vulnerable populations. 	
	<p>Surveillance</p> <ul style="list-style-type: none"> • Increase the performance of measles surveillance during the outbreak. 	
	<p>Risk communication, social mobilization and community engagement</p> <ul style="list-style-type: none"> • To provide effective public communications using trusted channels and interlocutors. • To engage with communities to establish two-way dialogue by listening to community concerns and feedback and continually refining the response according to community needs and perspectives. • To monitor and proactively address misinformation and rumours. 	
	<p>Evaluation of measles outbreak response</p> <ul style="list-style-type: none"> • Evaluate the effectiveness of response activities. • Identify gaps and lessons learned during measles outbreak preparedness and response activities to improve response system capacities. 	
<p>detection investigation</p>		

use of vaccination. During 2000–2016, the global annual reported measles incidence declined by 87% from 145 to 19 cases per million population. In 2016, using mathematical modelling, there were an estimated 89 780 measles deaths globally, representing an 84% decline since 2000. During 2000–2016, the number of reported cases decreased from 853 479 in 2000 to 132 490 in 2016 (23). However, since 2016 all of these indicators have been increasing, reaching 869 770 reported cases in 2019, with an incidence of 120 cases per million population and more than 207 500 estimated measles deaths (24).

Despite widespread use of measles-containing vaccines (MCV) worldwide, coverage has remained below 95% in many countries. Even in countries where vaccination has substantially reduced the incidence of measles, there has been failure to achieve very high ($\geq 95\%$) coverage with two doses of MCV through childhood immunization in all districts. This has resulted in continued cases and periodic outbreaks of this preventable disease. Measles outbreaks remain an important cause of death and disability.

1.3 Summary of objectives

Table 1 collates a non-exhaustive list of objectives from a number of sections of this guide, including readiness and preparedness, detection, investigation, outbreak response and recovery.

1.4 Disease characteristics

1.4.1 Measles

Measles is the most contagious disease affecting humans. It is caused by a paramyxovirus in the genus *Morbillivirus*. Measles virus transmission occurs from person to person primarily via aerosolized respiratory droplets. Airborne transmission via aerosolized droplet nuclei has been documented in closed areas (e.g. office examination rooms) for up to 2 hours after a person infectious with measles occupied the area.

Clinical presentation

The incubation period for measles is usually 10–14 days from exposure to onset of first symptoms, which generally consist of cough, fever, malaise, conjunctivitis and coryza (6). The incubation period may be as short as 7 days and very rarely possibly as long as 23 days, but for the programmatic purposes of quarantine and contact tracing, the incubation period is usually considered to be 7–21 days (i.e. 1–3 weeks) after exposure. The characteristic morbilliform rash appears 2–4 days after onset of the prodrome. Patients are usually contagious from about 4 days before eruption of the rash until 4 days after eruption, when the levels of measles virus in the respiratory tract are highest (6). The typical maculopapular rash is often accompanied by fever that peaks at 39.0–40.5 °C. Prior to the onset of rash, bluish-white Koplik's spots, which are pathognomonic for measles, may be seen in the oral mucosa. In uncomplicated measles cases, patients improve by the third day after rash onset, and have fully recovered 7–10 days after onset of disease.

Complications

Complications associated with measles most commonly involve the respiratory and/or digestive tract: pneumonia, croup, otitis media, oral sores and diarrhoea, but can also be complicated by seizures and encephalitis. Complications may directly result from measles infection, especially early in the disease, but are frequently the result of secondary bacterial infection. Rates of bacterial infections such as pneumonia, otitis and diarrhoea peak 2 to 3 weeks after rash. Vitamin A levels fall significantly during measles, particularly in children with pre-existing deficiency or malnutrition. Vitamin A is needed to support the epithelial cells of the respiratory and gastrointestinal tract, and children with vitamin A deficiency are more likely to succumb to viral and bacterial superinfections of the respiratory and gastrointestinal system following measles infection. Levels can fall low enough during measles to result in xerophthalmia (progressive eye disease caused by vitamin A deficiency), characterized by inflammation of the cornea,

Bitot's spots (conjunctival keratin), and corneal opacity, and may cause blindness. Vitamin A deficiency may also exacerbate measles illness and complications. Subacute sclerosing panencephalitis (SSPE), a progressive degenerative and fatal disease, is a long-term measles complication caused by persistent measles virus infection of the brain. SSPE occurs in one per 5000 measles cases (25) with onset starting an average of 7 years (range: 1 month to 27 years) after acute measles.

In adults, measles complications may include hepatitis and problems with pregnancy. Pregnancy complications caused by measles infection include miscarriage, preterm birth, neonatal low birth weight and maternal death.

Measles case fatality ratios (CFRs) vary from 0.01% in high-income countries (26) to 3% in low- and middle-income countries (27,28), but can be as high as 10–30% in populations with malnutrition, overcrowding and limited access to health care (6). Measles mortality is not only from direct infection by the virus, but also related to secondary infections. In addition, measles infection can cause immune system suppression and immunologic amnesia that increases susceptibility to all pathogens, including those to which the individual was previously immune.

1.4.2 Rubella

Rubella, also known as German measles, is caused by infection with a virus. Infection is usually mild, but infection in early pregnancy can cause serious birth defects or miscarriage. Rubella typically presents with symptoms similar to measles and should be considered in the differential diagnosis of fever rash illness. Laboratory diagnosis of measles and rubella are typically linked either as parallel or sequential testing processes.

Clinical presentation

The average incubation period for rubella is 14 days (range 12–23 days) from exposure to onset of first symptoms and is usually a mild, self-limited illness occurring during childhood (29). During the second week after exposure, there may be a prodromal illness, consisting of low fever (< 39.0 °C), malaise and mild conjunctivitis, which is more common in adults. Postauricular, occipital and posterior cervical lymphadenopathy are characteristic and typically precede rash by 5–10 days. A maculopapular, erythematous and often pruritic rash occurs in 50–80% of rubella-infected people, starting on the face and neck before progressing down the body, usually lasting 1–3 days (29).

Serological studies have shown that 20–50% of all rubella infections occur without a rash or are subclinical. Joint symptoms (arthritis, arthralgia), usually of short duration, may occur in up to 70% of adult women with rubella but are less common in men and children. Post-infectious encephalitis occurs in approximately 1/6000 rubella cases, but ratios as high as 1/500 and 1/1600 have been reported (29).

Complications

The most serious consequences occur when a pregnant woman gets infected, particularly during the first trimester. Rubella infection with either asymptomatic or symptomatic disease occurring just before conception and up to the first 8–10 weeks of gestation causes multiple congenital abnormalities in up to 90% of infections and may result in miscarriage or stillbirth (29). Congenital anomalies associated with maternal rubella infection are rare after the 16th week of pregnancy, although sensorineural hearing deficits may occur after exposure up to week 20 of gestation (29). The defects associated with congenital rubella syndrome (CRS) include ophthalmic (e.g. cataracts, microphthalmia, glaucoma, pigmentary retinopathy, chorioretinitis), auditory (e.g. sensorineural deafness), cardiac (e.g. peripheral pulmonary artery stenosis, patent ductus arteriosus or ventricular septal defects) and craniofacial (e.g. microcephaly) anomalies (29).

CRS can also present with other manifestations, such as meningoencephalitis, hepatosplenomegaly, hepatitis, thrombocytopenia, interstitial pneumonitis and radiolucency in the long bones (a characteristic radiological pattern of CRS) (29). Infants who survive the neonatal period may have serious developmental disabilities (such as autism, visual and hearing impairment) and developmental delay. Viral shedding can continue in infants born with CRS beyond 1 year of age, which may result in virus transmission (29).

Risk groups

The risk of CRS varies widely between countries. It is highest in those countries with ongoing rubella transmission in the population and high levels of susceptibility in women of reproductive age who lack previous rubella vaccination or natural infection.

1.5 Measles outbreak characteristics

Endemic measles virus transmission has a typical temporal pattern characterized by annual seasonal outbreaks and epidemic cycles. The epidemic cycles result from the accumulation of susceptible people over successive birth cohorts and the subsequent decline in the number of susceptible individuals due to infection with each outbreak. In temperate zones, annual measles outbreaks typically occur in the late winter and early spring, determined in part by social contact patterns facilitating transmission (e.g. congregation of children at school) and environmental factors favouring the viability and transmission of measles virus. Measles outbreaks in the tropics have more variable seasonal patterns, often lower during periods of more intense agricultural activity and higher during hot, dry seasons when people congregate in towns and cities.

As measles vaccination coverage increases, the epidemiological profile of measles changes. In endemic settings with low vaccination coverage, measles attack rates (AR) are typically highest among non-immune pre-school aged children who have not been fully vaccinated and who have not previously been exposed to circulating measles virus. As coverage increases over time, the age distribution of cases is shifted to both the right and the left, with larger proportions of measles cases occurring among older children and young adults as well as infants. In addition, the time between outbreaks typically lengthens as immunization coverage increases, sometimes to 5–10 years, reflecting the increased time necessary to accumulate enough susceptible individuals to sustain an outbreak. Infants born to non-immune mothers who missed measles vaccinations in their childhood and not been exposed to the measles virus are not protected by maternal antibodies, resulting in a higher proportions of measles cases now occurring in children younger than the recommended age of vaccination. Partial immunization of a population and episodic transmission results in more immunity gaps and subsequent infections among adolescents and adults (30). Drivers of measles transmission include travel and migration. Outbreaks may occur in association with importation following travel from endemic areas by susceptible people. Population density, as well as factors increasing the number of susceptible people such as vaccine refusal, disinformation, vulnerable or hard-to-access populations, vaccine stockouts, and poorly performing health systems all contribute to measles outbreaks.

Countries or regions that have eliminated measles are at continual risk of imported measles so long as measles virus is circulating in other parts of the world. In addition to measles morbidity and mortality, outbreaks in elimination settings result in high costs related to case investigations, contact tracing, outbreak responses and provision of health care.

2 Preparedness

OBJECTIVE

To ensure systems are established to enable a rapid, effective response to measles outbreaks.

2.1 Leadership and coordination

Coordination amongst measles outbreak responders is a critical component for effective response, with a sound outbreak coordination committee (OCC) (**Annex 2**). Measles and other vaccine-preventable diseases (VPD) coordination committees may be required at different levels of the health system (e.g. district, province and national), depending on the extent of the outbreak and response interventions being coordinated. Leadership should be understood at all levels in advance, including decision-making when OCCs are stood up at multiple levels of the health system (e.g. when an outbreak's geographic extension expands and becomes multijurisdictional). Indicators include describing the level of preparedness for the health sector's coordination mechanisms, including the private sector, the functionality of the public health emergency operations centre's (PHEOC) capabilities and linkages from the local/district level to the centralized national coordination system.

2.2 Preparedness and response planning

Realistic and clearly defined emergency preparedness and response plans are critical for timely and successful responses to an outbreak. Periodic review and revision of plans is also recommended to maintain currency and relevance (31). Preparedness indicators include review of the legal framework for measles outbreak response activities, verification that all levels of the health system have clearly defined roles and responsibilities, and planning provisions include personnel planning for how to maintain the continuity of care for essential services not directly related to the measles response.

Measles outbreak preparedness checklist

Measles preparedness is a crucial element of preparedness for infectious threats under the IHR.

While prevention of measles is the critical aim of the health system, there are instances when the health system must scale-up actions to be ready to respond to an imminent measles outbreak and limit its potential spread. The measles outbreak preparedness checklist provided in **Annex 1** of this guide is a tool designed to assist countries to be ready to respond effectively to measles outbreaks. It aims to enable countries to identify strengths and gaps in their level of capability to respond quickly and effectively to a measles outbreak. For this checklist, "complete/ready" indicates that the indicator is fully met, while "incomplete/not ready" indicates preparedness in this area could be improved. Annual administration of these checklists may be appropriate; however, countries should aim to integrate measles preparedness checklists into existing preparedness and readiness systems.

The findings from this checklist should provide information for countries to develop a measles outbreak preparedness plan. Indicators within the measles preparedness checklist are not exhaustive and may need to be further adjusted, based on the country context. Countries should also develop checklists for the subnational level to ensure that crucial aspects of district-level preparedness are in place (e.g. district measles outbreak response plan).

2.3 Contingency finance

Early access to funding at the operational level is critical for a country to be able to quickly respond to a measles outbreak. Facilities and local authorities must understand the procedures for quickly accessing operational funds that will enable rapid and effective response.

2.4 Surveillance

An effective disease surveillance system is essential to detect measles and rubella outbreaks quickly before they spread, cost lives and become more difficult to control. More effective surveillance systems also allow timely understanding of measles epidemiology and estimation of the underlying true incidence. National early warning surveillance systems are required to support the timely identification of outbreaks nationally. In the absence of such systems, high-risk areas should be among the geographic areas with early warning surveillance capacity (e.g. areas receiving tourists, migrant and seasonal workers, as well as areas along commercial routes, and with limited access to vaccines or with populations that are resistant to vaccination).

The WHO *Surveillance standards for vaccine-preventable diseases (4)* should be used by countries to determine the level of effectiveness and functionality of the surveillance system to detect suspected measles cases, including capabilities at the local level to detect and investigate potential alerts.

All countries should have well-functioning case-based measles and rubella surveillance systems that satisfy standard surveillance performance indicators. Such surveillance should be capable of rapidly detecting, reporting and investigating suspected measles and rubella cases so that appropriate interventions may be made to stop potential outbreaks. As countries reduce measles and rubella virus transmission and the number of cases decreases, surveillance standards may be modified to increase the sensitivity and accuracy of case detection and classification, as well as to verify elimination. The WHO *Surveillance standards for vaccine-preventable diseases* provides details, including indicators of the timeliness and completeness of reporting (including zero reports), and investigation, sensitivity, source classification, representativeness, specimen collection and testing adequacy, viral detection, timeliness of specimen transport and reporting of laboratory results (4).

2.5 Standard operating procedures

An integral part of preparedness is the use of SOPs, which are used to operationalize strategies and plans at field level. These procedures, developed in line with laws and regulations of the country, “describe the actions to be done in the management of outbreak situations” and can be applied at all levels of the response, from the national to the locally affected areas. Plans and guidance should be accompanied by SOPs to operationalize all aspects for all partners, standardizing key areas of the response such as case management, infection prevention and control (IPC) procedures, and other relevant areas.

2.6 Risk communication and community engagement

Risk communications and community engagement include a range of two-way communications and engagement activities through the preparedness, response and recovery phases in order to encourage informed decision-making, positive behaviour change and the maintenance of trust.

Tailored and evidence-informed risk communications and community engagement strategies for areas at risk for measles outbreak are often timepoint specific and critical to address behaviour change successfully, increase vaccination coverage, and provide information for households to get ready for the risk of measles. Goals include building awareness of risks and supporting communities to act on prevention messages that include vaccination.

2.7 Health workforce

Aligned directly with the health system building block “health workforce”, this key preparedness component focuses on the health workforce’s (technical and non-technical persons) current level of preparedness to respond to a measles outbreak. To describe the level of preparedness within the health workforce, it is recommended to consider both the management of personnel (staff hours regulations, roles and responsibilities defined) as well as the technical capacities of health workers.

2.8 Health structures

During a measles outbreak, hospitals and health facilities must remain operational to both respond to the measles outbreak and continue to safely provide essential care and services for non-measles cases (32).

Preparedness plans should include specific actions for health structures to put in place for infectious hazards as outlined in the WHO *Guide for clinical case management and infection prevention and control during a measles outbreak* (3). These measures may include but are not limited to:

- 1) reviewing and implementing IPC SOPs;
- 2) updating and adjusting the triage and patient flow system to limit any risk of health care acquired infections;
- 3) ensuring isolation capacity within the health structure (isolation rooms) (33); and
- 4) reviewing medical stock to ensure adequate supplies to cope with potential influx of measles cases, including those with complications.

2.9 Logistics and supply chain

There is widespread recognition that measles outbreak logistics and supply chains play a significant role in the effectiveness of outbreak response, particularly during the initial phase. Related activities include advanced logistical planning to increase vaccination capacity in areas that will conduct outbreak response immunization (ORI), ensuring cold chain management, procurement of medication, vaccines, supplies and PPE, and their transport as well as transport of personnel and risk communication materials. It is recommended that the country logistics/supply chain departments also review their current capabilities to be ready to respond to specific hazards that are identified.

2.10 Partner engagement

Partners can play a critical role in measles outbreak response. Country partners include but are not limited to public-private partnerships, nongovernment organizations (NGOs), civil society, community organizations, private sector and religious groups. In humanitarian settings, as local governments and civil society groups, health cluster partners are often the first responders during emergencies (along with the community); country partners are critical to fulfilling the humanitarian mandate.

3 Detecting and confirming measles outbreaks

OBJECTIVE

Detect and confirm measles cases to ensure proper case management and enable implementation of appropriate public health strategies to control further transmission.

3.1 Detection systems

Signal detection

Signals are any data or information that may represent an event of potential acute risk to human health and that require a rapid response. Many modalities can be used to detect signals that may represent an incipient outbreak. Signals can be detected through a sensitive high-quality measles-rubella case-based surveillance, as outlined in the WHO *Surveillance standards for vaccine-preventable diseases* (4). In addition, national early warning and response system (EWARS) capacities also exist in every country and are an additional source of signals to help quickly identify potential measles outbreaks. Depending on the setting, signals of measles-like illness may consist of individual reports or clusters of fever and rash cases or deaths, notified through event- or community-based surveillance systems. Some countries also have syndromic/aggregate surveillance systems which can serve as an indication that there might be an outbreak. All signals regardless of their source serve to alert public health authorities to suspected cases and need to be verified and investigated to determine if they truly represent measles. The WHO guide on *Early detection, assessment and response to acute public health events* provides further information (34).

Event verification

Once a signal is detected through event- or community-based surveillance, it needs to be verified. Verification is an essential step that is usually done remotely by the central level contacting peripheral health staff who can verify the event has truly occurred and thus whether or not to investigate further. The verification process is an opportunity to remotely collect information on things like the number of people affected and deaths, place and date of occurrence, presenting syndrome, and laboratory findings (if any). Verification will vary according to the source and the event, but frequently will consist of remotely contacting local health workers who can provide valid information about whether suspected cases of the disease are really occurring. Key elements of verifying reports are a clear understanding of the measles (and rubella) case definitions. However, it is important to note that meeting a suspected case definition does not confirm that the etiology is measles. Further investigation is needed including laboratory confirmation and epidemiologic investigation. All cases require laboratory or epidemiologic-linkage confirmation in countries achieving or near elimination. All measles cases first identified through signal detection systems should subsequently enter measles case-based reporting systems. To ensure surveillance is uniform, standard definitions are used.

3.2 Case definitions and case classifications

Cases meeting the definition of a suspected case need to be classified using information from the individual case investigation and based on clinical, epidemiological and laboratory criteria either as clinically compatible, epidemiologically linked, laboratory-confirmed, or discarded as non-measles/non-rubella, as defined in Table 2. Using a standard case definition and case classifications ensures that every case is

Table 2. Definitions to be used for measles public health surveillance

Case definitions for case finding	
Suspected measles case	An illness in a patient with fever and generalized maculopapular (non-vesicular) rash, or in a patient whom a health care worker suspects has measles. ^a
Clinical measles case	<ul style="list-style-type: none"> ● Any person in whom a clinician suspects measles infection; or ● Any person with fever and maculopapular rash (i.e. non-vesicular) and: <ul style="list-style-type: none"> – cough, or – coryza (i.e. runny nose) or – conjunctivitis (i.e. red eyes).
Final case classifications	
Laboratory-confirmed measles case	A suspected case of measles that has been confirmed positive by testing in a proficient laboratory, and vaccine-associated illness has been ruled out. ^{bc}
Epidemiologically linked measles case^d	A clinical case of measles that has not been confirmed by a laboratory, but was geographically and temporally related, with dates of rash onset occurring 7–21 days apart from a laboratory-confirmed case or another epidemiologically linked measles case.
Clinically compatible measles case	A clinical case of measles, but no adequate clinical specimen was taken and the case has not been linked epidemiologically to a laboratory-confirmed or epidemiologically linked case of measles or other communicable disease.
Discarded case^e	<p>A suspected measles case that has been investigated and discarded as non-measles through:</p> <ul style="list-style-type: none"> ● negative laboratory testing in a proficient laboratory on an adequate specimen collected during the proper time after rash onset; or ● epidemiological linkage to a laboratory-confirmed outbreak of another communicable disease that is not measles; or ● confirmation of another etiology; or ● failure to meet the clinically compatible measles case definition.
Other definitions	
Acute measles-related death	A measles-related death is a death in an individual with confirmed (clinically, laboratory or epidemiologically) measles in which death occurs within 30 days of rash onset and is not due to other unrelated causes, e.g. a trauma.
Suspected measles outbreak	Five or more measles cases ^f (with dates of rash onset occurring 7–21 days apart) that are epidemiologically linked.
Laboratory-confirmed measles outbreak	Two or more laboratory-confirmed measles cases that are temporally related (with dates of rash onset occurring 7–21 days apart) and epidemiologically or virologically linked, or both.

^a Countries may also use the clinical case definition of measles as the suspected case definition: fever, maculopapular rash, and at least one of the following: cough and/or coryza and/or conjunctivitis. If acute fever-rash surveillance is used the case may also be suspected for rubella by the health care worker.

^b A proficient laboratory is one that is WHO-accredited or has established a recognized quality assurance programme, such as International for Standardization (ISO) or Clinical Laboratory Improvement Amendments (CLIA) certification.

^c No recent vaccine given, or non-A genotype.

^d In countries using the WHO recommended suspected case definition of fever and rash, the specificity of epidemiological linkage can be improved by defining epidemiologically linked measles cases as a suspected case of measles, who has fever, rash, and cough, conjunctivitis, and/or coryza, that has not been confirmed by a laboratory, but was geographically and temporally related, with dates of rash onset occurring 7–21 days apart from a laboratory-confirmed case or another epidemiologically linked measles case. Cases without these clinical signs and symptoms who are not lab tested would then be classified as discarded.

^e Local surveillance guidelines may combine non-measles and non-rubella cases as discarded, especially if measles surveillance is in use.

^f Country-specific measles epidemiology should determine the measles case definition and the number of cases required to meet the suspected measles outbreak definition. For example, in the WHO African Region five or more “clinical measles cases” in a health facility or district in 1 month defines a suspected outbreak, while in the WHO South-East Asia Region five “suspected measles” cases are required.

defined and classified in the same way, regardless of where or when it occurred, or who identified it. This standardization facilitates confirmation of outbreaks, as well as aggregation, analysis and interpretation of data, and comparison between geographic areas and over time. Case definitions (along with those of other priority diseases) should be distributed to health facilities at all levels in the form of posters or as small pocket-size booklets. Health personnel should be trained on their use. Further details on measles and rubella case definitions and classifications, including vaccine-associated illness, are found in the WHO *Surveillance standards for vaccine-preventable diseases* (4).

Rubella

Surveillance for rubella should be integrated with measles case-based surveillance as described in WHO's *Introducing rubella vaccine into national immunization programmes* (35), and *Surveillance standards for vaccine-preventable diseases* (4). Suspected measles outbreaks may be eventually confirmed as rubella outbreaks, and some may be mixed measles/rubella outbreaks. In these situations, guidelines for rubella outbreak response should be followed. Further, mixed measles/rubella outbreaks require special vigilance to: 1) differentiate the burden of measles relative to rubella cases; and 2) continue collecting samples for ongoing laboratory confirmation to verify if the outbreak remains mixed, or if one disease (measles or rubella) transmission is interrupted. Ideally, all cases should have a specimen collected, if feasible. In addition, rubella outbreaks also require the implementation of congenital rubella syndrome (CRS) surveillance (35), through either strengthening of existing CRS surveillance, or establishing ad hoc CRS surveillance at appropriate sites. Further, rubella outbreaks may need additional IPC efforts around CRS cases. Infants with congenital rubella, including those without clinical manifestations of CRS, may shed rubella virus from body secretions, and should be considered infectious during the first year of life. Rubella outbreaks have occurred among health workers caring for infants with CRS. It is necessary to ensure that persons in contact with these infants (e.g. health workers, family members, friends) are immune to rubella (35). Note, CRS cases present very differently than rubella cases, see WHO's *Introducing rubella vaccine into national immunization programmes* (35).

Epidemiological linkage

In elimination settings, measles epidemiologic linkage is established when there is contact between two people involving a plausible mode of transmission at a time when all of the following three criteria are met:

- 1) one of them is likely to be infectious (4 days before to 4 days after rash onset); AND
- 2) the other has a rash onset that starts 7–21 days before or after this contact; AND
- 3) at least one case in the chain of epidemiologically linked cases (which may involve many cases) is laboratory confirmed.

Criteria for epidemiological linkage in elimination settings include being a known contact, i.e. being in the same physical setting as the case during their infectious period (4 days preceding until 4 days after rash onset) for any length of time (shared airspace such as at home, school, health facility waiting room, transport or workplace). Note, being in the "same physical setting" should take into account that the virus can remain viable in the air or on infected surfaces for up to 2 hours (4); this should be considered when conducting contact tracing as transmission can occur even if the contact was not in the same room at the exact same time as the case. In many highly endemic countries, settings often with limited resources to perform comprehensive contact tracing, being in the same geographical area (e.g. district, village or neighbourhood) within 30 days of a laboratory-confirmed case is used to define epidemiological linkage. In these settings, misclassification of cases may occur due to the broader definition for epidemiological linkage; it is important that cases classified as epidemiologically linked meet the clinical case definition.

3.3 Laboratory confirmation

The analysis of serum specimens for the presence of measles- or rubella-specific IgM antibodies is the most widely used testing method for laboratory confirmation. The enzyme immunoassay (EIA) is the method recommended by the WHO Global Measles and Rubella Laboratory Network (GMRLN) for the detection of virus-specific IgM antibodies in serum. Blood is collected at first contact with a suspected case of measles or rubella. In most instances, a single serum specimen will be sufficient to classify a suspected measles or rubella case based on the presence or absence of virus-specific IgM. For surveillance purposes, an adequate serum sample for measles or rubella is one that is obtained within 28 days after the onset of rash. If the test result is negative and the specimen was drawn within 3 days of rash onset, then a second specimen should be collected and tested for anti-measles IgM and IgG. While serum-based IgM detection is recommended by WHO for routine surveillance for measles and rubella, the use of dried blood spots (DBS) and oral fluid (OF) are acceptable alternative samples for antibody detection when logistical barriers exist for proper collection, processing and transport of serum specimens. In well-resourced settings, additional laboratory evidence may be generated through detection of measles virus by nucleic acid testing, isolation of measles virus, detection of measles virus antigen, a significant increase in IgG antibody level (except if the case has received a MCV within 8 days to 8 weeks prior to testing). To understand the genotype diversity of measles and rubella in a given country and provide evidence on the elimination of endemic circulation, collection and genomic analysis of representative clinical measles and rubella specimens is critical.

More information on laboratory testing and specimen collection as well as genotype analysis is available in the WHO *Manual for the laboratory-based surveillance of measles, rubella, and congenital rubella syndrome* (9).

4 Investigating measles outbreaks

OBJECTIVES

- **Determine the cause and extent of confirmed measles outbreaks.**
- **Identify potential measles contacts to target those at particular risk of disease for intervention.**
- **Determine the source of infection, including who infected the individual and whether the infection was imported, importation-related or endemic.**
- **Identify populations and areas with low coverage and at higher risk of outbreaks that require enhanced vaccination efforts.**

4.1 Prepare investigation

Assembling rapid response team (RRT)

An RRT should be assembled at the appropriate level (e.g. affected district) to carry out the investigation. The members of an RRT should ideally include a team leader, an epidemiologist, a clinician, an immunization expert and, if available, a laboratory technician, all with defined roles and responsibilities. If additional resources are available, then the team could also include a communication specialist, a logistician and a data manager.

Materials and documents

Before leaving for an outbreak investigation, the RRT should assemble the resources necessary to conduct the investigation, including documentation and logistical considerations. These include:

- **Documentation:** List of people to see, list of health facilities, information on case(s) already gathered (location, date of rash onset, signs and symptoms, date of hospital admission, severity, vital status, immunization status, etc.), guidelines and SOPs (case definition, treatment protocols, (preparing information sheets and data collection forms for cases and contacts, supplies for collecting and transporting specimens, preparing simple case and complicated case treatment kits, etc.).
- **Logistics:** Terrain-appropriate modes of transport (e.g. 4×4), maps of the area of concern, appropriate means of communication (radio, cell phones with chargers), camera, global positioning system (GPS), lodging, electricity, food, etc.
- **Supplies:** Case investigation forms (CIFs), standardized questionnaires, treatment kits, specimen collection and shipment supplies, personal protective equipment (PPE), electronic equipment (e.g. laptop, etc.), stationery, educational material to interact with the community and local health care practitioners, pictures of measles patients for active search in the community.
- **Mandate:** Pre-authorization from the local authorities and/or local leaders, as required.

- **Data available at national level:**

- surveillance data from the past 5 years: epidemic curves and attack rates (AR) during the same periods in previous years and information on previous epidemics;
- epidemiological situation in adjacent areas and neighbouring countries; and
- information from the national immunization programme: data on vaccination coverage from both routine immunization (RI) as well as any supplementary immunization activities (SIAs) in the affected area, age groups, high-risk groups, etc.

4.2 Outbreak investigation

OBJECTIVE

Detect and confirm measles cases to ensure proper case management and enable implementation of appropriate public health strategies to control further transmission.

4.2.1 Initial field investigation

Collecting data from suspected case(s)

For each case, an adequate investigation requires a completed CIF that should include the WHO-recommended 12 core variables, as well as other setting specific variables, e.g. nomads, internally displaced persons (IDPs) etc., and a classification of whether or not the case was preventable (see WHO *Surveillance standards for vaccine-preventable diseases (4)*). Line listings that include key core variable data may be used when the number of suspected cases becomes too large to complete CIFs for all cases. Local authorities should conduct initial case investigations and conduct an intensification of RI (where necessary), regardless of whether the case or cluster of cases triggers the need for additional investigation by any higher health authority teams (e.g. RRT).

Gathering initial evidence

Once the RRT arrives in the outbreak area, the team should initially gather all existing clinical, epidemiological and laboratory evidence of suspected cases in both the communities of origin of the suspected cases and the health facilities and locations where the measles cases might have been vaccinated or received care. Surveillance data should be analysed (number of suspected and confirmed cases, place of residence, weekly case numbers, case numbers by age groups or birth cohorts, vaccination status of cases, number of deaths and case fatality ratios, epidemic curve, laboratory results).

Other relevant information includes:

- Review measles case-based surveillance performance indicators to assess the surveillance data quality.
- Epidemiological link to health care facilities to identify infections that occurred in these settings.
- Presence of external risk factors in the affected community such as:
 - migrant populations, IDPs, minority or indigenous communities, congregated settings, prisons, refugee camps, urban slums, rural and remote populations, new settlements, and areas of insecurity;
 - large influx of tourists;
 - high-traffic border areas;
 - high-traffic transportation hubs/major roads or highly industrialized areas; and
 - areas with mass gatherings (i.e. trade/commerce, fairs, identify typical market days for localities reporting cases, sporting events, religious events).
- Community feedback and key informant interviews regarding knowledge of any persons with signs and symptoms of measles.

- Health facility and community feedback on areas with low participation in RI programming and any known reasons for low participation.
- Health facility performance information including challenges in providing routine services.
- Identify areas with low vaccination coverage:
 - identify available data from administrative sources, surveys, surveillance, such as children who have never been vaccinated from acute flaccid paralysis (AFP) and fever rash illness surveillance and triangulate these data sources to try to identify areas that historically have been poorly vaccinated (36); and
 - consider conducting rapid convenience assessments of coverage in the surrounding communities to get “a quick impression of the completeness of vaccination” and barriers to immunization. Protocols for rapid coverage assessments can be found elsewhere (37).

During the outbreak investigation, the field team should visit health facilities in the affected areas. It is an opportunity to gather information on current vaccination programme performance and to reinforce messages for improving immunization going forward.

If most of the cases are among people < 2 years of age, assessment of the nearest health facility may give insight into the immunization programme weaknesses that led to the accumulation of susceptibles and the outbreak in the community. If most of the cases are among people > 5 years of age, it is likely that immunization programme weaknesses contributing to the outbreak occurred years earlier. However, an assessment of the health facility’s current immunization activities would still be necessary to assess if there are any new or ongoing risks.

Common reasons for low coverage include inadequate vaccine supply, service delivery and/or demand:

Supply

- inadequate amount of vaccine and/or injection equipment leading to stockouts.

Service delivery

- services do not meet need;
- insufficient or poorly placed facilities; and human resources to serve population;
- too few sessions;
- sessions not in areas at times appropriate to the population served;
- all vaccines, particularly BCG, MCV/RCV, are not offered at every session/may wait for a minimum number of children to open a vial;
- exclusion of a portion of the population for any reason; and
- in some rare cases, there may be problems with vaccine handling, leading to non-potent vaccine being administered.

Demand

- hesitancy due to religion or other beliefs;
- hesitancy due to fear of adverse events following immunization (AEFI);
- discontent with the quality of services; and
- physical and/or financial barriers.

A sample RI assessment tool for the health facility level is provided (**Annex 3**). Any issues should be immediately brought to the attention of district and regional teams for action. This information may be further used in the root cause analysis.

4.2.2 Confirming suspected measles cases

Laboratory testing is necessary to confirm suspected cases and outbreaks (9). Specimen collection kits should be made available in health facilities so that samples can be taken at the first contact with the health care system. To confirm the outbreak as measles, specimens should be collected at a minimum from the first five to ten reported suspected cases with rash onset occurring within 2 months of each other in the affected geographic area. If two or more of the suspected cases test positive for measles,

the outbreak is confirmed as measles. To estimate the magnitude of the measles outbreak, however, it is helpful to collect specimens from at least 10 or more suspected cases and, based on the results, to calculate the test positivity rate (TPR). The TPR is calculated as the percentage of suspected measles cases with specimens collected and tested that are then laboratory-confirmed for measles. In outbreaks with little measles virus circulation or where herd immunity exists, the TPR would be expected to be low and most reported suspected measles cases are unlikely to be true measles cases; during true measles outbreaks among susceptible populations, the TPR may be as high as 75% or more. Thus, when the TPR is low (e.g. < 50%), or during mixed outbreaks where some cases are laboratory-confirmed as measles and others are laboratory-confirmed as rubella (or another disease), specimen collection from suspected cases should continue to ensure accurate classification of suspected cases.

Suspected measles cases may also be confirmed by epidemiologic linkage, as defined above. In countries that define epidemiologic linkage loosely as those living in the same district with rash onset within 30 days of the referent confirmed case, the likelihood of case misclassification can be estimated by calculating the TPR for that district. The actual number of measles cases among both “epidemiologically linked” and “clinically compatible” cases can then be estimated by multiplying that number by the TPR. As noted above, when the TPR is low, it is better to continue to collect specimens from suspected cases rather than rely on estimated magnitude of disease, and thus avoid case misclassification.

Identification of measles virus genotypes and named strains through molecular epidemiologic methods can be highly useful for understanding importations, chains of transmission and as a line of evidence for elimination. In addition to serologic specimens for case confirmation, oro- or naso-pharyngeal specimens (or urine) should be collected from between five and ten suspected cases for virus detection by reverse transcription polymerase chain reaction (RT-PCR), ideally within 5 days but no later than 14 days following rash onset, followed by sequence analysis following the protocols described in the WHO *Manual for the laboratory-based surveillance of measles, rubella, and congenital rubella syndrome* (9). The WHO *Measles elimination field guide* states countries should aim for 80% laboratory-confirmed measles virus chains of transmission with genotypic data available (14). While highly specific, clinical specimens collected for molecular analysis are more easily prone to degradation and because viremia last up to 14 days after onset of rash, RT-PCR is not as sensitive as serology: a negative PCR test does not necessarily rule out measles. Molecular epidemiology also can be helpful to *rule out* a link between cases (if the cases have different genotypes or named strains). However, it may not definitively *confirm* a link between cases without additional epidemiologic data.

If the measles outbreak continues, serologic and virologic specimen collection from at least five to ten suspected additional cases should be repeated every 2 months, and if the outbreak spreads, then specimens should be collected from five to ten cases from the new area to confirm the outbreak is measles.

Post laboratory-confirmation

The laboratory must notify relevant health authorities of test results, usually within 24 hours. Health authorities must ensure all relevant stakeholders are aware at national and local levels.

4.2.3 Additional case finding

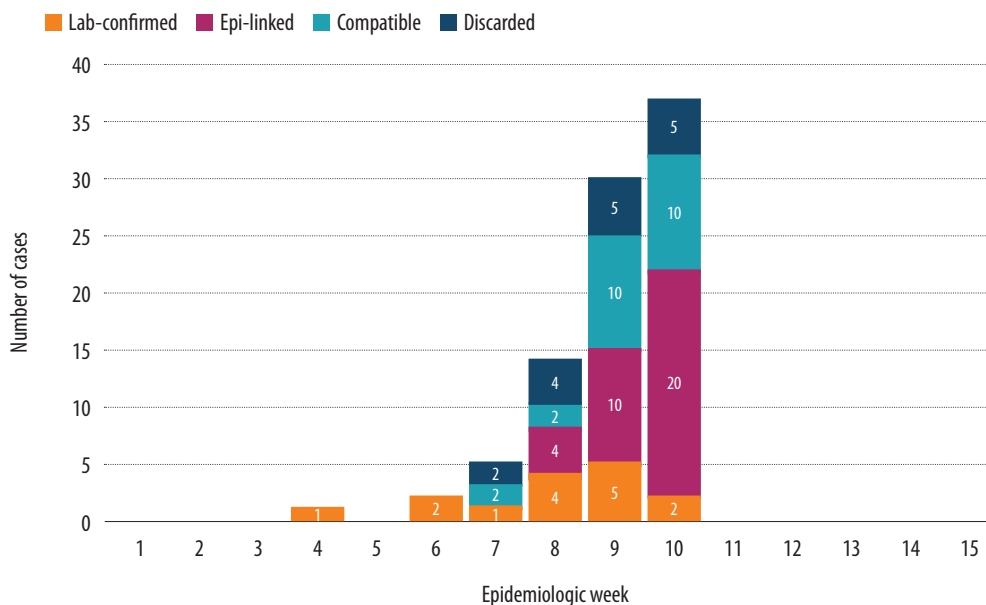
To determine the magnitude of the outbreak and implement further prevention and control measures, it is critical to search for additional suspected cases in the affected community and in neighbouring areas during the initial investigations. Strengthening surveillance system performance and capacity is an essential element of the ongoing response to an outbreak. Further details on scaling up surveillance across all settings is found in the outbreak response section of this guide.

4.3 Descriptive epidemiology

The next step is to describe the outbreak in terms of time, place and person to enable a targeted response. For countries verified as having eliminated measles or that are near elimination or with low measles incidence (e.g. < 10 per million population), it is critical to determine whether the outbreak started from importation of measles virus or resulted from ongoing endemic transmission. In all settings, descriptive epidemiologic analyses of measles cases in terms of, **time, place** and **person** provide valuable information to determine the extent of the outbreak, identify risk factors and reveal causes that may direct appropriate interventions.

→ **Time:** Charting the number of cases by date of rash onset (or date of facility presentation if unavailable) allows the creation of an **epidemic curve (Fig. 1)** that illustrates the evolution of the outbreak over time and helps inform how quickly and how much the number of cases is increasing or decreasing, and whether control efforts are having an impact.

Fig. 1. Measles cases, by classification status and epidemiologic week, Province A, YYYY*

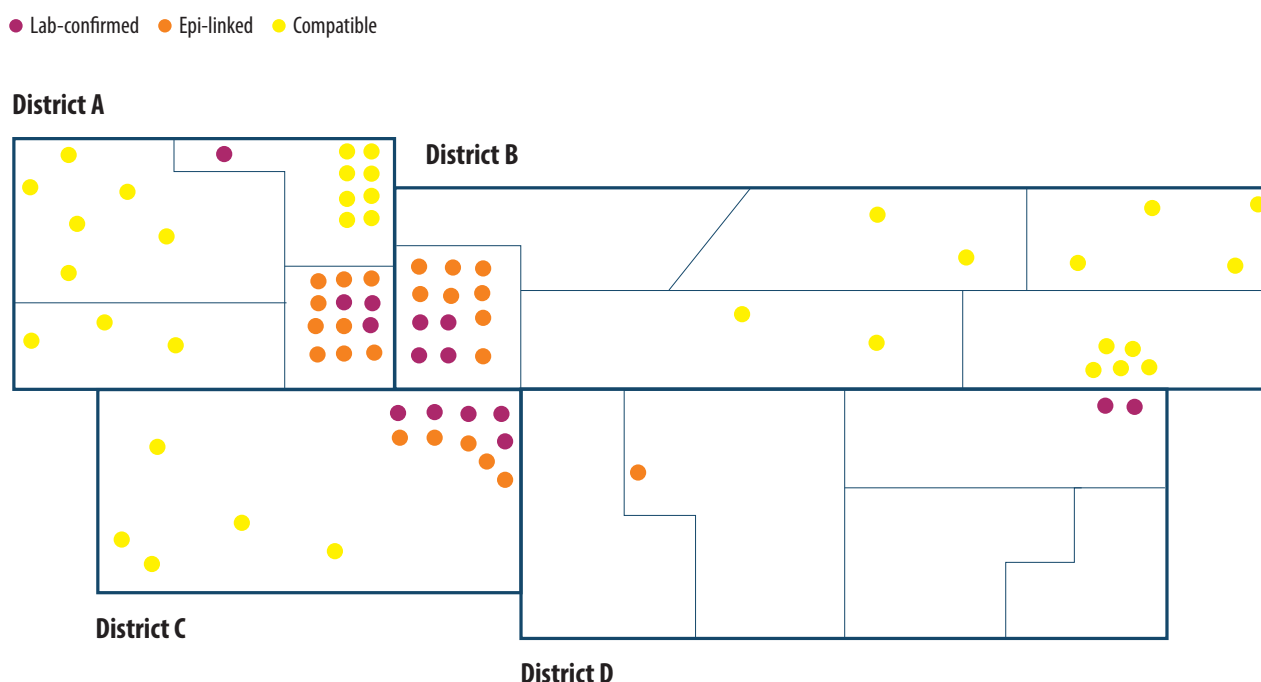


*For cases with rash onset through week 10, YYYY.

Figure 1 shows that the index case, which was laboratory-confirmed, had rash onset in epidemiologic week 4. The outbreak progressed slowly through week 7, and then appeared to increase dramatically and consistently from weeks 8–10. However, as only 2 of 7 (28.6%) of cases with specimens tested were laboratory-confirmed in week 10, it is possible that many of the clinical and “epidemiologically linked” cases identified with rash onset during week 10 may not have been true measles cases. It is also possible, but less likely, that true measles cases may have been discarded because of a false negative serologic laboratory result that occurs in 20–30% of true cases when specimens are collected within the first 3 days after rash onset. Specimen collection from suspected cases should continue to determine the actual magnitude and extent of measles virus transmission.

→ **Place:** Mapping and visualizing the distribution of cases and/or specific attack rates by geographic area helps to visualize the geographic extent (**Figure 2**) of the outbreak and identify areas with clusters of disease.

Fig. 2. Measles cases, by district, subdistrict and classification status, Province A, YYYY*



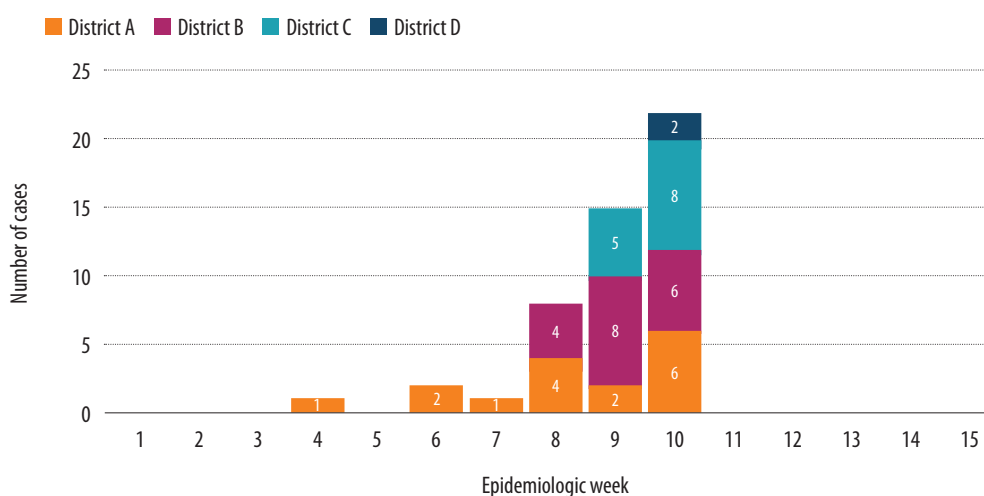
*For cases with rash onset through week 10, YYYY.

Figure 2 is a spot map that shows which cases were laboratory-confirmed, epidemiologically linked and clinically compatible in each subdistrict through week 10. Three adjacent subdistricts in three different districts (Districts A, B and C) have two or more laboratory-confirmed cases and a cluster of associated epidemiologically linked cases. Most clinically compatible cases appear to be scattered in different subdistricts in the four districts, raising a question as to whether they are true measles cases. However, five clinically compatible cases in one subdistrict of District B live in communities adjacent to two laboratory-confirmed cases in a subdistrict of District D, suggesting these clinically compatible cases may in fact be true measles cases. Further investigation into this cluster may identify epidemiologic linkage or a common source of infection. Similarly, a subdistrict of District A has one laboratory-confirmed case and a cluster of eight clinically compatible cases; as the subdistrict is adjacent to another subdistrict in District A with a large number of laboratory-confirmed and epidemiologically linked cases, further investigation here also may determine if the outbreak in District A has extended to involve the adjacent subdistrict.

When the number of measles cases is large, alternative representations of case counts may be used instead of spot maps. One option is a choropleth map, where “patterns”, usually represented by different colours, correspond either to a range of numbers of cases or specific attack rates by geographic area. Dot maps or choropleth maps may be challenging to interpret when the size of the areas varies greatly, with larger geographic areas looking more affected than a smaller area actually having a higher burden. Another option is to superimpose a circle over an affected area, with the size of the circle proportional to the number of cases.

In addition to spot and choropleth maps, the geographic evolution of the outbreak can also be described by stacking the bars of epidemic curves by geographic area by (e.g. district) (**Figure 3**).

Fig. 3. Laboratory-confirmed and epidemiologically linked measles cases, by district and epidemiological week, Province A, YYYY*



*For cases with rash onset through week 10, YYYY.

Figure 3 is an epidemic curve of laboratory-confirmed and epidemiologically linked cases that shows the outbreak started in District A during epidemiologic week 4, then spread to District B during week 8, District C during week 9 and District D during week 10. It also shows the number of laboratory-confirmed and epidemiologically linked cases generally increased over time in Districts A, B and C, suggesting immunity gaps in the respective districts that facilitate the spread of measles virus. Note the analysis to develop this epidemic curve is restricted to laboratory-confirmed and epidemiologically linked cases in order to provide greater certainty in describing the evolution of the outbreak. If more suspected cases had specimens collected and tested and the TPRs in each district are high (e.g. $\geq 75\%$), then it would be reasonable to include clinically compatible cases in this analysis as the probability of case misclassification likely would be low.

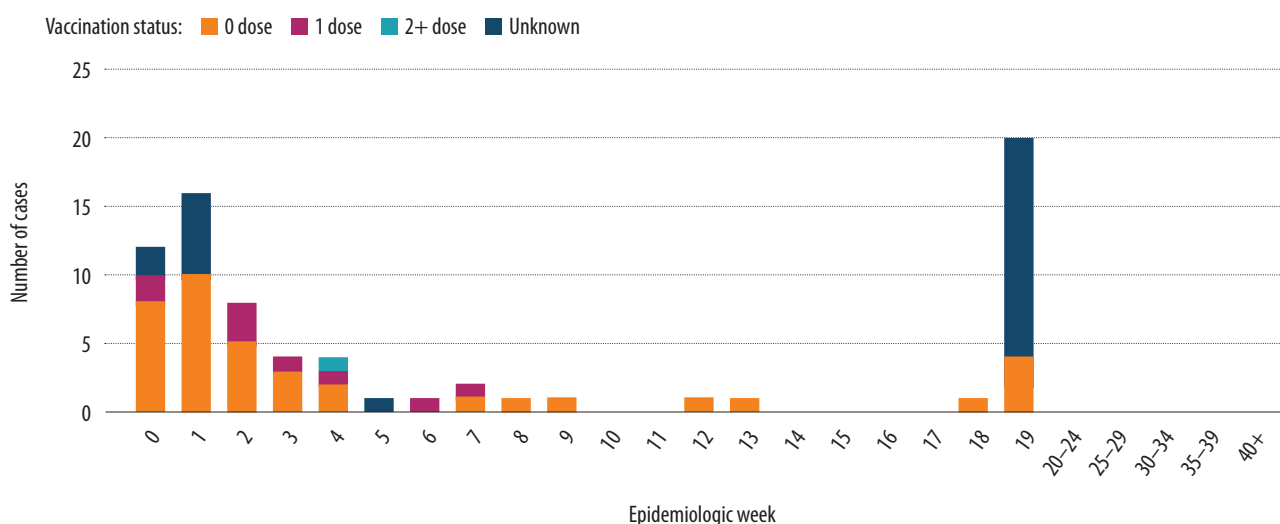
→ **Person:** Tables and charts that describe the personal characteristics of the cases (e.g. age distribution, vaccination status, sex, occupation, etc.) help to determine potential risk factors for disease to define the target population and customize approaches for ORI and other interventions.

Descriptive epidemiologic analysis of personal case characteristics should include, at a minimum:

- 1) age by year (cut points could also be used at the ages when MCV1 and MCV2 are recommended, or by month if < 24 months old);
- 2) vaccination status (by number of doses given);
- 3) sex;
- 4) occupation (including if the case was a student at any age or attended pre-school);
- 5) history of any of the following 7–21 days before rash onset to identify potential sources of infection and/or 4 days before to 4 days after rash onset to determine who the case may have infected:
 - travel history;
 - visiting guests;
 - exposure to other possible cases (i.e. contacts that may have infected the case); and
 - exposure to any health facility the case may have visited;
- 6) outcomes (e.g. hospitalization, death); and
- 7) risk groups (e.g. IDP, refugee, nomads, itinerant labourers etc.).

One common way to describe both age distribution and vaccination status on a single graph is to prepare a bar chart of the number of cases by age stacked by vaccination status (0, 1, 2+, unknown doses) (**Figure 4**). Some countries group “unknown” vaccination status with those who have received zero doses; however, when calculating the percentage of cases vaccinated it is better to restrict the analysis to cases with available data rather than to assume that those with unknown vaccination status have never received measles vaccine. When vaccination coverage is high, the majority of measles cases may occur in appropriately immunized children (**Annex 4**).

Fig. 4. Laboratory-confirmed, epidemiologically linked and compatible measles cases, by age and vaccination status, Province A, YYYY*



*For cases with rash onset through week 10, YYYY.

Figure 4 shows that most of the cases occurring in the province were among persons < 5 years of age or 19 years of age. The majority of the child cases < 5 years old were unvaccinated. These data would suggest that ORI should target children 6–59 months of age. Further investigation is needed to determine if the 19-year-old cases had anything in common so that a subgroup might be specifically targeted for vaccination, and to identify any factors that may have led to immunity gaps in this age (low RI coverage, omission from earlier SIAs, etc.). These cases may come from a common source, such as an educational institution, a sports team, or a workplace. Note that all laboratory-confirmed, epidemiologically linked and clinically compatible cases were included in the analysis. This approach would be appropriate if most of the suspected cases tested were laboratory-confirmed (e.g. $\geq 75\%$ TPR). If not, then a separate analysis of laboratory-confirmed only and possibly laboratory-confirmed and epidemiologically linked cases would be important to validate the findings.

It is important to describe the age distribution of cases by year of age rather than by age group as immunity gaps are likely to exist among children in specific birth cohorts rather than over the entire age group. In the example above, virtually all cases in the 15–19-year age group were 19 years old, suggesting further investigation and/or response would not need to include those 15–18 years old. Results from a measles-susceptibility/immunity profile of each birth cohort also would be helpful to triangulate data to guide ORI activities (37).

Determining vaccination coverage among cases by birth cohort is important to assess the possibility of vaccine failure. Measles seroconversion rates of 9-month-old children are approximately 85%; hence 15% of children vaccinated with a single dose of measles vaccine at 9 months of age would remain susceptible to measles and may become cases during a measles outbreak. In fact, when measles vaccination coverage is high, most measles cases are likely to be among the 15% that never seroconverted and would therefore

represent the expected “vaccine failures”. If coverage data are available, a screening method can be applied to check whether vaccine effectiveness is lower than expected, using the proportion of cases vaccinated (38). A nomogram with standardized curves corresponding to different levels of vaccine effectiveness can also be used noting where the proportion of cases vaccinated on the y-axis intersects with the proportion of the population vaccinated on the x-axis (**Annex 4**).

When analysing and interpreting epidemiologic data, it is important to note that many suspected measles cases reported during an outbreak may not actually have measles infection, including those classified as clinically compatible. First, the differential diagnosis of febrile rash illness includes not just measles, but rubella, parvovirus, dengue, zika and others; many different febrile rash illnesses may also be accompanied by coryza, red eyes and/or cough. Second, as awareness of a measles outbreak increases, reporting of suspected measles cases is likely to increase in many areas and over time. Often outbreaks have some geographic heterogeneity: a measles outbreak may in fact be occurring in one area but not the other, or more intensively in one area than another, despite similar numbers of reported suspected cases. Similarly, the percentage of reported suspected measles cases that are actually infected with measles may be high at the outset of the outbreak but diminish substantially over time. Epidemiologic analysis of data that includes compatible and even epidemiologically linked cases (when epidemiologic linkage is broadly defined by geographic proximity (e.g. residing in the same district) and within an overly broad time window (e.g. rash onset within 30 days of rash onset in the referent laboratory-confirmed case) may provide misleading results that cause misguided interventions if many cases misclassified as measles are included in the analysis.

Descriptive epidemiologic analyses should, whenever possible, distinguish between laboratory-confirmed, epidemiologically linked and clinically compatible cases to help the investigator interpret the reliability of the findings. For example, the bars in an epidemic curve may be stacked by classification status (i.e. laboratory-confirmed, epidemiologically linked, clinically compatible, discarded) as in **Figure 1**, and the dots of a spot map can indicate by colour the location of the laboratory-confirmed, epidemiologically linked and clinically compatible cases as in **Figure 2**.

In addition to the above risk factors, an analysis of outcome (e.g. death) and calculation of CFRs should be performed, overall, by age group, by geographic area, and by other potential risk factors as described below.

Attack rate (AR): Number of cases/population; ARs should be calculated overall and stratified by characteristics (e.g. age group, geographic area, sex, occupation, etc.) to allow comparison between groups and identify potential risk factors for disease.

Weekly incidence: This enables assessment of the speed with which new cases of disease are reported in the population during a given period when calculated each week during an outbreak. Weekly number of new cases \times 1 000 000/total population.

Case fatality ratio (CFR): Number of measles-related deaths/number of measles cases; as with ARs, CFRs should be calculated overall and by age group, geographic area, sex, occupation, etc. to help identify potential risk factors for death in populations and evaluate the quality of case management. However, it is important to keep in mind that measles-related deaths are not always reported or captured through surveillance systems. Most cases visit health facilities early after rash onset, whereas a measles-related death is defined as a death within 30 days of rash onset and often occurs later in the illness progression. Careful longitudinal studies of measles cases find that rates of serious complications (pneumonia, diarrhoea) are highest 2–3 weeks after rash onset, as compared with non-cases, but deaths during this period are often erroneously not counted as a measles death. Where resources permit, follow up of cases to determine the outcome of disease is desirable to estimate the CFR.

If a measles outbreak has extended across several geographic boundaries (e.g. districts or subdistricts) or among vulnerable groups (migrant groups or ethnic minorities), then the epidemiology should be

described for each geographic area or group. Moreover, as the epidemiology may change over time, epidemiologic analyses should be conducted for cases likely to be measles (as described above) and with rash onset at specific time intervals (e.g. at 2-month intervals) to enhance understanding of the causes of the outbreak, routes of transmission and overall evolution. National-level epidemiologic findings may not be representative of each district, nor do district-level epidemiologic findings necessarily reflect each affected subdistrict or health centre/post catchment area.

Analytic epidemiologic analysis may follow to determine vaccine effectiveness and potential risk factors for cases and death (i.e. if important differences in CFRs exist between age groups, geographic areas, sex, occupation, ethnic group, etc.), preferably based on statistical tests of significance. It should be noted that it is often quite difficult to estimate CFRs unless there is a plan to follow up case-patients for clinical outcomes for at least 30 days.

5 Responding to measles outbreaks

OBJECTIVES

- **Interrupt measles virus transmission.**
- **Reduce measles morbidity, mortality, complications and sequelae.**
- **Identify root causes so that immunity gaps and/or system weaknesses can be addressed to reduce the risk of future outbreaks.**

The type and magnitude of the response to measles outbreaks should be based on the characteristics of the outbreak and feasibility of mounting an appropriate response. The more rapid the response, the more likely it is to mitigate the impact of the outbreak. This section covers key elements of response including coordination, case management, IPC, surveillance and laboratory, logistics, vaccination, risk communication, social mobilization and community engagement and disease control in special settings.

5.1 Triggers for public health response

The triggers for measles outbreak response vary by setting. In countries nearing elimination or having eliminated measles or at risk for high levels of measles virus transmission (e.g. in IDP or refugee camps, prisons, military barracks) a single laboratory-confirmed measles case should trigger a public health response (35). In low-resource countries with high levels of endemic transmission, the response will depend on the size and other characteristics of the suspected outbreak. In these settings, a suspected outbreak definition might be met once a threshold in the number of notifications is exceeded (e.g. five reported clinical measles cases during a 30-day period within a defined geographic area). In settings where measles and/or rubella are still endemic, the number of cases that will trigger a response will depend on local epidemiology (4,39).

As with measles, a single laboratory-confirmed rubella case should trigger an aggressive public health investigation and response in an elimination setting. While responses for measles and rubella are similar, rubella outbreaks require some additional public health responses including communicating the risk to women who are or may be pregnant and establishing CRS surveillance. For rubella-endemic settings, an outbreak investigation should be conducted to evaluate the risk to women of child-bearing age, and, if rubella-containing vaccine (RCV) is in the schedule, to consider ORI. Concurrent outbreaks of measles and rubella can occur and may require increasing laboratory testing of cases, as well as outbreak response activities for both measles and rubella.

5.2 Outbreak response immunization

OBJECTIVE

Reduce the extent and duration of the outbreak and interrupt transmission.

5.2.1 Outbreak response immunization strategies

As soon as an outbreak is suspected, preparations need to be made quickly for rapid ORI planning and implementation (**Figure 5**). The initial response includes the reinforcement of RI activities, and the implementation of selective vaccination activities. Selective vaccination refers to routine checking of the child's vaccination status based on the vaccination card, registration book or electronic registry. If vaccination is documented in such reliable records, the vaccine is not administered. The decision to conduct non-selective ORI targeting specific ages, groups and areas will depend on:

- magnitude and epidemiologic analysis of the outbreak;
- the result of the local risk assessment (based on RI and SIA coverage, Penta 1-MCV1 dropout rates, migration into and out of the affected and surrounding areas, etc.). The WHO Measles Programmatic Risk Assessment Tool may be helpful for this analysis, particularly for large geographic areas (**Annex 5**); and
- available resources and the local capacity to conduct a high-quality immunization campaign.

The capacity to conduct high-quality ORI depends on:

- the ability to mobilize sufficient amounts of bundled vaccine and other supplies within the timescale necessary; and
- the availability of staff and financial resources (both internal and external) for ORI operations.

As such, it is important that measles outbreak preparedness plans and supplies be in place and ready to execute for any district or province that may be affected by a measles outbreak.

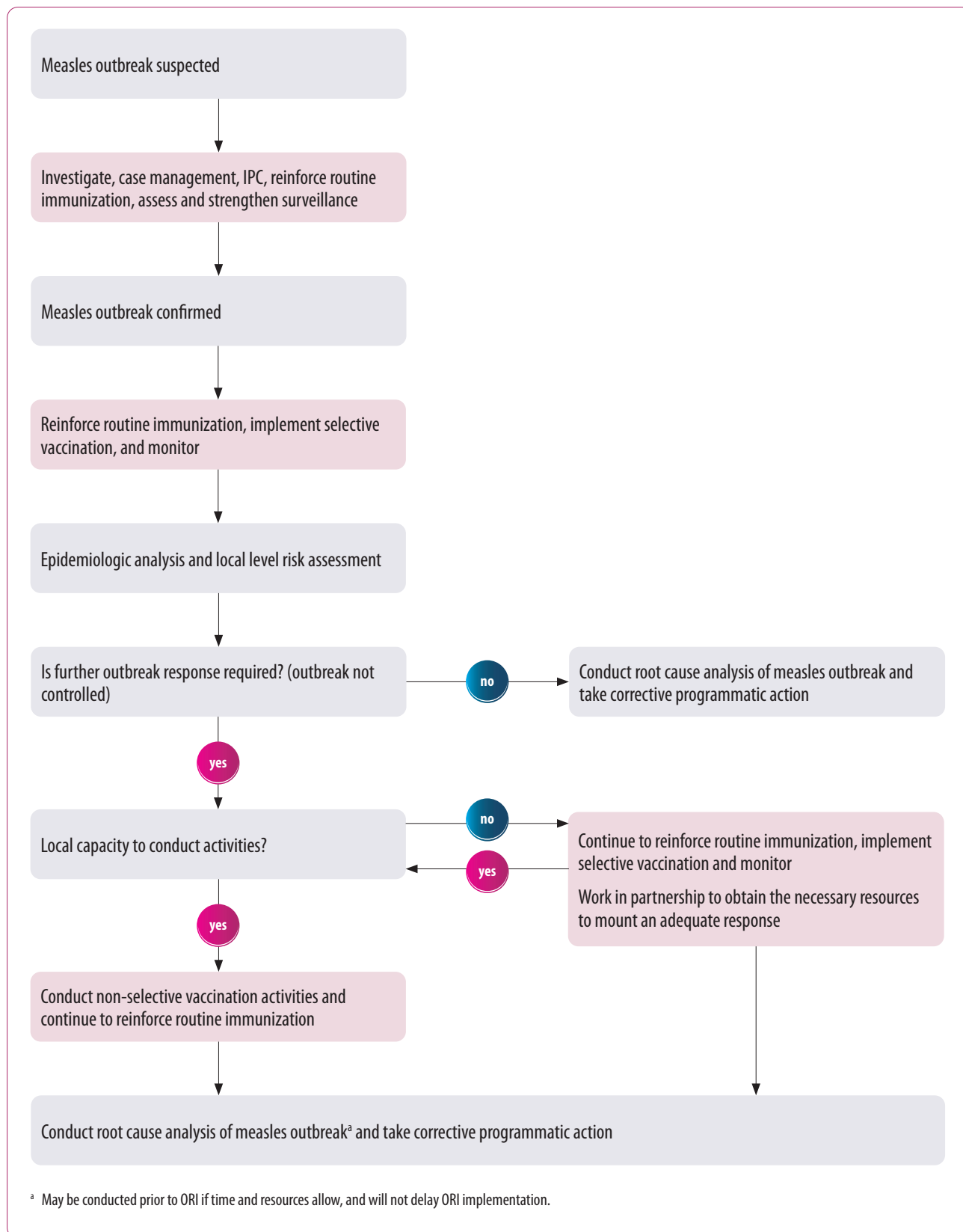
- If the result of the risk assessment indicates low or medium risk of spread of the measles outbreak, the ORI may be limited to selective vaccination of potentially susceptible children in the affected and immediately surrounding areas and reinforcement of RI activities. The situation will need to be closely monitored (number of reported cases closely followed, monitor progression of the outbreak, etc.).
- If the result of the risk assessment indicates that there is a high risk of spread of the measles outbreak to neighbouring and other areas, ORI should include a non-selective vaccination of susceptible persons in the affected and at-risk areas. If resources are insufficient, the authorities should work as quickly as possible to mobilize the material, financial and human resources needed to stop the outbreak.

Concurrent measles/rubella outbreaks

If concurrent measles and rubella outbreaks occur, some aspects of the response (i.e. type of vaccine to use) depends on if RCV is in the national schedule. If a country has introduced RCV, it should be used in measles-only outbreaks in addition to concurrent measles and rubella outbreaks. Further, laboratory testing may be required for more cases as establishing reliable epidemiologic linkage in concurrent outbreaks is difficult and creates challenges to final classification. This situation should be assessed and addressed with a specific protocol by the national public health system, considering its capacities and resources. Further, more stringent definitions of epidemiological linkage (see Section 3.2) and continued laboratory testing of cases should be considered to understand the age groups and areas affected by measles as opposed to rubella. In resource-limited settings, the first step should be collecting specimens from 5–10 cases every month to track the evolution of the outbreaks. Expanding testing is especially important after

an immunization response activity. Rubella case definitions and classifications are found in the WHO *Surveillance standards for vaccine-preventable diseases* (4). Once an initial investigation proceeds, the findings can drive the focus of the RRT to planning for how to respond to the outbreak.

Fig. 5. Basic decision tree for measles vaccination response at the local level



^a May be conducted prior to ORI if time and resources allow, and will not delay ORI implementation.

Target populations during ORI

Choosing the target population for vaccination response depends upon the susceptibility profile of the affected and at-risk population. The following data may be used to develop and tailor an appropriate and proportionate response, e.g. to determine age, risk groups to be targeted for vaccination and the strategy and scope of the response:

- epidemiologic findings from the outbreak investigation, including age-specific attack rates and absolute numbers of cases, by age and geographic area;
- routine immunization coverage and Penta1-MCV and MCV1-MCV2 dropout rates, by geographic area; and
- surveillance performance and surveillance case data, by geographic area.

Target ages and areas for ORI should be determined as quickly as possible based on a thorough review of available epidemiologic data and risk assessments. Children 6–11 months old at risk of exposure during a measles outbreak should always be included in the target population during ORI as these children are susceptible and at increased risk of severe complications and death from measles. A simplistic approach targeting persons up to and including 70% or 80% of the cumulative age distribution of cases is not recommended as it is likely to ignore important epidemiologic findings that can provide a more accurate assessment of risk and determination of appropriately targeted interventions. Using the example from **Figure 4** revealed a bimodal distribution of cases < 5 years and 19 years old. Targeting persons up to the 70th or 80th percentile of age in this outbreak would result in the unnecessary targeting of everyone < 20 years old instead of a targeted approach for children 6–59 months old and those 19 years old persons with identified risk factors.

High-risk and vulnerable groups

Health staff should pay particular attention to ensure that groups and areas with a high likelihood of not being reached (i.e. with known low coverage) and/or at high risk for measles-related complications are reached during the vaccination activities, and that any necessary supplemental measures such as the provision of vitamin A are provided. These vulnerable groups and areas may include:

- young children, particularly those under one year of age;
- malnourished and vitamin A-deficient children;
- infants and children of HIV-infected women, HIV-infected infants and children, and other immunocompromised children;
- certain ethnic and religious groups who may have poor access to immunization;
- populations with poor access to health care;
- staff at hospitals and other health facilities; and
- all children 6 months of age and older who are attending hospitals (inpatients and outpatients) or who are visiting the hospital.

Priority populations

Using information captured during case and outbreak investigations, calculating location-specific attack rates allows identification of geographic areas and subpopulation groups to be targeted first, including:

- particularly high-risk areas: paediatric inpatient units, feeding centres, facilities for children (e.g. childcare centres, schools, orphanages, etc.);
- densely populated areas (cities, slums, refugee camps, displaced population, etc.);
- areas with the highest attack rates; and
- areas with low vaccination coverage.

The response should target both outbreak-affected and adjacent or other areas to which the risk assessment shows a high risk of spread. High-risk areas include those with generally low coverage or with significant communities that are zero dose for measles, as well as those with poor quality coverage or surveillance data, remote regions and hard-to-reach communities, areas with recent large movements of people, and areas to or through which affected cases may have travelled or will travel.

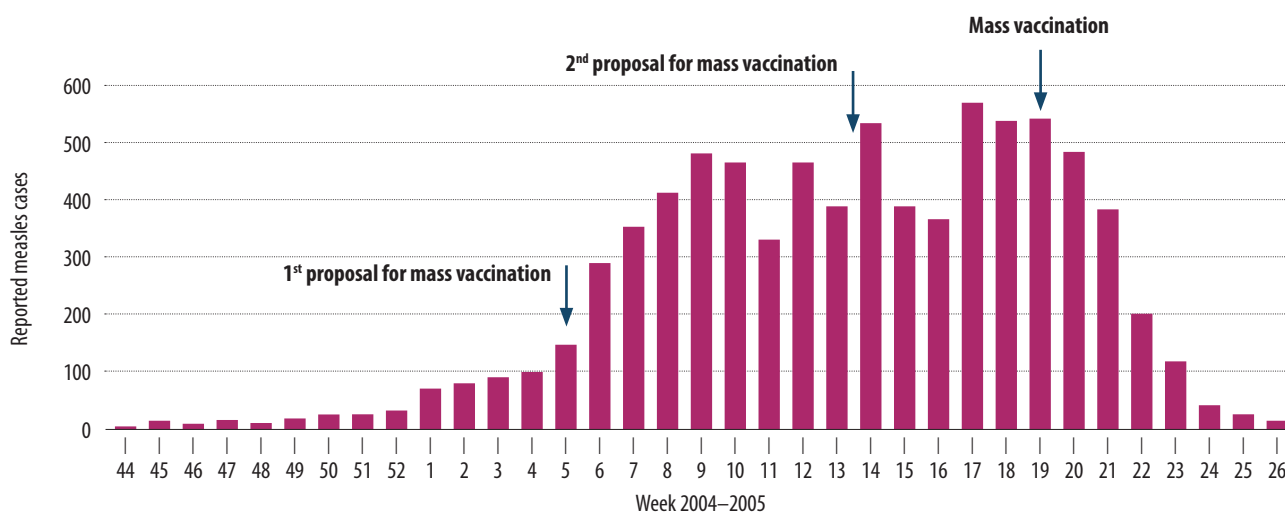
For mixed measles-rubella outbreaks, the age and geographic distribution of rubella cases should also be evaluated, with appropriate targeting of the response to reach populations at risk for both measles and rubella. In countries that have introduced RCV, a measles-rubella vaccine should be used for all measles, rubella and mixed measles-rubella ORI activities (6).

Assess if immunity gaps occur elsewhere, outside the outbreak area. Develop a plan with resources to address programmatic problems in outbreak areas. Results from the root cause analysis, if conducted prior to ORI (described below), can help inform specific strategies and tactics for ORI in addition to the information it provides to improve RI coverage. However, because time may not allow for the root cause analysis to be conducted before ORI, it may be done afterwards.

Timing of mass vaccination campaign

Once the decision to conduct large scale ORI has been made, it is critical to act as quickly as possible to minimize the number of severe measles cases and deaths and further transmission of the virus. Disease transmission during a measles outbreak is very rapid due to the number of people each case infects. The timing of the intervention plays a key role in the number of cases and deaths that may potentially be prevented. Ideally, large-scale ORI should be completed within 7–10 days of confirmation of the outbreak. **Figure 6** shows a real-life epidemic curve from a high-burden country in 2004–2005. An intervention was proposed at the beginning of the outbreak during week 5, and again midway through the outbreak during week 13, and was finally implemented beginning in week 20, about 5 months after the start of the outbreak. Had the intervention occurred earlier, a large number of measles cases and deaths would have been prevented. Even though ORI occurred late, the intervention likely shortened the duration of the outbreak, prevented measles cases and deaths, and contributed to improving population immunity to prevent future outbreaks among the target population. When delays of greater than 1 month between ORI planning and execution occur, it is important to update plans based on the evolution of the outbreak and its evolving epidemiology.

Fig. 6. The epidemic curve in a high burden country, 2004–2005



Operational issues (40)

The objective of the ORI campaign is to stop transmission of measles virus by vaccinating at least 95% of the target population. Countries should find a balance between speed, planning, training, and communications. Whenever possible, begin with densely populated zones (e.g. urban areas, refugee/IDP camps, etc.), because that allows rapid protection in the areas identified in the risk assessment where transmission is likely to be most intense and where accessibility, logistics and supervision are generally easier. The proposed vaccination hours should take into consideration the population’s activities and work schedule. The WHO field guide *Planning and implementing high-quality supplementary immunization activities for injectable vaccines* covers operational issues of mass campaigns in detail (10).

In urban and densely populated areas

Provision needs to be made to not compromise patient care in health facilities, and that, if possible, vaccination activities should be conducted in a separate area from the patient care areas of health facilities. At the end of the campaign, vaccination campaign sites should be maintained in the health facilities for at least one additional week to vaccinate latecomers.

Other approaches are combined with setting up vaccination sites:

- Temporary outreach sites:
 - in primary and secondary school settings; children could also be brought to the vaccination sites during the less busy times, especially smaller schools;
 - in other groups settings (e.g. day care centres, nursery school, orphanages, detention centres);
 - for populations living far from health centres or in remote areas; and
 - for groups that do not like to mix with others (e.g. for religious reasons).
- Mobile vaccination teams:
 - door-to-door and other alternative approaches for groups identified with low vaccination coverage.

In rural areas

The response strategy combines several approaches:

- Ad hoc reinforcement of vaccination activities for existing care facilities: mobilization of existing human, logistic and technical resources.
- Established and additional temporary outreach sites.
- Mobile teams to be sent into areas that are far away from health centres, especially in those areas with communities with impaired access to care (e.g. nomads). The team can stay several days in selected locations, serving several localities. It is important to inform the communities of concern in advance.

Achieving high vaccination coverage in rural areas requires significant logistical resources and implementing the campaign activities for longer than in urban areas. Supervision can also be quite challenging in remote areas, given geographical constraints.

Documentation of ORI doses

In principle, all doses of vaccine delivered (including through ORI and SIAs) should be documented on vaccination cards, registration books, and/or, for those countries with computerized record systems, in the patient electronic records. The supplementary doses administered during non-selective ORI are tallied but not included in the routine administrative national coverage data. These are often captured in a separate section in immunization records capturing “supplementary” doses given (41). Selective ORI, i.e. when records are reviewed and only children missing a dose are vaccinated, is considered a periodic intensification of routine immunization (PIRI) approach and the doses should be reported in the routine administrative immunization coverage (42).

Concomitant and synergistic activities

Vitamin A distribution should be a standard intervention in outbreak response campaigns. Other interventions could also be added, provided the integration does not delay the implementation of the campaign.

Vitamin A distribution

Taking the opportunity of the ORI campaign to distribute preventive vitamin A (check before if previous or planned distribution) is a key mortality reduction strategy.

Administration of other vaccinations

This might be justified if there is another epidemic occurring at the same time (especially polio and diphtheria) or in certain special situations: refugee camp, population displacement, remote areas with very low polio, pneumococcus, *Haemophilus influenzae*, or yellow fever vaccination coverage. Integration should be considered (including planning for human resources if a second injectable vaccine will be added), if conducting selective vaccination.

Examples of other concurrent activities

Deworming medicine, distribution of insecticide-impregnated mosquito nets, nutritional supplements, hand washing, etc. The WHO guide on *Working together: an integration resource guide for immunization services throughout the life course* provides further information (43).

Approaches

When deciding on the needs, target groups and the most appropriate strategies for ORI, it is important to take into account the epidemiologic analyses, results of the assessment of risk of a large-scale outbreak, financial and human resources, vaccine and logistics supply availability, regulatory framework and the attitude towards immunization among potential target groups and health staff. The potential impact of the intervention will be greater if implemented early in the course of the outbreak and in settings with a substantial number of susceptible people, where the risk of widespread transmission is higher.

Analysis of reported suspected cases only for the purposes of making decisions on who and where to vaccinate should not be used routinely for decision-making, as this analysis would include cases that have been discarded as non-measles as well as other non-measles cases classified as measles. Countries with large numbers of measles cases reported through aggregate systems (e.g. integrated disease surveillance and response) may need to triangulate data from that system with analyses of case-based data and results of immunity profiles.

In some settings with high population immunity and strong surveillance, a response strategy relying on targeted activities for health workers and susceptible contacts of cases may be considered. However, the availability of adequate capacity for implementing effective testing of cases and tracing and follow up of all case contacts is critical for this approach to be successful. In most settings, it will be necessary to expand ORI strategies beyond only vaccinating susceptible health workers and case contacts. These ORI strategies can include selective and/or non-selective immunization of the most affected and/or at-risk populations.

Analysing context

Planning a response requires a rapid and complete analysis of the context. Gathering comprehensive knowledge of the national situation and the situation in the affected area(s) is critical. Important contextual aspects to understand are government and private sector resources, local structures and legislated responsibilities, available partner support, potential security issues (e.g. disruption of civil society war, civil unrest), the administrative boundaries of the area of concern (maps with location of towns and villages, means of transportation, etc.), access to and utilization of health services (including but not limited to past vaccination coverage and surveillance quality in the affected and neighbouring areas). During this phase it is also crucial to gather demographic and other data, including:

- number of people living in the affected areas;
- means of transportation (buses, boats, planes, etc.) for outbreak response activities;
- information on population density, mobility and specific lifestyles, type of employment;
- sociocultural characteristics of the local communities: ethnic, religious, or linguistic minorities, immigrant communities, and nomadic groups, international borders; and
- vulnerability: poor urban areas, populations with weak access to health services, refugees and IDPs, local HIV prevalence and nutritional status.

Implementing outbreak response requires organizing different components of the response at the relevant affected levels within a country. Staff need to be available for measles surveillance, case management, logistics, resource mobilization and communication. Medical supplies and materials need to be procured. Further, local capacity is necessary to organize targeted immunization activities or a mass immunization campaign (size of target population and geographic distribution, logistics, transportation, cold chain, success of recent vaccination campaigns). Capacity is also needed to conduct monitoring and evaluation activities. Local commitment should be assessed and key influencers (e.g. trusted leaders in faith-based organizations) identified. Rumours and views related to measles and immunization, and any other active disease outbreaks or health activities among the population should be identified and understood in order to inform communication and outreach efforts.

5.2.2 Reinforcement of routine immunization activities

Immunization is an essential health service that should continue without interruption to the maximum extent possible under all circumstances. Timely and complete vaccination is key to ensure individual- and population-level immunity to measles and other VPDs.

Surveillance that identifies areas of low coverage (0 dose among fever/rash cases, 0–2 doses among non-polio AFP cases) or, failing that, a measles outbreak, provides the opportunity to identify weaknesses in the immunization system which might contribute to an outbreak and a chance to correct them. During a measles outbreak, the following activities should be implemented in the affected and at-risk areas:

- Use administrative and other coverage data to identify chronically missed areas or groups to be targeted in health facility microplans and district annual plans. This can be complemented with surveillance data for measles/rubella and AFP, which includes vaccination status of suspect cases and may show pockets of zero-dose children.
- In low routine coverage areas, PIRI can be conducted that targets areas or high-risk groups.
- During outbreak investigation, identify potential reasons for non-vaccination and incomplete vaccination (see Section 4.2). **Annex 3** is a two-page health facility questionnaire on immunization services and **Annex 6** is a community-based survey of five children to evaluate client attitudes on RI services. Note that these questionnaires are different than the more comprehensive root cause analysis instruments that focus on the root causes of the measles outbreak.
- Given the urgency of outbreak response, vaccines stocks from the RI programme are often used for ORI. Assure planning for replacement of these stocks to avoid interruption of services.
- Risk communication and community engagement – assure that all messaging in relation to the outbreak and ORI include the importance of RI and support increasing immunization coverage, especially in low-coverage areas or among hard-to-reach populations.
- AEFI surveillance should be reinforced as much as possible, including reminders to all providers to report all AEFI, training and resources to investigate serious AEFI, training and resources to an independent AEFI committee for causality assessment and preparation of draft risk communication messages/designation of spokespersons for all possible scenarios.
- Updating and reinforcement of waste management policies.
- Intensified immunization activities may be considered to identify un/undervaccinated children. These activities may disrupt the ORI or require additional staff for screening and record-keeping. Examples of less burdensome approaches may include the following:
 - If conducting a selective campaign for those missing MCV doses, staff for screening are already planned and budgeted. These staff can take the entire vaccination history and refer children for missing doses to the nearest health facility.
 - In non-selective campaigns, screeners can ask if the child is unimmunized (or “measles zero dose”) and keep count of these zero-dose children by age group and locality of residence. Any locality with a large number of zero-dose children would be visited for follow up post campaign to: 1) verify the status; 2) investigate barriers to vaccination; and 3) plan for improving vaccination in the area.

5.2.3 Implementation of selective vaccination activities

Selective vaccination of likely susceptible people involves the assessment of potential immunity of individuals from the target group based on vaccination history and providing vaccination to people deemed likely susceptible to measles (i.e. without a proof of receipt of two valid, age-appropriate doses of MCV, or history of disease). This strategy could be the first step to address immunity gaps while investigating the outbreak and planning ORI. Selective immunization can be the sole vaccination strategy used for outbreak control purposes when the outbreak is of limited geographic scope or within population subgroups and expansion appears unlikely, as indicated by the risk assessment. Availability of easily accessible and reliable individual written record of vaccination and medical history is essential for successful implementation of selective immunization. This approach is not recommended for situations of transmission over large geographic areas or large populations, as conducting assessment of susceptibility on an individual basis is time consuming and very costly.

The following steps should be taken:

- Enhance social mobilization and communication activities to inform the affected communities about the suspected measles outbreak, which specific age group of previously unvaccinated children is targeted for measles vaccination, where caregivers should bring their at-risk children for vaccination, to bring documentation along and to address barriers to vaccination previously identified.
- Vaccinate children 6–59 months of age (or determine the target age group according to the local disease epidemiology) presenting to a health facility or an outreach vaccination site without a completed medical history, including measles vaccination. Screening and catch-up vaccination should be conducted at places where immunization services are routinely provided, including fixed, outreach and mobile vaccination sites. As part of outbreak response, screening and catch-up vaccination may also be done at additional sites (i.e. hospitals, nutrition centres, schools, childcare centres). If time does not allow for the root cause analysis to be conducted before the response, it may also be done afterwards.
- Since immunogenicity of the measles vaccination is less in younger age groups, any dose received prior to the first scheduled routine dose (e.g. at 6 months of age), is not counted towards the completion of the primary series of vaccination. Children receiving an ORI dose before the scheduled age should be referred for their first routine dose at the appropriate age and after a minimum interval of 4 weeks.
- It should be noted that the recommendation to vaccinate children 6–59 months may not comply with the national catch-up vaccination policy. If that is the case, the outbreak would be an opportunity to advocate to align the national policy with WHO recommendations, i.e. no upper age limit on measles vaccination.
- In countries with a second routine dose of MCV in the national immunization schedule, ensure all children have received two doses of MCV. Countries with no MCV2 in the national immunization schedule should permit this second dose through SIAs and consider aligning their routine schedule with the Strategic Advisory Group of Experts' recommendations for two routine doses.
- Ensure sufficient supplies of material resources. Use stock management records to determine currently available quantity and location of MCV and vitamin A, as well as auto-disable syringes and other vaccination supplies (e.g. cold chain equipment, recording and reporting tools). Estimate and request the additional supplies so that activities are not interrupted due to stockouts.
- Monitoring the success of a selective campaign in the absence of a complete vaccination registry may prove difficult. It is usually unclear how many people should be vaccinated and then how many were reached.
 - Rapid convenience monitoring or lot quality assurance sampling can be conducted to get a rapid idea of the performance of the campaign. Nevertheless, those types of assessments cannot provide an estimate of coverage.

- If estimating vaccination coverage is desired, a vaccination coverage survey can be conducted. Such a survey will allow determining coverage before and after the selective campaign and explore what percentage of children who needed a vaccine dose were reached, as well as qualitative factors related to the campaign. Accurate ascertainment of vaccination status will depend on the availability of home and or/health facility records (44).
- Standard questions to assess behavioural drivers of vaccination that can be added to any survey or rapid assessment (45). Such questions can be adapted to the local context using cognitive testing as described in the tools.

5.2.4 Implementation of non-selective mass vaccination campaigns

Non-selective immunization implies providing an additional dose of the vaccine to all individuals in the target group regardless of their previous immunization or disease history. This approach allows immunization of people without the need for reviewing individual immunization records and verifying disease history. For outbreak response purposes, non-selective vaccination is indicated in the case of outbreaks among populations with inadequate levels of population immunity and have been shown to reduce outbreak duration and extent. For non-selective mass vaccination campaigns, the timing, target age group and area for vaccination should be determined as outlined above. An accelerated microplanning exercise should be performed to determine the bundled vaccine, logistics, staffing and communications needs for campaigns (10).

5.3 Coordination

OBJECTIVE

Coordinate the outbreak risk assessment, planning, implementation and evaluation of measles outbreak response and recovery.

Coordination committees

To enhance the capacity to respond to measles outbreaks, a district-level outbreak coordination committee (OCC) or any equivalent subnational-level multidisciplinary group should be created prior to the occurrence of outbreaks. The OCC roles are provided in **Annex 2**. The OCC of the lowest level health authority (e.g. district) should be responsible for coordinating the initial response to measles outbreaks. Multijurisdictional outbreaks (e.g. multiple districts) should be managed by OCCs at higher levels (e.g. province or national) with triggers for higher level coordination and vaccine use for outbreak response agreed at all levels prior to an outbreak. The outbreak response coordination system should enable cohesive operations at all relevant levels involved in the response. Local level RRTs operate under the coordination of the local level OCC.

5.4 Determine the risk of spread

OBJECTIVE

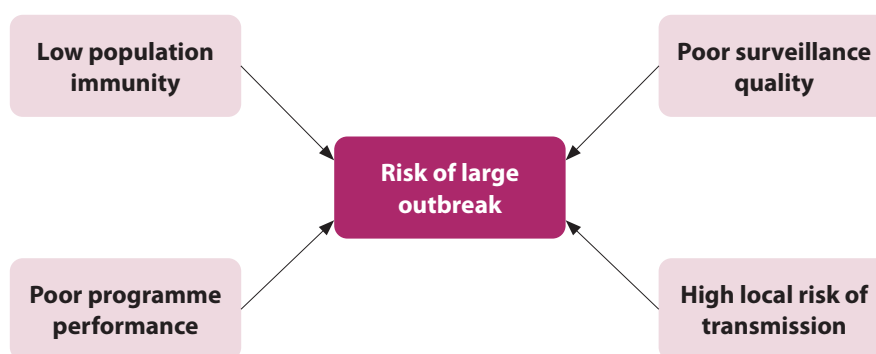
Determine the risk of a large outbreak with high morbidity and mortality, as well as the risk of further transmission and potential for geographic spread both in the affected and neighbouring areas.

WHO developed the Measles Programmatic Risk Assessment Tool (**Annex 5**) to help national programmes identify areas not meeting measles programmatic targets, and based on the findings, guide and strengthen measles elimination programme activities and reduce the risk of outbreaks (46). Although this tool is intended for large areas (e.g. districts), not individual communities, subdistricts or districts that have populations below 100 000, it may be useful for large outbreaks and planned subnational SIAs. For small

outbreaks, a simpler assessment of adjacent areas of potential spread can be made based on routine and prior SIA vaccination coverage, population immunity, a non-quantitative assessment of surveillance quality, and other local factors, like groups known to be reluctant to vaccinate their children.

This risk assessment should help define the scale of response that is needed to prevent further spread of the outbreak. As illustrated in **Figure 7**, the risk of a large outbreak depends on several factors, including population immunity, surveillance quality, programme performance, and the local risk of transmission.

Fig. 7. Measles outbreak: risk assessment



5.5 Intensification of surveillance

OBJECTIVE

Increase the performance of measles surveillance during the outbreak.

5.5.1 Approaches to measles case-based surveillance during outbreaks

High-quality case-based surveillance data are extremely important to guide the outbreak response activities, better inform the root cause analysis and enable using measles as a tracer for identifying areas where immunization service delivery requires strengthening. In all settings, close coordination between the laboratory, surveillance and Expanded Programme on Immunization (EPI) staff at national, regional, district and local levels is essential once the outbreak is confirmed. Preparedness plans should be implemented that include a surge capacity for the laboratory and surveillance system.

Enhanced passive surveillance

- The number of reporting units and frequency of reporting of cases may need to be increased. Weekly zero reporting of cases from health facilities to district and from districts to higher levels, meaning the reporting of zero cases when no suspected cases have been identified, should be ensured at a minimum, regardless of the frequency of reporting prior to the outbreak. The performance (e.g. completeness, timeliness, accuracy etc.) of these systems should be reviewed and strengthened. Daily reporting is the gold standard during outbreaks. Weekly zero reporting systems should continue for the duration of the outbreak and for at least 46 days (i.e. two maximum incubation periods) after the onset of the last laboratory-confirmed or epidemiologically linked case. Any suspected case should be reported immediately. If completion of CIFs for all suspected cases during an outbreak is not feasible due to a large number of cases, essential case-based data should still be collected on a line-listing form as part of the outbreak investigation and entered into a database for regular analysis as soon as possible. If measles was acquired in another district, province, state or country, the place of infection (if determined) should be recorded in notifiable diseases databases in accordance with jurisdictional protocols, IHR mechanisms and data systems.

- In some settings community health workers (CHWs), volunteer and polio networks and others may provide support.
- In addition to increasing the number of reporting units and frequency, it is important to increase awareness of local measles transmission among the population. Commonly, all doctors (public and private), health facilities, emergency departments, as well as networks like the polio networks and CHWs should receive official communication from the public health authorities. This is to alert them to the outbreak and the possibility of further cases, encourage them to immediately notify suspected cases, remind them of adequate case management activities, including isolation and IPC precautions and to collect appropriate specimens. Weekly zero-reporting is frequently implemented. Similar messages should be shared with laboratories, to increase their awareness of the current epidemiologic situation and the possible increase in laboratory workload.
- At schools, day care centres and religious institutions, as well as in the community, identify key informants (e.g. school principals, teachers, pastors/imams, village leaders) and establish a passive and/or active reporting system for fever and rash or suspected measles. This activity can be aided by using pictures of a measles case. If adolescents and adults are affected by the outbreak, enhanced surveillance may be expanded to include affected universities, the military or workplaces.
- Supplies and equipment (including sample collection equipment, laboratory request forms) must be available to trained staff to enable laboratory testing of specimens collected from the suspected cases of measles.

Active surveillance

- It is good practice to establish regular contact (e.g. daily or weekly) with hospitals, doctors' offices, clinics, schools and laboratories to obtain reports of persons with febrile rash illness or other symptoms indicative of measles. Active surveillance at hospitals and health facilities (public and private) should include review of inpatient and outpatient logbooks for diagnoses and consultation with health staff to identify all suspected cases of measles. If using the WHO suspected measles case definition, then public health authorities request reporting of all patients with fever and maculopapular (non-vesicular) rash; however, clinicians may form a differential diagnosis which includes suspected measles based on their experience, clinical suspicion and the epidemiological context. This is because public health wants to detect every possible case and uses a sensitive case definition, while clinicians frequently are formulating a differential diagnosis based on specific clinical criteria.
- Active case searching in communities can also be conducted during a community outbreak by going house to house and asking about symptoms and performing testing. Public health information about measles signs, symptoms and management, the risk-benefit of prevention measures, including vaccination, and what to do in the event of illness compatible with measles should be provided. Informal information on vaccine confidence can be captured during household visits.

5.5.2 Focus on the response when outbreaks become too large

- When outbreaks become too large to maintain normal case investigation protocols, contact tracing should be deprioritized in favour of large public health responses.
- Case investigations should move to collecting the minimum number of data elements (unique identifier, name, residence, age, clinical symptoms, date of rash onset, date of specimen collection if done, vaccination status, travel history) and if paper forms are used then moving to line listing of cases.
- An additional five to ten samples for case confirmation should be collected every 2 months to ensure the outbreak is still measles, and samples should be collected for genotyping as well.
- Intensified passive and active surveillance should be established in neighbouring villages, districts, and provinces still not affected by the outbreak.

5.6 Clinical case management

OBJECTIVE

To reduce measles morbidity and mortality through early adequate clinical management.

During an outbreak, early and adequate treatment and clinical case management of suspected measles patients is essential to reduce measles morbidity and mortality. Case management measures should not be delayed while waiting for laboratory confirmation of measles. Once an outbreak is confirmed, ensuring adequate supplies for case management, including vitamin A supplementation and IPC equipment is critical. The WHO *Guide for clinical case management and infection prevention and control during a measles outbreak* provides further information (3).

5.6.1 Immediate administration of vitamin A

Children

Vitamin A should be administered to all acute measles patients under 5 years of age, irrespective of the timing of previous doses of vitamin A. Most patients with measles, even in high-income countries, have laboratory or clinical evidence of vitamin A deficiency. Reduced blood levels of vitamin A may be partially due to the acute phase response that occurs during infection (47). However, low blood levels of vitamin A are associated with more severe measles illness and complications, especially ophthalmologic disease. Two doses of vitamin A are recommended for all suspected measles cases in children under 5 years of age, immediately on diagnosis and repeated the next day, according to the dosing indicated in **Table 3**. This treatment has been shown to reduce overall mortality in children and pneumonia-specific mortality in children with measles under 2 years of age (48). If a patient has any clinical signs of vitamin A deficiency, such as xerophthalmia, including Bitot's spots and corneal ulceration, then a third same age-specific dose should be given 4–6 weeks later. Every effort should be made to ensure all health facilities have adequate supplies of vitamin A and that HCWs have guidance on this mortality reduction strategy.

Table 3. Vitamin A dose recommendations

Age	Vitamin A dose
Infants aged < 6 months	50 000 IU
Infants aged 6–11 months	100 000 IU
Children aged 12–59 months	200 000 IU

Adults

Based on evidence in children and the theory surrounding the benefits of vitamin A supplementation, it is possible that it may be of value in adults with measles, particularly in specific populations in which patients may have vitamin A deficiency. Women of reproductive age in whom vitamin A deficiency is suspected should only be treated with lower, but more frequent, doses of vitamin A (e.g. daily oral dose of 5000–10 000 IU vitamin A for at least 4 weeks) due to concerns about its teratogenic effects.

5.6.2 Preventing and managing complications

Approximately one third of patients with measles have at least one immediate or delayed complication. Because measles alters epithelial barriers, attentive care of eyes, mouth and skin is necessary to prevent secondary infections. Ensuring adequate nutrition is essential. Severe manifestations or complications of measles should be managed using the same standards used in non-measles patients. When available, use local or national patient care guidelines, including antibiotic guidelines.

Administering prophylactic antibiotics is not recommended in adults and children with measles. However, early empiric antibiotics should be considered for suspected secondary bacterial infections. See the WHO *Guide for clinical case management and infection prevention and control during a measles outbreak* for more detailed information on clinical case management during a measles outbreak, including early supportive care for severe illness, severe pneumonia and respiratory distress syndrome, sepsis and shock, croup and upper airway obstruction, and antivirals (3).

5.7 Infection prevention and control

OBJECTIVE

To prevent health worker infections, reduce transmission in health care settings, and reduce the risk of spread to vulnerable populations.

Note: This section relates to IPC in health care settings; however, isolation, quarantine and other IPC measures are also required in the community.

Early infection prevention and control: apply standard and airborne precautions

The implementation of IPC measures is important to prevent health worker infections, reduce transmission in health care settings, and reduce the risk of spread to vulnerable populations. IPC measures (including hospital isolation of stable cases) should not be delayed while waiting for laboratory confirmation of measles.

Update existing IPC guidelines

Hospitals and public health authorities should review IPC guidelines and update them as necessary with specific IPC measures and airborne precautions for measles.

Health worker immunization

Ensure that all health workers (anyone in contact with patients, e.g. receptionists, cleaners, outbreak investigation teams etc.) have evidence of measles immunity, which may include written documentation of two doses of MCV, laboratory evidence of immunity or previous disease (e.g. measles IgG positive in serum); equivocal test results are considered negative.

Health worker training

Provide all HCWs with job-specific training on basic concepts of measles transmission and clinical case management, including early recognition of suspected cases and IPC measures on prevention of measles transmission. Ensure HCWs are educated on and can demonstrate use of PPE appropriately, according to risk evaluation, prior to caring for measles cases. Train all HCWs after receiving medical clearance on the use of tight-fitting respirators (N95 or equivalent), which must be fit tested.

Administrative controls

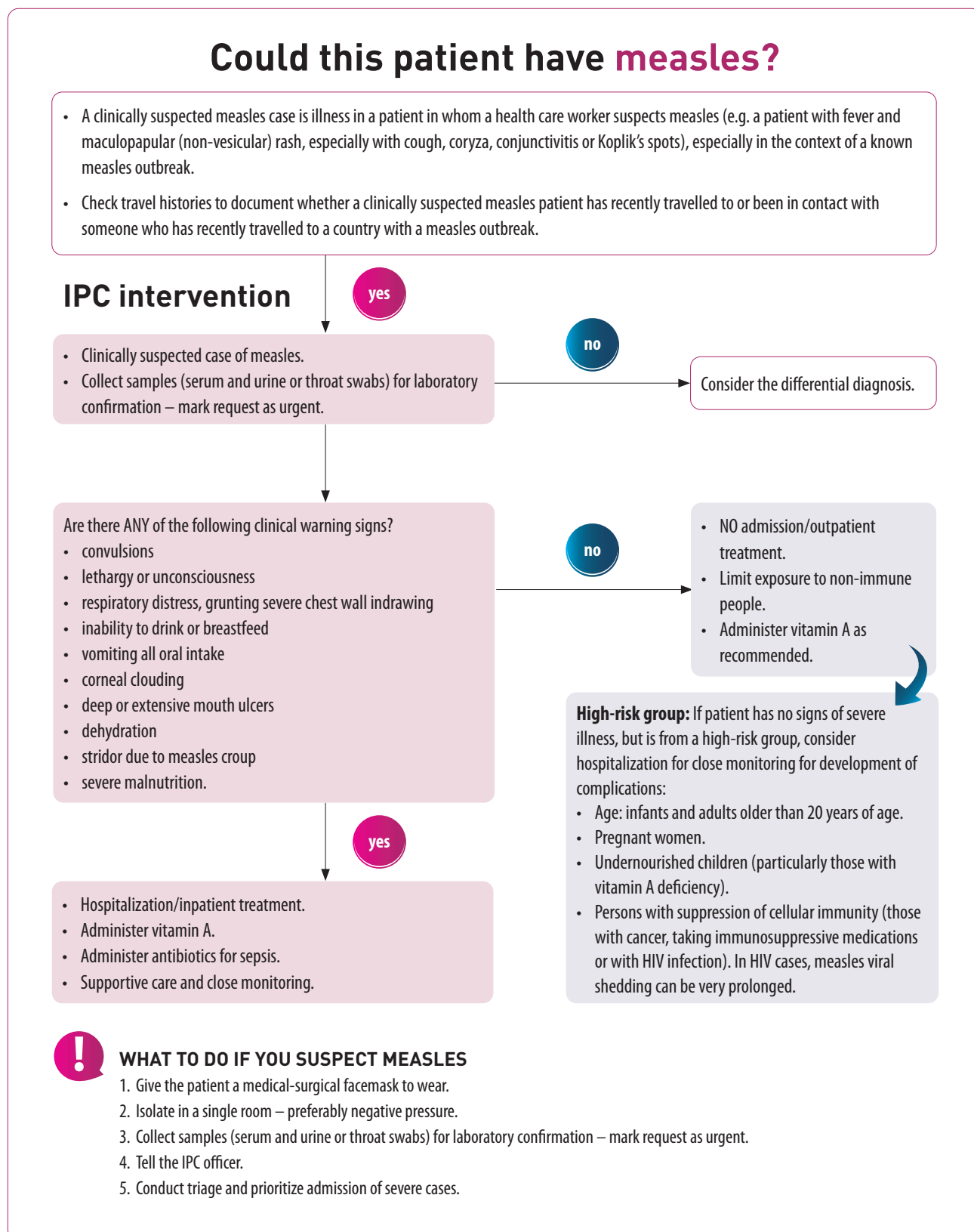
Place visual aids (signs, posters) about respiratory etiquette (cover nose and mouth when coughing/sneezing with tissue or medical-surgical facemask, dispose of used tissues and masks, and perform hand hygiene after contact with respiratory secretions) and medical-surgical masks at the facility entrance and in common areas (e.g. waiting rooms). Provide supplies to perform hand hygiene and make available to all persons in the facility. Ensure SOPs for IPC in hospitals and health settings are available. Perform routine audits and feedback on isolation practices to ensure HCWs are performing them correctly. Develop plans for safely receiving measles cases, either sporadic or in outbreaks. Where possible, facilities may plan for providing dedicated entrances, examination rooms and exits for suspected cases, or even separate dedicated buildings. Further, scheduling visits at the end of the day or after hours can be helpful.

Ensure early recognition, notification and immediate isolation

It is important that suspected measles cases do not enter waiting rooms or places with other patients, and that triage should occur outside outpatient waiting areas. Where possible, while scheduling appointments for suspected measles cases by phone, provide instructions for arrival, including which entrance/facility to use and what precautions to take (e.g. how to notify hospital staff, don a medical-surgical facemask

upon entry, follow triage procedures, see **Figure 8**). It is important to check travel histories to establish whether patients with suspected measles have recently travelled to or been in contact with someone who has recently travelled to a country where measles transmission is occurring. In low-resource setting, the health centre staff should immediately notify the next administration level up, for example, district or

Fig. 8. Early recognition/triage of patients with suspected measles or severe illness



province, using the quickest available means of communication in accordance with local procedures. The notification form should include available information on name, age, sex, clinical symptoms, date of rash onset, date of specimen collection, vaccination status, travel history and residence. If cases are reported along border areas, health officials in the adjoining areas should be notified and efforts should be made to share information. The receiving facility should be notified in advance when transporting suspected cases. Use dedicated triage stations; suspected cases should don a facemask and be immediately isolated upon identification. In areas where isolation rooms are not available, a separate area or structure for suspected measles patients should be used. Isolation should continue until the case is discharged, or for 4 days after rash onset, whichever is first. Efforts should be made to discharge the patient as soon as medically possible.

Distribution of resources should occur according to priority. Prioritize the hospitalization and airborne precautions of patients with clinical warning signs. Non-severe measles cases should receive outpatient treatment and be isolated at home, although in some settings where isolation areas are available, the patients can be under observation for 24 hours. Limit exposure to non-immune people. Ensure that patients with confirmed or suspected measles do not remain in outpatient departments and other areas where they may infect vulnerable individuals (infants, immune-compromised etc.). Provide patients with confirmed or suspected measles with a medical-surgical facemask and separate these individuals from non-measles patients prior to or as soon as possible upon entering a health care facility. Limit transport of patients with suspected and confirmed measles to essential reasons only, and if movement is unavoidable then use all necessary precautions (medical-surgical facemask on patient).

Isolation and cohorting practices

Immediately place patients with known or suspected measles in a separate area until examined or in an airborne infection isolation room, where available. Patients with suspected measles and clinical warning signs should be managed in a facility with isolation capacity – a single room is preferred. If this is not possible, then cohort patients in confined areas, separating suspected and confirmed cases. Keep the isolation area segregated from other patient care areas. Consult infection control staff before patient placement to determine the safety of alternative rooms (or locations) that do not meet engineering requirements for isolating patients with airborne diseases. Create a negative pressure environment in the converted area of the facility to create ad hoc patient isolation rooms (fans, open windows for external ventilation). Where resources allow, discharge air directly to the outside, away from people and air intakes, or direct all air through high-efficiency particulate air (HEPA) filters before it is introduced to other air spaces. Immune-compromised persons with measles infection should remain in airborne precautions for the duration of the illness due to the potential for prolonged virus shedding. Manage visitor access and movement within the facility. Ensure that only persons (health workers, family, visitors) with presumptive evidence of measles immunity enter the room of a suspected or confirmed measles patient or have contact with these patients in other areas of the facility.

Environmental cleaning and waste management

Use standard cleaning and disinfection procedures as these are adequate for measles virus environmental control in all health care settings. Standard precautions are recommended for dealing with PPE and medical waste items from measles patients.

5.8 Contact tracing and management

OBJECTIVE

To identify potential measles contacts, to identify the source of the outbreak, and to target those at particular risk of disease for intervention.

Contact tracing

In elimination settings, two major goals of the investigation are to find the source who might have infected the initial case under investigation (i.e. the index case), and to quickly find those whom the index case and subsequent cases may have infected to enable timely prevention of further transmission. Source identification is done through contact tracing, identifying the index case, and their travel status. Where no source of infection can be found from the index case, molecular epidemiology may become more useful. A separate line list can be prepared for contacts.

5.8.1 Managing contacts

There are two types of contacts: 1) source contacts that may have infected the case (7–21 days before rash onset in the case); and 2) infected contacts that the case may have infected 4 days before to 4 days after their rash onset.

A contact is anyone who has or may have shared the same airspace (e.g. enclosed area like a doctor's waiting room, restaurant, classroom, office, dwelling, or other enclosed areas) for any length of time with a laboratory-confirmed, epidemiologically linked or clinically compatible case where a high index of suspicion of measles exists while the case was infectious (4 days before and 4 days after rash onset). A high index of suspicion may include known exposure events (e.g. history of travel to a location where measles transmission is occurring), being unvaccinated, and pathognomonic signs of measles.

For contacts that may have infected cases, a contact is anyone with fever and rash who may have had contact with the respective case 7 to 21 days before rash onset in the case. It should be documented if the case has a travel history to areas where measles virus is circulating.

Contact management options are determined based on resources and may not be applicable in all settings. In well-resourced settings and those near elimination, identifying contacts of measles cases is required to determine who has been exposed to an infectious case, to assess their susceptibility to infection and to provide advice and implement post-exposure prophylaxis (PEP), where appropriate. Contacts are considered susceptible to measles if they cannot provide evidence of immunity to measles.

Post-exposure prophylaxis (PEP)

In all settings, consideration should be given to providing susceptible contacts with PEP, including a dose of MCV (see WHO *Guide for clinical case management and infection prevention and control during a measles outbreak* (3)) or normal human immunoglobulin (NHIG) (if available) for those at risk and in whom the vaccine is contraindicated. Given it may not be feasible for authorities to identify all susceptible contacts and arrange time-bound PEP, contacts may need to be prioritized based on risk (e.g. exposures in a cancer clinic versus among healthy adults). Households (shared living), schools and educational settings, health settings such as emergency departments, and workplaces should all be considered for contact tracing and PEP.

Immunization of potentially infected contacts can limit or even prevent the disease from that exposure (83–100% effectiveness for MCV within 72 hours, 69–100% for NHIG within 7 days (49,50)), but every susceptible contact should be vaccinated irrespective of the timing of their exposure. Contacts who have already developed measles do not need to be vaccinated. Measles vaccination should be delayed for 5–8 months after receiving NHIG, depending on the dose and route of administration.

In well-resourced settings, MCV should be provided to susceptible contacts within 3 days. For contacts for whom vaccination is contraindicated or is not possible within 3 days post-exposure, consideration can be given to providing NHIG up to 6 days post-exposure. Infants, pregnant women, and the immunocompromised should be prioritized.

Inform susceptible contacts (or their caregivers) of the risk of infection and advise them to watch for signs or symptoms beginning 7 to 21 days after the last contact with an infectious case. People who receive vaccine and NHIG should be advised that they may still develop measles infection, however, signs, symptoms and time course of illness may be atypical. If not quarantining, contacts should avoid mixing with young children (under 12 months of age or unvaccinated), hospitals, pregnant women and immunocompromised people during this period.

Quarantine and restriction

Quarantine separates and restricts the movement of people who were exposed to measles to see if they become sick. These people may have been exposed to measles and may unwittingly infect others. Quarantine and restrictions vary based on a person's susceptibility to measles as well as receipt and timing of PEP. Susceptible individuals in contact with a measles case during the infectious period should be placed under self-quarantine for up to 21 days after their last exposure to the case. Countries may make pragmatic risk-benefit decisions on the duration of quarantine in the context of timely PEP receipt.

If a confirmed case (staff or student) attends an educational institution, then advise susceptible contacts (or parents/guardians) of the risk of infection and counsel them to watch for signs or symptoms beginning 7–21 days after the first contact with an infectious case regardless of receipt of PEP (or 28 days if the contact receives NHIG as it can prolong the incubation period).

Susceptible contacts (staff and students) may return immediately if vaccinated with MCV within 3 days (72 hours) of first exposure to an infectious case or if they receive NHIG within 6 days (144 hours) following exposure. Such decisions should be made following an assessment of the intensity of exposure, and whether the contact would subsequently expose vulnerable groups. If a child or staff member receives MCV more than 72 hours after exposure and hence requires exclusion, they may return to the facility if they remain well and more than 21 days have elapsed since their last contact with a case and they should receive a second dose. If not under quarantine, they should avoid contact with young children (under 12 months or unvaccinated), hospitals, pregnant women and immunocompromised people during this period. Advise that if symptoms consistent with measles develop, they should self-isolate and telephone the health authorities, and that if they need medical attention then they should arrange for a home visit or call ahead before visiting doctors' rooms, hospital emergency departments or pathology services so as to avoid mixing with other people in waiting rooms. Information should be provided to individuals in their own language where available.

Exceptions may be necessary and should be considered in relation to the risk of infecting others, should the contact develop measles. For instance, return to work may be possible for susceptible contacts in settings with no vulnerable people to expose in the event the contact in fact becomes infectious. Consider making a daily phone call to monitor compliance with quarantine and encourage contacts to request a clinical assessment if their condition changes and is clinically indicated.

Note: The maximum incubation period for measles of 21 days can be used to determine exclusion periods; however, again pragmatic decisions often guide national policies, following a risk-benefit assessment. For example, 21 days is used in the United States of America, while some other countries use 18 days. In a facility with numerous people the exposure opportunities for each individual may be difficult to identify. Pragmatic decisions are required. Immunocompromised children or staff are excluded (regardless of their measles vaccination status) until 14 days after the onset of the rash in the last case occurring at the facility. Exclusion is advised for their own safety, even if they receive NHIG.

5.9 Managing measles exposures in health settings

Health workers

The criteria for health workers to return to work are stricter than in educational settings because of the high risk of health care acquired infections for vulnerable populations. Work with public health authorities to evaluate exposed health workers, patients and visitors for presumptive evidence of measles immunity and take necessary actions including administration of PEP. For health workers with presumptive evidence of immunity, PEP and work restrictions are not necessary. However, the health workers should be monitored for 21 days after the last exposure. For health workers without presumptive evidence of immunity, PEP should be administered and they should be excluded from work from the 5th day after the first exposure until the 21st day after the last exposure (regardless of receipt of PEP). Health workers with known or suspected measles should be excluded from work from the time of prodromal symptoms until 4 days after the rash onset (with rash onset considered as Day 0), or for the duration of illness if immune-compromised because of prolonged shedding.

Patient contacts

Patients exposed to measles without presumptive evidence of measles immunity should be placed under airborne precautions for 21 days after the last exposure, or until discharge, and should be administered PEP. The hospital should inform the public health authorities when discharging exposed patients within their possible incubation period. Actively screen all children coming to hospitals/health centres for curative or preventive services to verify they have received two doses of MCV. Ask if they have received vitamin A in the last 6 months. Provide any missed measles vaccination as early as possible, as well as supplemental doses of vitamin A.

5.10 Special considerations

Schools

Vaccination check at school, including against measles, should be strengthened in affected and at-risk areas during measles outbreaks or instituted if not in place. Vaccination should be provided to children who have not received the number of vaccine doses recommended for their age. When there are cases or an outbreak, quarantine and exclusion of inadequately vaccinated/susceptible individuals may be considered until the outbreak is over or until children are considered immune against measles (i.e. 3 weeks after immunization).

In schools where recent measles cases attended while infectious, parents and staff should be provided with information about the disease and its prevention. Written information such as a fact sheet is recommended, but an information meeting for parents, caregivers and school staff with the opportunity to ask questions of trusted sources of health information may also be useful. Consider holding an immunization clinic at the educational facility to help identify and provide missed vaccine doses to children. Vaccination of all susceptible contacts of measles cases aged ≥ 6 months is recommended, even if it may be too late for the

vaccine to be protective in relation to the exposure. Susceptible contact students and staff should not be allowed to enter the school until the outbreak is over or they can document immunity (i.e. 3 weeks after vaccination).

Monitor for occurrence of further cases at the school for two incubation periods after the last attendance by an infectious case. All suspected cases should be investigated, and measures taken to minimize or eliminate secondary transmission from these cases.

Transport

For measles exposures on flights, public health follow up is necessary to ensure timely provision of PEP but requires consideration of risk and the cost-benefit of intervention. Individual-level contact tracing of airline passenger contacts is resource intensive. In some settings where the probability of secondary cases is low, less intensive strategies have been adopted (51). In other settings, intensive contact tracing is still performed. Less intensive strategies might be relevant if there are delays in diagnosis and notification of the index case, and/or delays in access to passenger manifests meaning the time for PEP administration is too limited. Timely access to flight manifests helps determine contact information for people seated within a range of specific seating rows to then locate potentially susceptible exposed passengers in sufficient time for PEP to be protective.

Less intensive strategies, conducted in collaboration with the airline, that reach more passengers include:

- general media alerts; and/or
- email or SMS messaging or social media alerts, if airlines can provide details or undertake messaging on behalf of health authorities, using a provided script.

Circumstances in which individual contact tracing for airplane flights might be justified include those where:

- diagnosis and notification have been early;
- flight manifests are readily available and passenger contact information can be provided promptly; and
- multiple infectious cases, especially children, reported on a flight.

Cases on other forms of transport should be managed using similar risk-benefit principles as per flights (e.g. cruise ships, international buses etc.).

Mass gatherings

For measles exposure at mass gatherings, the risk is dependent on population immunity. In general, immunity will be likely higher in gatherings where participants are older (e.g. Hajj) but may be lower where participants are younger (e.g. music festivals). However, the risk should be assessed on a case-by-case basis.

Strategies for follow up are determined by risk-benefit. Few resources are usually required to implement things like:

- general media alerts; and/or
- email or SMS messaging or social media alerts, if festival organizers can provide details or undertake messaging on behalf of health authorities.

Measles exposures at mass gatherings involving international travellers should be notified through the IHR to enable health authorities in other countries to alert their clinical networks.

5.11 Risk communications, social mobilization and community engagement

OBJECTIVES

- **To provide effective public communications using trusted channels and interlocutors.**
- **To engage with communities to establish two-way dialogue by listening to community concerns and feedback and continually refining the response according to community needs and perspectives.**
- **To monitor and proactively address misinformation and rumours.**

When an outbreak is confirmed, there is likely to be widespread public concern and media attention, including social media. It is important to keep the public informed, to address concerns and encourage positive behaviours, including seeking RI services.

5.11.1 Ways to communicate with the public

- If a maternal, newborn, child and adolescent health (MNCAH) or immunization-related communications working group is active, coordinate communication efforts with them. This would involve utilizing their knowledge of the population groups to support communication planning and rapid, appropriate and effective communication of key messages.
- If outbreaks or immunization campaigns have not been accurately portrayed in the media previously, consider holding a briefing for journalists on the outbreak response, the rationale for immunization, how vaccines work, and related topics, perhaps including a story lead at the end of the briefing.
- Leverage the reach of key stakeholders to establish community mobilization teams with members that are acceptable to the local community.
- Broadcast clear, concise and culturally informed messaging to support positive health-seeking behaviours, including who is and who is not included in the ORI.
- Consider numeracy and health literacy when developing materials, and ideally, pre-test messages and materials with target population, then modify as needed. Adapt messages as the outbreak evolves.
- Use multiple channels to message the community, including radio and/or television; newspapers; social media, text messages, posters and fliers; meetings with health personnel and with community, religious and political leaders; and orientations at markets, community or religious centres, health centres and schools.
- Prioritize key groups in planning, engagement and communication, particularly those most at risk of measles and its impacts where inequities in access to health already exist.
- Offer multiple ways the public can contact the health teams with questions or concerns, such as a WhatsApp line or phone number. The mode of communication should be based on early consultation with key groups.
- Appoint one trusted and credible media spokesperson and conduct regular press releases and news conferences to enable accurate, timely dissemination of relevant information through the media. They should also be authorized to speak in the event of an AEFI.
- Consider active monitoring for nascent rumours, especially on social media, to allow for rapid response.

The involvement of health workers in advocacy- and communication-related outreach activities is crucial. Messages conveyed through the outreach should be clear, concise and tailored to targeted populations regarding:

- the existence of an outbreak and the benefits of measles vaccination;
- who is eligible to receive measles vaccines and how many doses they should have received;
- clear recommendations to be vaccinated from trusted spokespeople;
- information on locations and opening hours of vaccination sites;
- how to respond to any common questions or concerns that may be raised by the community;
- signs and symptoms of the disease; and
- encouragement of parents to bring their children who develop rash and fever illness to a health care facility early after symptom onset; noting, however, if their child has a fever and they suspect their child has an infectious disease, they should call ahead to tell the staff at the clinic or let the staff at the hospital know when they arrive. The staff should support and help the child, and tell the parents how they can protect people who might be in the waiting room from catching an infection.

Consider equipping health staff with a short frequently asked questions (FAQ) document where the most common questions are compiled with clear answers. This is especially useful when health workers are expected to run educational sessions or speak to community members in group sessions. Further detailed information is available in the WHO *Outbreak communication guidelines (52)* and *Outbreak communication planning guide (53)*.

Lastly, consideration may also be given to the post-measles environment, where follow-up communications may be needed to resolve any remaining questions and address any lingering public health issues. If the outbreak has been severe, there may be a need for well-crafted psychosocial support, particularly for the mental health of communities that have lost family members to measles, as well as exhausted and traumatized staff.

5.11.2 Addressing vaccine concerns

Measles vaccine rejection and hesitancy is a challenge that faces immunization programmes globally. Some individuals and communities have concerns related to a vaccine, or mistrust in those promoting vaccination, and may be hesitant to accept it. The best defence against the risk of insufficient demand for measles vaccine after an outbreak has occurred is to better understand the population and the various behavioural and social drivers of vaccination before the outbreak. These data may be quickly obtained through a rapid survey, complemented by holding several focus group discussions with caregivers or community leaders. These data collection methods can help inform messages and materials, communications strategies, and enhancements to service quality.

No two communities are the same, and while immunization is generally held as a positive universal norm, outbreaks can occur in the context of social and political events that may cause concerns for caregivers or reduce demand for vaccines. Evidence-based strategies (e.g. service enhancement, community engagement, communications, etc.) should be developed and targeted to address the needs of population groups where lower coverage is anticipated or recorded. Consider what gaps there may be in health worker training to better listen to and address caregiver concerns during health visits and work to strengthen their interpersonal communication skills. Rely on trusted influencers and messengers in communities where low vaccine demand is a challenge to speak to families about the importance of immunization and to listen to and address concerns that may arise from community discussions. Consider if misinformation is a source of the concern, and if so, develop strategies to mitigate it, especially online, such as through making social media-friendly versions of information, education and communication (IEC) materials, sharing simple text messages proactively sharing accurate information, using radio to promote accurate messages, or holding a community meeting to collate concerns and questions to inform development of an FAQ document for use by health workers. WHO's *Best practice guidance: how to respond to vocal vaccine*

deniers in public provides basic, broad principles for a spokesperson of any health authority on how to behave when confronted by and on how to respond to vocal vaccine deniers (54).

5.12 Responding to measles outbreaks in the context of other high-impact diseases

Countries may sometimes postpone measles outbreak response activities due to co-circulation of other high-impact diseases (e.g. COVID-19, Ebola etc.). To support decision-making, WHO developed the disease-specific *Guidance for immunization programmes in the African Region in the context of Ebola* (55), and the generic *Framework for decision-making: implementation of mass vaccination campaigns in the context of COVID-19* (56).

For countries affected by both measles and other high-impact disease, the benefits of a safe and effective measles ORI that reduces mortality and morbidity must be weighed against the risks of increasing transmission of the other disease, which may burden essential health services and can be complex. The starting point for such considerations is a risk-benefit analysis that reviews in detail the epidemiological evidence and weighs the short- and medium-term public health consequences of implementing or postponing measles immunization activities, weighed against a potential increase in transmission of the other high-impact disease(s) (e.g. COVID-19, Ebola etc.).

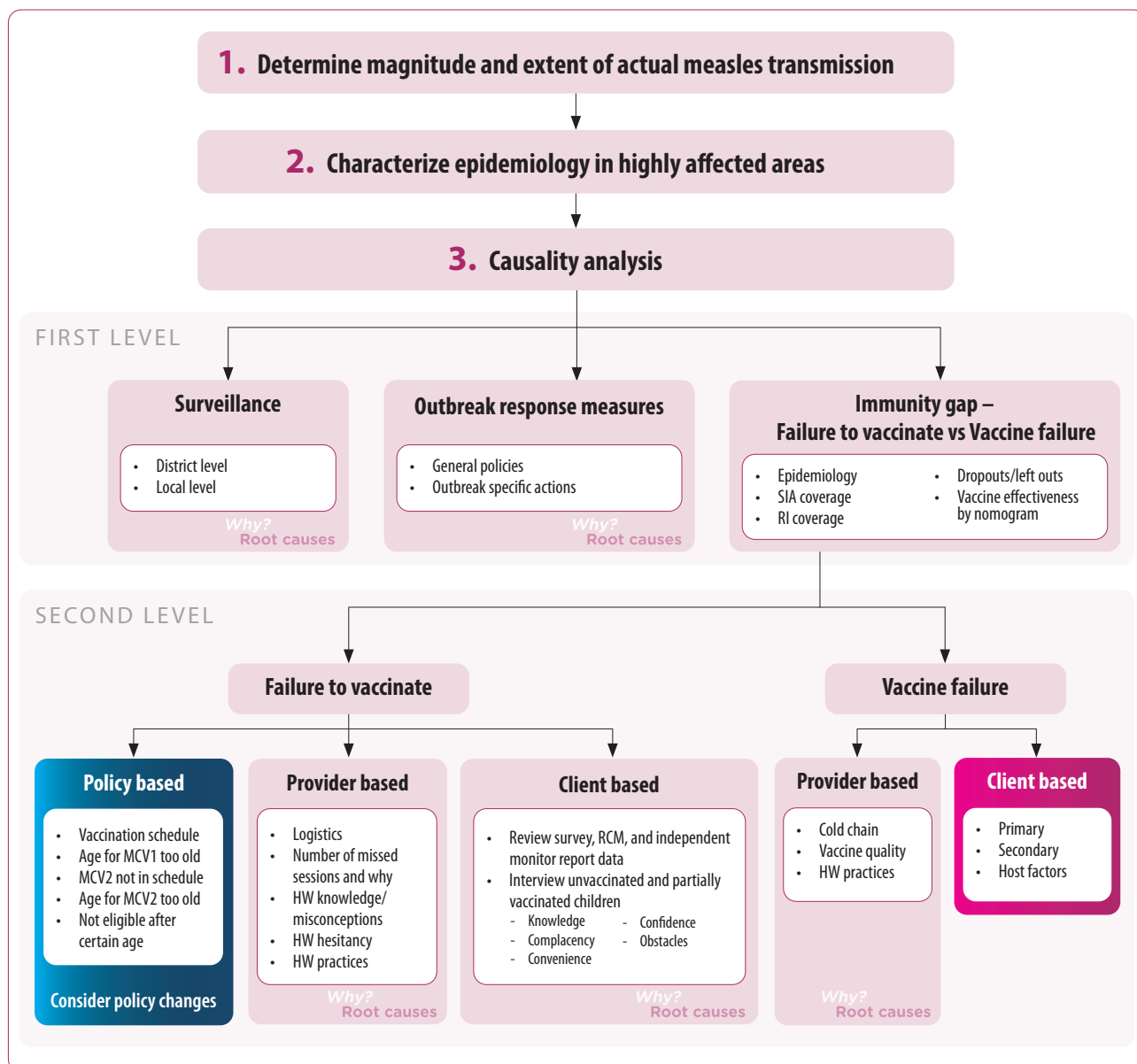
For Ebola virus disease, WHO's *Guidance for immunization programmes in the African Region in the context of Ebola* states that ORI should be conducted as long as: 1) the planning and human resources are adequate to ensure a successful campaign achieving high coverage; and 2) the recommended IPC precautions can be effectively implemented at all times (55).

While the urgency and public health imperative for conducting an ORI may differ, the decision-making method is similar. WHO proposes that the comparative assessment of the relative risks and benefits is evaluated on a case-by-case basis, taking a five-step approach: 1) assess the potential impact of the high-impact disease outbreak using epidemiological criteria; 2) assess the potential benefits of a measles ORI and the capacity to implement it safely and effectively; 3) consider the potential risk of increased transmission of the other high-impact disease associated with the ORI; 4) determine the most appropriate actions considering the epidemiological situation of the other high-impact disease; 5) if a decision is made to proceed with the ORI, implement best practice. This should take account of the coordination, planning; IPC, vaccination strategy approaches, community engagement and equitable access to supplies. The ORI should be conducted in accordance with: WHO's disease-specific guidance for outbreak control; WHO guidelines for IPC in the context of outbreaks of the other high-impact disease; and local prevention and control measures and regulations. These five steps are generally implemented in sequence but are not strictly chronological. A certain degree of overlap in the stepwise process can be expected. Irrespective of the other high-impact disease, community engagement is essential for a successful response to both outbreaks.

5.13 Assessing the root causes of outbreaks

Measles outbreaks provide opportunities to strengthen the immunization programme by identifying the underlying causes of the outbreak and addressing them with evidenced-based strategies tailored to the local context. Initial measles outbreak investigations might determine the extent to which the outbreak was due to failures to vaccinate and vaccine failures. However, further investigation is needed to dig deeper to determine why persons were not vaccinated and/or why the vaccine failed to protect them and if these resulted from provider-based and/or client-based reasons. It should be noted, however, that some causes

Fig. 9. Measles outbreak root cause analysis flowchart



of client-based vaccine failure among specific individuals (e.g. primary and secondary vaccine failure) may not be immediately preventable and some provider-based policies may create permissive environments for failure to vaccinate (e.g. not allowing vaccination after a certain age). Ultimately, the root causes of the outbreak may be determined through a series of “why” questions, where the answer to each “why” question leads to another “why” question that reveals the chain of causality down to the most fundamental causes. **Figure 5** is a flowchart illustrating the stepwise approach to conducting a root cause analysis (RCA) of measles outbreaks.

Step 1: This is particularly important when outbreaks involve multiple districts, so that the investigator can identify where large numbers of estimated true measles cases are located.

Step 2: Characterizing the epidemiology of the outbreak, also described above, combined with a review of district- and subdistrict-level epidemic curves, helps to provide an initial understanding of how and why the outbreak occurred and progressed over time, and provides direction for a deeper dive into the potential

root causes of the outbreak in each location. Analysis of the following case characteristics, or risk factors, is critical to point the way towards further investigation into what caused the outbreak to occur and why it has been sustained:

- **Age distribution:** The age distribution of cases may identify at what point in programmatic history the immunity gaps developed. For outbreaks of long duration, the age distribution should be analysed at periodic intervals (e.g. 2 months) to see if it is changing over time. Evaluating age distribution over time may also contribute to understanding transmission patterns that can also help define appropriate interventions.
- **Vaccination status:** When vaccination status is determined by year of age, the analysis may point to specific years and places (i.e. subdistricts or districts) when failure to vaccinate or vaccine failure may have occurred. This analysis may also reveal whether vaccine administration was timely and according to the recommended schedule. Bar graphs of numbers of cases by year (or month for cases < 24 months) of age stacked by vaccination status (0, 1 or 2+ doses) are an effective way to describe the epidemiology and identify these potential causes. This is also an opportunity to review immunization coverage data quality. Was it known that coverage was too low in the affected group/location? If no, why was coverage data incorrectly high? If yes, why was no action taken to address gaps before?
- **Sex:** Sex differences in vaccination coverage are uncommon. However, previous vaccination strategies and differences in health seeking behaviour may lead to differences in sex-specific attack rates.
- **Living/working situation:** Risk of exposure to measles virus is high among persons living or working in congregated settings, such as pre-school, primary school, high school, university students, military recruits, jails, factories, airports, buses/train stations, markets, public transportation. It is also high among those with frequent contact with the sick and strangers, such as health workers, police and travel industry workers. The occupation of cases is therefore another potential causative factor for a measles outbreak that needs to be identified to stop the current outbreak and/or prevent future outbreaks among these or other potentially high-risk occupations.
- **Travel history:** Travel history and identification of visitors or other contacts that may have infected the case are critical to track the pathway of measles virus as the outbreak evolves. Travel and visitor history should be analysed in conjunction with dates of rash onset by subdistrict and district and as described in epidemic curves, as such analysis may reveal potentially preventable transmission factors. Finally, identifying health facilities that the case may have visited during their infectious or incubation period will help identify potential sources and underlying causes of nosocomial transmission of measles virus.
- **Family clustering:** When there is more than one case in a family, it is important to understand the characteristics of the first case compared with secondary cases. For example, if the first case is a child attending school, then transmission within the school setting may be implicated as the source of infection. On the other hand, if the first case is an infant, other transmission sources for that infant's infection need to be considered.

Step 3: Once steps 1 and 2 have been completed, the investigators should determine the chain of causality that led to the measles outbreak.

The *first-level (most immediate) causes* of ongoing measles outbreaks include:

- immunity gaps;
- poor surveillance performance; and
- inadequate outbreak response.

Any or all of these may contribute to ongoing transmission of measles virus, and each of the three have constituent, or second-level, causes that should be considered individually.

Second-level causes contributing to the immunity gaps can be categorized as:

- failure to vaccinate (client based-reasons, and provider-based reasons);
- vaccine failure (client-based reasons, and provider-based reasons).

Second-level causes contributing to surveillance performance include:

- inadequate/insensitive and/or untimely case detection and notification;
- inadequate and/or untimely case investigation (completion of CIF, specimen collection and/or shipping to the national measles/rubella laboratory); and
- inadequate and/or untimely specimen testing and providing results to all levels.

Second-level causes related to case and/or outbreak response (if the outbreak continued) could include:

- inadequate and/or untimely searching, identifying and investigating additional cases through intensified surveillance;
- inadequate and/or untimely source identification and contact tracing for those that may have infected the case and those that the case may have infected;
- inadequate and/or untimely isolation for cases and quarantine measures for contacts; and
- inadequate and/or untimely ORI with respect to:
 - target age;
 - target area; and
 - type of ORI: selective vs non-selective.

As with first-level causes, more than one second-level cause may have contributed to the status of the current outbreak and should be considered individually. Once the second-level causes have been identified, further investigation into lower level causes through a series of “why” questions may be undertaken until the root causes are identified. Such root cause analyses are used to guide future programme and policy directions.

RCA instruments are available from the M&RI to help determine provider-based and client-based reasons for failure to vaccinate to be administered at the district, health centre and community level. Ideally, the RCA should be conducted as quickly as possible as part of the initial outbreak investigation, as it may further inform effective and efficient outbreak response strategies and tactics. However, if an immediate response is required to prevent further disease and potential death, the RCA may be conducted after ORI is completed.

5.14 Outbreak reporting

Initial briefing

An immediate briefing, including information on the number of cases and deaths by age group, vaccination status and date of rash onset, laboratory confirmation, geographical location of the outbreak and the activities planned to investigate and manage the outbreak, should be communicated to all levels by the investigators. In addition, any supplies and additional technical support should be sought at this time (e.g. if there are diagnostic challenges). If cases are reported along border areas or imported from other countries, health officials in the adjoining areas should be notified and efforts should be made to share information. Such cases may require notification under the IHR. Regular briefings should be a feature of communication within public health authorities during protracted outbreaks.

Initial investigation report

Every outbreak investigation should be documented in a report which summarizes the findings of the investigation and the subsequent analysis. A proposed report structure is presented in **Annex 7**. It must be summarized so it can be effectively communicated to key stakeholders and outbreak response decision-makers.

Why communicate the findings?

- To confirm the outbreak and outline what control and prevention measures have taken place and are recommended.
- To share new information or insights about the outbreak.
- To document the magnitude of the problem and request needed resources from national and international partners.
- To assist other countries with their own investigations when published.
- To inform the public of what is going on with the outbreak, which may help prevent future cases.
- To formally alert relevant authorities and stakeholders in order to mobilize resources.

All measles outbreaks should be reported to the health authorities at the local, regional and national levels. At the national level, the IHR's decision instrument (Annex 2 of the IHR) for the assessment and notification of events that may constitute a Public Health Emergency of International Concern (PHEIC) should be used to determine if the measles outbreak should be notified to WHO (above and beyond routine measles case reporting systems). If so, the outbreak should be notified through the national IHR focal point. Neighbouring countries and regions should be notified of the confirmed outbreaks so that they can assess their own need for response, including enhanced surveillance and targeted vaccination activities.

Situation reports

Outbreak situation reports may be daily or weekly, depending on the visibility of the outbreak and the needs of the ministry of health (MOH). These reports should consider the audience(s) likely to read the reports and be written by dedicated members of the RRT. They should highlight any changes since the previous report, summarize key data since the start of the outbreak, provide updates for the current reporting period and recent periods and highlight gaps or needs for the response. If ORI is part of the response, updates should be given on planning and preparedness, and during implementation updates on coverage should be provided.

Final outbreak report

The final outbreak report should be written soon after the outbreak is declared over and may follow a similar format to the investigation report. The report should clearly communicate the gaps identified through the RCA and after action review and serve as an advocacy document to support improvement of national and subnational systems.

5.15 Evaluation of measles outbreak response

OBJECTIVES

- **Evaluate the effectiveness of response activities.**
- **Identify gaps and lessons learned during measles outbreak preparedness and response activities to improve response system capacities.**

Outbreak response immunization monitoring and evaluation

Activities are monitored to ensure that operations run smoothly, to monitor the results and to identify rapidly any problems so they can be resolved quickly. Monitoring is done from the start of the outbreak to the end, either weekly (epidemiological surveillance and patient care) or daily (vaccination). The results of the analyses should guide the actions in the field. The scope of the assessment to be conducted during and in the close follow up of measles mass immunization campaigns has been extensively described in other existing guidelines and field guides, including the *Planning and implementing high-quality supplementary immunization activities for injectable vaccines: using an example of measles and rubella vaccines (10,40)*. This assessment includes the following components:

- real-time monitoring (RTM);
- rapid convenience monitoring (RCM) of vaccine uptake during the campaign;
- vaccination coverage survey;
- vaccine effectiveness (VE) study;
- evaluation of vaccination campaign impact;
- monitoring of ORI implementation practices with standardized checklists by either external monitors or supervisors or both;
- assessment of missed opportunities for vaccination; and
- assessment of the behavioural and social drivers of uptake.

Evaluation of immunization campaigns

An ORI should be evaluated per indicators defined during the planning process and can address issues such as timeliness of the response, percentage of targeted children reached as well as process indicators. An impact evaluation takes longer than a process evaluation because it requires measuring the effect on disease control and/or RI services and is addressed in **Annex 8**.

Real-time monitoring (RTM) (57)

RTM interventions can strengthen the campaign's effectiveness. RTM activities employ digital technologies to accelerate the sharing, analysis and use of data to improve campaign quality. This is achieved through improvements in the quality, timeliness and completeness of data; more accurate microplans; stronger accountability of field teams; and better collaboration, partnership and communication at all levels. Using RTM, campaign teams can better identify and take corrective actions promptly and achieve campaign targets. RTM approaches support faster collection of standardized data and its integration with other digital solutions. For example, android-based smartphones offer additional capabilities, including built-in GPS functionality and other applications that can be integrated into electronic data collection, such as GPS, barcode scanning, digital photography and automated timestamp information. The tracking of vaccination teams and vaccination progress through digital means can help teams reach the settlements they are supposed to cover and help supervisors monitor the level of coverage. Finally, RTM can support media monitoring and addressing vaccine hesitancy and rumours while the campaign is ongoing.

Rapid convenience monitoring (RCM)

The most important objective of RCM is to find unvaccinated children in order to vaccinate them during the ORI. Additional goals are to identify reasons for non-vaccination and plan and execute rapid corrective action. RCM data provide information on the general performance of the SIA and suggest how to refine strategies for reaching the hardest-to-reach children. RCM is a pass/fail assessment of the areas surveyed, not a coverage assessment. RCM data are collected using methods that are not designed to be representative of the population targeted for the SIA and, therefore, do not produce valid coverage estimates. RCM should be used while the ORI is still ongoing (referred to as intra-ORI RCM), and at the end of the ORI (referred to as post-ORI independent monitoring) (**Annex 9**).

Post-campaign coverage survey (PCCS)

The objective of a PCCS is to determine the coverage obtained in the campaign among the target population, and if designed appropriately, among selected subgroups. A PCCS can also provide insights on factors associated with vaccination during the campaign. Nevertheless, surveys can be costly; require adequate planning, training and field work for quality implementation and analysis; and often the results become available after the campaign is over, making PCCS more actionable for a subsequent campaign than to improve what has already been done (44).

AEFI reports

The objectives of AEFI surveillance are to:

- rapidly detect and respond on time to the occurrence of an AEFI;
- identify, correct and prevent immunization error related reactions;
- facilitate AEFI causality assessment;
- recognize clustering or unusually high rates of AEFI, including those that are mild and/or “expected”;
- identify potential safety signals (including previously unknown vaccine reactions), and generate hypotheses that may require further investigation; and
- generate information with which to effectively communicate with parents, the community, media and other stakeholders, regarding the safety of vaccines. The AEFI surveillance cycle is shown in Figure 10. See the Harmonia website (<http://gysi-aeftools.org/aeftools/training/index1.html>).

Fig. 10. AEFI surveillance cycle



Vaccine recipients themselves and/or parents of immunized infants/children, health care providers at immunization facilities and staff in immunization facilities are those most likely to recognize or detect AEFIs when they first occur. Any AEFI case that is therefore notified to any health care provider working within the health care system, should be reported to the local level immunization focal point (e.g. district) using the standard reporting form through the fastest means possible. This person should in fact be informed of any serious AEFI cases by telephone and this should be followed up by completion and submission of the reporting form (see WHO website for latest version of the AEFI reporting form). This person should review the AEFI report and determine if the reported AEFI case meets the criteria required for a detailed investigation. If necessary, they should contact the primary reporter and visit the locality of the event and interview relevant stakeholders for additional information. The case may be considered:

- 1) Not warranting detailed investigation if it is a minor AEFI and NOT serious AEFI. They should indicate this on the reporting form and send the same to the state and national levels to the following:
 - the concerned immunization focal point at the next administrative level;
 - the national immunization programme; and
 - the national regulatory authority.
- 2) Warranting a detailed investigation if it is a serious AEFI (death, hospitalization, significant disability, life threatening, or congenital anomaly/birth defect);
OR
is a part of a cluster;
OR
a part of a group of events above expected rate/severity;
OR
a suspected signal.

After investigation, the completed CIF along with the supporting documents such as the medical report, vaccine, logistic samples, laboratory reports e.g. cerebrospinal fluid, serum (or other biological products), should be sent to the appropriate higher level for causality assessment.

Vaccine effectiveness (VE) study

VE means that the vaccine has demonstrated its ability to protect under real-life conditions. It reflects the clinical efficacy of the vaccine, the characteristics of the individual vaccinated (age and immune status) and programme errors (cold chain and vaccine preparation and administration technique). Several methods allow VE to be estimated, including the screening method (which allows a rapid estimation of VE) and epidemiological studies (e.g. cohort or case-control study).

Criteria for declaring an outbreak over

An outbreak is considered over after there have been no further epidemiologically or virologically linked cases for two incubation periods (46 days) from the date of onset of the last case.

After action review (AAR)

Following a measles outbreak response, an AAR seeks to identify what elements of the response worked well, or not, and how practices can be maintained, improved and institutionalized. AAR is similar to RCA, but is focused on the response, not the disease outbreak itself. The review should cover all aspects of the response, including but not limited to: preparedness, detection, verification, risk assessment, coordination, stakeholder engagement, control strategies including vaccination, surveillance and laboratory, clinical management, logistics, medical supplies, communication, and IPC. AAR findings should inform preparedness planning. WHO's *Guidance for after action review (AAR)* provides further information (58).

6 Recovery from measles outbreaks

OBJECTIVE

To strengthen health and immunization systems to sustainably contribute to reduction in morbidity and mortality from measles and improve the health status of the outbreak-affected population. Measles outbreaks can have profound impacts on affected communities, as well as highlight gaps in immunization programme performance.

After responding to the outbreak, it is important to focus on strengthening essential primary health care services, including immunization service delivery, and adequately addressing the needs and gaps in the health system to improve access to and the quality of essential health and immunization services. Such efforts will require government commitment, leadership and ownership at all levels and tailored strategies to address identified gaps and barriers. Although not all measles outbreaks will result in suspension or disruption of essential health services, in such situations the recovery phase should support reactivation of essential health services at the earliest opportunity. The WHO *Recovery toolkit: supporting countries to achieve health service resilience* consolidates resources to guide countries in the reactivation of health services and to implement their national health plans during the recovery phase of a public health emergency, such as a measles outbreak (59).

Coordination of the recovery

For large-scale outbreaks, a recovery working group should be established to identify key lessons learned and work with the appropriate entities to develop recovery and improvement plans. For more local outbreaks, the district or regional team can follow the following steps to assure recovery is planned and implemented.

Those developing a recovery plan will identify what information is known, and what additional information is required to:

- 1) Define lessons learned from the outbreak, the outbreak investigation/routine immunization assessment and ORI (see evaluation section).
- 2) Share these lessons learned with the responsible immunization and surveillance authorities.
- 3) Identify any additional information gaps.
- 4) Work together to develop plans to incorporate lessons learned into appropriate plans.

Planning for recovery should include programmes addressing areas identified as contributing to the outbreak, case fatality, campaign planning and implementation.

- IPC
- nutrition
- vulnerable population groups (nomads, refugees, other)
- immunization
- surveillance.

Step 1: Identify factors contributing to and affected by the outbreak. Using the outbreak investigation reports, root cause analysis and other sources of information, identify gaps in:

- IPC: Was there nosocomial transmission of measles?
- Nutrition and case management: Was the case fatality rate higher than expected? Is this due to underlying factors such as nutrition deficits? Was treatment timely and appropriate?
- Routine immunization:
 - Are national policies aligned with WHO recommendations for high coverage (e.g. vaccination > 12 months of age, reducing missed opportunities)?
 - Did the outbreak identify zero-dose communities?
 - Does routine immunization reporting accurately identify low-coverage areas for prioritization?
 - Were other gaps identified in the outbreak investigation etc.:
 - facility-level gaps including staff shortages and stockouts etc.;
 - demand-side gaps?
- Did the outbreak occur in or disproportionately affect high-risk groups such as IDPs, refugees, itinerants etc.? Do these populations have equitable access to vaccination? Other barriers?
- Outbreak preparedness: Did the risk assessment accurately identify high-risk areas? Were opportunities to act missed?
- Surveillance: Did surveillance detect the outbreak in a timely fashion?
- ORI implementation: Did the ORI achieve high coverage? Were AEFI reported, were investigation and causality assessment conducted as planned? Were there any severe AEFI and was risk communication effective?
- Border protection: Were early cases imported? If yes, are policies and programmes adequate to prevent future importation/propagation?

Step 2: Work with appropriate programmes to address gaps identified:

- Work with the appropriate programmes to identify and tailor strategies to address identified barriers and gaps (**Annexes 10 and 11**). Assure that strategies are included in appropriate plans: immunization annual plans, other programme plans, district annual plans or facility microplans. These plans should include budgets and indicators for monitoring recovery. For the immunization programme, this would include the national immunization strategy, district annual plans and facility microplans (**Annex 12**).
- To the extent possible, planning should be funded by local resources. Following an outbreak, particularly a large, disruptive one, it may be possible to identify additional local resources. Advocacy messages should be developed highlighting the risks of future outbreaks. **Annex 13** is a template for a post-outbreak recovery plan.

National-level preparedness checklist for measles outbreaks

	Preparedness indicator	Complete	Incomplete
Leadership and coordination	Are national, regional and local measles outbreak preparedness and response coordination mechanisms functional (or can be reactivated quickly)?		
	Is the health coordination mechanism established and documented with defined roles and responsibilities (e.g. surveillance and vaccination leads) to coordinate measles preparedness and response actions?		
	PHEOC is functional and ready to support measles response coordination activities.		
	Have the PHEOC and measles response plan, roles and procedures been tested through a simulation exercise (or outbreak response) and adjusted based on outcomes and evaluations?		
Preparedness and response planning	Has a national plan for measles outbreak preparedness and response been developed in consultation with key stakeholders?		
	Does the national measles preparedness and response plan define the roles and responsibilities of the subnational and local levels, including partners?		
	Is a list of high-risk areas for measles outbreaks regularly updated, based on surveillance and immunization performance data to target preparedness and response activities?		
	Does the country have a national legal framework defining and enabling measles outbreak response authorities and measures (e.g. public health act in line with IHR)?		
Contingency finance	The country has an established contingency fund mechanism to support emergency response (i.e. measles) with clear description how national, subnational and local levels can request support.		
	Measles treatment is free, with clear communication disseminated within the community.		
	Country has clear policy/protocol for cost of treatment/user fees including (laboratory tests, outpatient care, hospitalization, referral, medical exam and pharmaceuticals) for suspect measles cases, which is disseminated to public and private facilities and the community.		

	Preparedness indicator	Complete	Incomplete
Surveillance and outbreak investigation	Vaccination coverage rates are well-mapped (for 1 dose and 2 dose) in-country.		
	Vaccination coverage rates are well-mapped (for 1 dose and 2 dose) in-country.		
	National and subnational immunity profiles developed to turn coverage data into estimates of overall immunity.		
	Country has analysed and described the historical measles outbreak pattern, including identifying areas at high risk for measles outbreak.		
	The country's surveillance system for measles detection and reporting is well-functioning.		
	Standard case definition for measles is well-established and disseminated throughout the health sector.		
	Measles surveillance performance indicators are evaluated routinely at national and subnational/local levels.		
	The measles surveillance reporting system has integrated private and public facility data in its regular reporting.		
	Case investigation forms (CIF) are standardized and available at all levels (local, regional and national).		
	Country has sufficient laboratory capacity or access to laboratory testing to confirm measles outbreak.		
	Laboratory capacity for specimen testing for measles within the country has been mapped (national and subnational levels).		
	The system for collecting, transporting and testing samples for measles and rubella and reporting the results is well-functioning.		
	Designated measles testing sites have the required laboratory testing materials and laboratory equipment, including sufficient supply of reagents.		
	Rapid response team(s) or outbreak investigation team(s) are well-trained, equipped and ready to investigate suspicion of measles outbreak (and other diseases) (within < 24 hours of alert).		
	Rapid response team or outbreak investigation team (includes at minimum one clinical team member, i.e. doctor, nurse or clinical officer) is trained and equipped to support collection of samples and refer patients if additional suspected cases are identified during investigation.		
Standard operating procedures	Have national standard operating procedures (SOPs) for outbreak preparedness and response have been developed and disseminated to respondents at all relevant levels of the health sector?		
	SOPs for outbreak prevention and control.		
	SOPs for clinical management (including co-morbidities), triage and infection, prevention and control (IPC).		
	SOPs for effective communication and public awareness.		
	SOPs for microplanning/vaccination campaigns (inclusive of waste management plan and cold chain and IPC for other diseases, e.g. COVID-19).		
	SOPs for laboratory surveillance (including testing protocols during outbreaks).		
	SOPs or policies/procedures are in place to manage external workforce support for emergency response.		

	Preparedness indicator	Complete	Incomplete
Risk communications	Are communication systems and plan(s) developed to ensure communities are well-informed and engaged in message dissemination, surveillance, case management and vaccination, including during outbreak immunization response campaigns?		
	Existing community-based health services within the health system have been mapped.		
	The health sector has identified and trained a key spokesperson(s) on measles outbreaks to the public.		
	Trusted key persons and organizations (e.g. faith-based organizations, national society volunteers etc.) within communities have been identified and mapped.		
	Clear, practical public health messages and information that are tailored to affected population(s) are available (in local languages) based on community feedback and assessment(s).		
	Social media communication strategy is developed to monitor commonly shared topics related to measles; engage with key groups on platforms relevant to them; and when and how to address the rumours and myths on social media (e.g. Facebook, Weibo, Twitter, etc.).		
	Vulnerable populations for measles have been identified as part of the risk communication and community engagement strategy link to geographic areas.		
	Data on behavioural and social drivers of measles vaccination and measles infection are collected, including attitudinal and practical barriers affecting uptake, and factors informing the seeking of treatment for measles-like symptoms. Data are analysed, documented and disseminated to relevant populations.		
Health workforce	Is there health workforce and surge capacity available and ready to respond to measles outbreaks for protracted periods?		
	All health workers have presumptive evidence of immunity to measles (two documented MCV doses, history of disease or evidence of immunity through serologic verification).		
	Staff roster and surge capacity roster (including retired staff) listing are available to mobilize workforce with contact information, availability and described skillset.		
	Country emergency medical team(s) are ready to support measles outbreak response.		
	Are there mechanisms for signalling for and managing external emergency health workforce surge?		
	Health facilities and health authorities have established mechanism to request additional health workforce resources to relevant health authorities in the event of an outbreak (e.g. national field epidemiology training programme, medical students).		
	Country aware of international mechanisms for surge support (e.g. Global Outbreak Alert and Response Network etc.).		

	Preparedness indicator	Complete	Incomplete
Health structures	Health structures (public, private) are well-mapped (including type of facility, health services and staffing, and isolation capacity) and regularly updated.		
	Health structures have capacity to treat complications associated with measles (pneumonia, diarrhoea, etc.).		
	Referral mechanisms for measles cases with complications are well-established, inclusive of roles and responsibilities for all indicated actors (i.e. ambulance services, emergency dispatchers, etc.).		
	Health structures can maintain routine immunization as part of essential health care, even during outbreaks and emergencies.		
Logistics/ supply chain	Do public health systems have access to vaccines and treatments for outbreak response at the point of care?		
	Country has mapped cold chain capacity at every level to support emergency response vaccination, and planned expansion of its cold chain capacity for outbreaks in line with WHO <i>Immunization supply chain sizing tool (60)</i> .		
	Country has established vaccine and logistics supply pipeline in the event of emergency measles vaccination response.		
	Country has sufficient waste management materials to support measles emergency response vaccination.		
	Country has adequate and appropriate medical supplies available for measles case management.		
	The country has adequate stock of vitamin A and distribution systems to enable adequate supply at facility level, even during outbreaks.		
	Capacity exists at national and subnational levels to produce a regular gap analysis and pre-positioning of the required stock at subnational level.		
	Adequate storage and warehousing exist at national and subnational levels for PPE and other medical supplies in support of a scaled-up measles emergency response.		
	The country's supply chain and movement of supplies is well-mapped and functional.		
	Measles preparedness/response tools, including case investigation forms, cases and contact line-list forms, laboratory specimens, are readily available and in sufficient quantity at subnational level.		
Partner engagement	Are partner roles articulated in the national strategic response plan?		
	Country partners include but are not limited to public-private partnerships, NGOs, civil society, community organizations, private sector and religious groups. In humanitarian settings, ensure local governments, civil society groups and health cluster partners have been mapped and integrated into the national measles plans.		

Outbreak coordination committee

The roles and responsibilities of health authorities at district, regional and national level during an outbreak must be clear to ensure that the team works cooperatively, and that a systematic, efficient, and organized investigation is conducted. Relevant international and NGOs should be involved as early as possible. Assigning responsibilities prior to an epidemic reduces the need to divert time and energy during the outbreak. When an epidemic is declared, the OCC must convene on a regular basis to plan and oversee activities. These meetings should include a review of the most recent epidemiological data, an agreement on control measures and the assignment of a person responsible for the implementation of each measure. The response will need to be monitored regularly and must ultimately be subjected to formal evaluation after the outbreak.

Members of the OCC

The committee should be replicated at all levels (national and subnational), be chaired by a government official, if available, and include all potential partners, including representatives from:

- the MOH:
 - immunization
 - clinical management
 - nutrition (including vitamin A)
 - medical supplies
 - IPC
 - logistics
 - media and risk communication, community engagement
 - hospitals (clinicians and nurses) and laboratories
 - community health programmes;
- NGOs (e.g. Médecins Sans Frontières);
- National Society of the Red Cross/Crescent and managers of outreach programmes to special populations;
- police and other public safety officers;
- community leaders and representatives of faith-based organizations; and
- private-sector representatives (e.g. officials from private hospitals, clinics or laboratories).

Roles and responsibilities of the OCC

The OCC should ensure that the following actions are carried out:

- assess the supplies and equipment and resources currently available;
- estimate and identify resources and procedures for outbreak response vaccination campaigns;
- estimate and identify additional resources needed for rapid outbreak response;
- ensure the availability of staff and training for outbreak response;
- analyse epidemiological information as the outbreak progresses;
- assign responsibilities to staff with clear tasks and lines of communication;
- meet regularly to review data and monitor implemented measures and adapt strategies;
- communicate with the general public and the media, adapting messages;
- identify causes for the outbreak and develop plans to address root causes; and
- evaluate the response.

Routine immunization facility assessment during measles outbreaks

HEALTH FACILITY QUESTIONNAIRE			
Routine immunization facility assessment during measles outbreaks			
1. Identification			
1.1	Name of facility:	1.2	Name of region/state:
1.3	Name of district:	1.4	Date: DD / MM / YY
2. Human resources			
2.1	How many vaccinators are there in this facility?		
2.2	Catchment population 0–12 months of age for the current calendar year <i>Calculate population/vaccinator</i>		
3. Planning			
3.1	Does facility have a current year plan for routine immunization?		
3.2	Are fixed immunization sessions planned on every working day at this facility?		
	<i>If not, why not (mark all that apply)?</i>		
3.2a	<i>Lack of/distance to cold chain</i>		
3.2b	<i>Insufficient staff</i>		
3.2c	<i>Small population in area</i>		
3.2d	<i>Other (specify):</i>		
3.3	Are outreach immunization sessions part of this facility's annual plan?		
3.3a	<i>If yes, how many outreach sessions were planned in the past 6 months?</i>		
3.4	Are there population groups in this area which are not included in the fixed and outreach planning?		
	<i>If yes, who is left out?</i>		
3.4a	<i>People living in remote areas (e.g. separated by distance or geographical barrier)</i>		
3.4b	<i>People moving for seasonal work/harvest/nomadic</i>		
3.4c	<i>People from other countries or areas, including IDPs and refugees</i>		
3.4d	<i>Religious groups that refuse vaccine</i>		
3.4e	<i>Minority ethnic groups (e.g. marginalized, insular)</i>		
3.4f	<i>Other hard to reach* populations (specify):</i>		
3.4g	<i>Other populations with low demand** (specify):</i>		
4. Vaccine stock management and cold chain			
4.1	Has this facility experienced any vaccine/supply shortages in the previous calendar year?		
	<i>If yes, who is left out?</i>		
4.1a	<i>MCV (measles). If yes, for how many months:</i>		
4.1b	<i>Diluents</i>		
4.1c	<i>AD syringes</i>		
4.1d	<i>Vaccination cards/booklets</i>		
4.1e	<i>Other vaccines (specify):</i>		

4.2	Examine the cold chain equipment and stocks and record your findings below.		
	4.2a	<i>Cold chain equipment is functioning?</i>	
	4.2b	<i>Temperature inside the refrigerators currently between +2 °C and +8 °C?</i>	
	4.2c	<i>Other issues (specify):</i>	
4.3	Does the health facility's cold chain and stock contain the following?		
	4.3a	<i>Expired vaccine (any antigen)</i>	
	4.3b	<i>VVM at stage 3 or 4 (any antigen)</i>	
5. Service delivery			
5.1	Have any routine immunization sessions been cancelled in the last year?		
5.2	<i>If yes, what was the % cancelled, by type?</i>		
	5.2a	<i>% fixed cancelled</i>	
	5.2b	<i>% outreach cancelled</i>	
5.3	<i>If yes, what were the reasons sessions (fixed or outreach) were cancelled? (mark all that apply)</i>		
	5.3a	<i>Cold chain breakdown/lack of fuel for cold chain</i>	
	5.3b	<i>Staff shortages/strikes/illness</i>	
	5.3c	<i>Staff too busy with other activities (e.g. competing priorities, training)</i>	
	5.3d	<i>Insufficient transport or fuel for transport</i>	
	5.3e	<i>Insufficient funding</i>	
	5.3f	<i>Stockout of vaccines or supplies</i>	
	5.3h	<i>Other (specify):</i>	
5.4	Are MCV/RCV and other lyophilized vaccines offered at every fixed session?		
5.5	Are MCV/RCV and other lyophilized vaccines offered at every outreach session?		
5.6	Do they open a vial of MCV/RCV for even just one child at a session?		
5.7	Is there a maximum age limit for MCV1 vaccination?		
	5.7a	<i>If yes, up to what age?</i>	
5.8	Is there a maximum age limit for MCV2 vaccination?		
	5.8a	<i>If yes, up to what age?</i>	
6. Monitoring			
6.1	Does the facility calculate coverage and know their target coverage for the current calendar year?		
6.2	Is there a system for tracking defaulters (those who don't complete series)?		
6.3	Have recording/reporting or defaulter tracking been affected by any stockout of the following?		
	6.3a	<i>Immunization registers</i>	
	6.3b	<i>Recording and reporting tools (tally sheets, vaccination cards, monthly report forms)</i>	
6.4	Review documents and record the number of measles doses given in the previous year and coverage?		
7. Surveillance			
7.1	Do vaccinators and clinical staff know the suspect case definition for measles and rubella?		
7.2	Has this facility reported suspect measles in the previous year?		
7.3	Did suspect measles cases occur in a particular area or among a high-risk group?		
8. Closing			
8.1	Describe the most critical challenges to providing vaccination services, particularly for unvaccinated infants:		
	1) If there are issues that can be resolved at the local level, share findings with the team and help them identify solutions before leaving. This includes increasing coverage for the current year if they are not on track to meet national objectives.		
	2) If the challenges identified are resource or policy issues, share the reports with the appropriate level for resolution.		

* Other hard to reach includes any supply-side barriers not detailed above.

** Other demand-side barriers might include distrust, unaware of vaccination, lack of time or financial barriers.

Measles outbreak: root cause analysis

Epidemiologic analysis can help identify immunity gaps that may have resulted from failure to vaccinate and/or vaccine failure. These two causal categories are not mutually exclusive. Moreover, these categories may be further categorized as either client-based or provider-based causes. Failure to vaccinate and vaccine failure may both be attributable to policy-based causes.

Vaccine failure

Evidence of vaccine failure may be found by estimating the vaccine effectiveness (VE). In settings where infants are vaccinated from 9 months of age, vaccine failure is suggested if the VE of cases that received one measles vaccine dose at 9–11 months of age is substantially less than 85%. The same formula can be used in settings where infants are vaccinated at 12 months of age or older. VE can be estimated through several methods: cohort studies, case-control studies, test-negative designs, and the screening method. These methods are very sensitive to misclassification of disease or vaccination status, with misclassification resulting in lower vaccine efficacy than the true value. Cases should all be laboratory confirmed or linked using stringent criteria, and vaccination status should be documented by a vaccination card or clinic immunization registry. Two papers by Orenstein and colleagues review the methods and the impact of misclassification (61,62).

Using a retrospective or prospective cohort, one can calculate the attack rate in the vaccinated (ARV) and the attack rate in the unvaccinated (ARU) and then calculating the risk ratio (RR) (63,64). The VE is equal to 1 minus the risk ratio.

	Cases	Non-cases/controls	Total
Vaccinated	A	B	A+B
Unvaccinated	C	D	C+D
Total	A+C	B+D	

$$ARV = A/A+B$$

$$ARU = C/C+D$$

$$RR = ARV/ARU$$

$$VE = 1 - RR = 1 - ARV/ARU$$

Alternatively, if a case-control study is conducted, one can calculate the odds ratio (OR) and determine the VE by subtracting the OR from 1.

$$OR = AD/CB$$

$$VE = 1 - OR = 1 - AD/CB$$

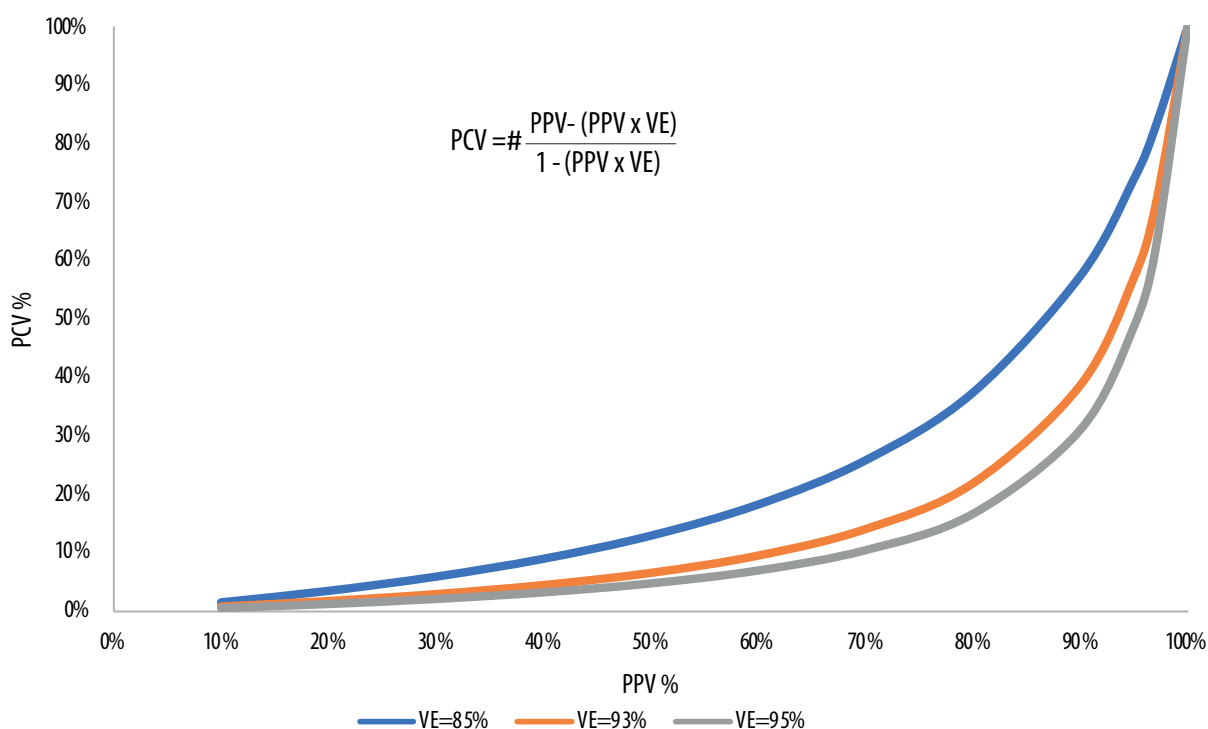
In the test-negative design, cases are laboratory-confirmed measles cases and controls are cases testing negative for measles; non-tested cases are excluded (65,66). This design relies on existing data and can be done quickly. However, as with the other methods, VE estimates will be biased if vaccination status is not

known or is inaccurately recorded in surveillance data. The method may also not be appropriate when testing stops after an outbreak has been confirmed. This method also assumes no relationship between vaccination status and health seeking.

If attack rates among the vaccinated and unvaccinated are uncertain, and a case-control study is not feasible, one can estimate the VE by including the proportion of cases vaccinated (PCV) among children ≥ 12 months old and the proportion of the at-risk population vaccinated (PPV) determined from prior coverage surveys or other existing estimates of population vaccination coverage in the following equation:

$$VE = 1 - (PCV/1-PCV) * (1 - PPV/PPV) \text{ (61)}$$

A series of curves representing VE from 40% to 100% can be generated from this equation by relating PCV with PPV in a nomogram (61).



The above nomogram was designed assuming a single-dose schedule at 9 months of age. It serves as a useful reference to estimate VE in the field when the PCV and PPV are known. This nomogram can serve as a screening tool to see if there is any evidence for vaccine failure that would result in a lower than expected VE. This method assumes that the population coverage corresponds precisely to the population where cases come from, that coverage estimates are accurate, and that coverage rates are relatively stable over time (67). Vaccine failure would be suggested by a VE substantially less than 85% when MCV1 is given at 9 months of age. Note that when the PPV is 90%, approximately 60% of cases (i.e. more than half) would be expected to have been vaccinated with MCV1. Reasons for vaccine failure may be provider-based or client based.

Provider-based reasons for vaccine failure are more common than client-based reasons and may include:

- administration of spoiled vaccine due to cold chain defects or inappropriate vaccine handling practices, including exposure to sunlight;
- administration of an insufficient dose (i.e. volume) of reconstituted vaccine; or
- administration of expired vaccine.

Client-based reasons for vaccine failure are listed below. They are usually non-preventable and would typically involve few children.

- Primary vaccine failure due to vaccination of individuals who biologically do not produce an adequate immune response because of:
 - immaturity of the immune system;
 - maternal antibody;
 - congenital or acquired immunodeficiency disorders; or
 - recent administration of high-dose steroids, immunosuppressive drugs, or antibody containing blood products, including immunoglobulin.
- Secondary vaccine failure that occurs with waning antibody and T-cell mediated immunity levels among previously vaccinated and protected individuals after a long period of time. Fortunately, secondary vaccine failure is uncommon.

Most causes of provider-based vaccine failure are episodic rather than chronic and therefore may not be readily apparent when calculating or estimating VE in an outbreak affecting relatively wide age groups (e.g. 12–59 months). Moreover, it is possible that both failure to vaccinate and vaccine failure may be responsible for a given measles outbreak. Regardless of the estimated VE, it is worth reviewing vaccine quality, cold chain practices, stock management, and vaccine handling practices with staff to verify that appropriate procedures and practices are being applied. Assessing any changes to vaccine handling practices over time may also be helpful, as some poor practices may have been addressed and may not be currently observed. If deficiencies are identified, then indepth interviews with responsible health staff will be needed to answer the series of “why” questions that ultimately reveal the root causes of these inappropriate procedures and/or practices that lead to vaccine failure.

Failure to vaccinate

Immunity gaps due to failure to vaccinate may be reflected in data from surveillance, outbreak investigation, and RI programme and SIA monitoring records, all of which should be reviewed. Specific indicators of failure to vaccinate include:

- 1) a large percentage of cases being unvaccinated;
- 2) historically low RI and/or SIA coverage by administrative reports and/or survey; and
- 3) historically high BCG-MCV1, Penta1-MCV1 and/or MCV1-MCV2 dropout rates by administrative reports or onsite EPI registration book review.

Look for evidence of failure to vaccinate by checking surveillance, outbreak investigation, and vaccination coverage data at district, subdistrict and health facility level. Determine among which specific birth cohorts immunity gaps may exist. Surveillance and outbreak investigation data will indicate the affected ages and their vaccination status. Routine and supplementary immunization data, by birth cohort, will indicate potential age-specific immunity gaps.

Regardless of which birth cohorts are affected by the outbreak, the investigator should also evaluate evidence of failure to vaccinate children from recent birth cohorts, where failure to vaccinate represents a potential immediate risk of infection and death. Vaccination report forms and EPI registration books may be reviewed to determine MCV1 coverage and dropout rates; specifically, registered children-MCV1, BCG-MCV1 and Penta1-MCV1 dropout rates, as well as MCV1-MCV2 dropout rates (if MCV2 is given during the 2nd year of life). If older birth cohorts are affected by the outbreak, vaccination report forms and EPI registration book data, if available, may be reviewed from the corresponding years in which those birth cohorts were eligible for MCV1 and MCV2. To assess the number of potentially left out (i.e. never vaccinated) children and actual coverage by birth cohort, EPI target population (i.e. denominator) data may be cross-checked with other birth data sources such as birth registries and family planning records.

Vaccination prior to the scheduled age may result in vaccine failure but may also be considered as a failure to vaccinate (on time). For countries whose immunization schedule includes MCV1 at 9–11 months of age,

MCV1 administered before 9 months of age is considered an invalid dose. In addition to determining local level coverage and dropout rates, the EPI registration book also can be reviewed to evaluate timeliness of MCV1 and MCV2 administration as a percentage of children vaccinated, i.e. if they are invalid or valid:

- 1) Invalid: number and percentage of children given MCV1 < 9 months (< 270 days) after birth, and/or MCV2 < 4 weeks after the first dose.
- 2) Valid: number and percentage of children given measles vaccine \geq 9 months (\geq 270 days) after birth and/or MCV2 \geq 15 months after birth.

Failure to vaccinate may also result from specific policies such as the national vaccination schedule and eligibility criteria for vaccination. Examples could include:

- 1) Most cases were < 12 months of age and the vaccination schedule does not allow for children to receive MCV1 until 12 months of age.
- 2) Most cases were 18–59 months old, and the national schedule provides MCV2 at 6 years of age.

Cases should be categorized as to whether they were programmatically preventable (they should have been vaccinated but were not) or not programmatically preventable (they were too young or otherwise ineligible for vaccination, they received one dose but were too young for the second, they had received one dose but had not yet been vaccinated in an SIA, or they had received two doses) (68).

Once the immunity gaps resulting from failure to vaccinate in different birth cohorts have been identified, the investigator may then investigate the reasons why children in those birth cohorts were not vaccinated. These may be provider-based, client-based and/or policy-based. Outbreak epidemiology (e.g. age distribution and vaccination status) may point to policy-based causes. Other important sources of information include relevant routine and supplementary immunization data: these might include survey data, independent monitoring reports and rapid convenience monitoring data. All these sources typically collect data on reasons why children were not vaccinated and may include both client-based and provider-based reasons. Provider-based reasons for failure to vaccinate may also be identified by reviewing stock ledgers, vaccination session records, staff attendance, etc. Note that the data sources need to be from the time periods corresponding to the birth cohorts in which the immunity gaps were identified. However, these reasons or causes for failure to vaccinate are not the root causes. Ultimately, interviews with health staff at different levels, clients and potentially others at the community and higher levels will be needed to answer the series of “why” questions to reveal the root causes of failure to vaccinate.

Examples of **provider-based causes of failure to vaccinate**, each of which also have contributing causes, include:

- sessions not being planned and/or conducted;
- vaccine or logistics stockouts;
- incorrect understanding of vaccine contraindications; or
- written and unwritten vaccination policies or misunderstanding of these policies such as:
 - failure to open a vial unless a certain number of children present for vaccination;
 - failure to vaccinate a child over a certain age; or
 - provider is not following the recommended immunization schedule.

Examples of **client-based causes of failure to vaccinate**, each of which have further contributing causes, include:

- lack of knowledge regarding vaccination;
- vaccine hesitancy due to complacency, convenience and or confidence; or
- physical, social and/or other obstacles.

Contributing factors include improper or unpleasant attitudes by staff towards clients.

District and health facility level questionnaires and community-based focus group discussion guidelines are available to evaluate potential provider-based and client-based reasons for failure to vaccinate and vaccine failure.

Surveillance

Surveillance that is not sensitive and/or timely and/or investigations that are not complete can result in undetected measles virus transmission that also contributes to the development of outbreaks. Outbreak investigations should therefore include an assessment of measles and rubella surveillance and, based on the outcome, should then explore the root causes of poor surveillance performance that also contribute to the measles outbreak. These also may include failure to intensify both passive and active surveillance, including community-based reporting, as part of outbreak response immediately after the outbreak was identified.

The first step in evaluating measles and rubella surveillance is to review the standard WHO-recommended measles and rubella surveillance performance indicators (4), which may vary slightly by region.

Indicator	Target
1. Percentage of surveillance units reporting to the next highest level on time, even in the absence of cases.	≥ 80%
2. Annual reporting rate of discarded measles and rubella cases.	≥ 2/100 000 population
3. Percentage of suspected measles and rubella cases that have had: 1) an adequate investigation; ^a and 2) initiated within 48 hours of notification.	≥ 80%
4. Percentage of suspected cases with adequate specimens for detecting acute measles and rubella infection collected and tested, excluding epidemiologically linked cases from the denominator.	≥ 80%
5. Percentage of laboratory-confirmed outbreaks with samples adequate for detecting measles virus collected and tested in an accredited laboratory.	≥ 80%
6. Percentage of specimens received at the laboratory within 5 days of collection.	≥ 80%
7. Percentage of IgM results reported to public health authorities by the laboratory within 4 days of specimen receipt.	≥ 80%
8. Percentage of confirmed cases for which source of transmission is classified as endemic, imported or importation related.	≥ 80%

^a An adequate investigation includes the collection of all the following data elements from each suspected measles or rubella case: name or identifiers, place of residence, place of infection (at least to district level), age (or date of birth), sex, date of rash onset, date of specimen collection, measles-rubella vaccination status, date of all measles-rubella or measles-mumps-rubella vaccination, date of notification, date of investigation, and travel history.

Evaluating surveillance quality as one of the potential causes of an outbreak may start with a review of the above measles and rubella surveillance performance indicators at the district level during the previous year. If the population size of the district is < 200 000, one can group together the affected district and adjacent districts or review surveillance performance for the province in order to provide a meaningful interpretation of the indicators. The adequate investigation indicator (#3 in the above table) should be separated into its two component parts in order to distinguish timeliness of the investigation from its completeness:

- 1) The percentage of investigations that were “adequate” as defined above.
- 2) The percentage of suspected cases investigated within 48 hours of notification.

Each of the two components of indicator #3 has a target of ≥ 80%. For “inadequate” investigations, the data should be further analysed to identify which data elements were not completed in the case investigation forms. Discussions then should be held with relevant officials to identify reasons for not meeting specific surveillance performance indicators, using the sequential “why” approach as described above.

The next step is to review surveillance performance at the local level to identify possible unreported cases and/or delays in notification, reporting, investigation and classification. Ideally, the investigator should

obtain information during the past 12 months from the case investigation, line listing, and other forms and/or databases. The investigator then should list all reported cases and for each, if symptoms and signs were consistent with the:

- 1) Surveillance case definition of measles (fever and maculopapular rash).
- 2) Clinical case definition of measles (fever, rash and at least one of the following: cough and/or coryza and/or conjunctivitis).

Next to each reported case, the investigator also should list the core variables related to timeliness. These include date of rash onset, date of notification, date of investigation, date of specimen collection and date specimen was shipped to the laboratory. The date of arrival of the specimen to the laboratory, date of laboratory result and date when the local staff were informed of the laboratory result should also be documented. The investigator may then calculate the following sequential intervals to assess surveillance timeliness at each step (timeliness targets recommended by WHO are in parenthesis) and identify specific causes of delay:

- 1) Date of rash onset to date of notification (no target).
- 2) Date of notification to date of investigation (≤ 48 hours).
- 3) Date of rash onset to date of specimen collection (0–28 days).
- 4) Date of specimen collection to date the specimen arrived at the laboratory (≤ 5 days).
This indicator may be further analysed as:
 - a) date of specimen collection to date specimen was shipped;
 - b) date specimen was shipped to date the specimen arrived at the laboratory.
- 5) Date the specimen arrived at laboratory to date results were available to the programme (≤ 4 days).

Of critical importance is the time it takes from rash onset in the suspected case to when the case is known by the local staff as confirmed or discarded as measles, i.e. to get from #1 to #5 above. Confirmation of suspected cases within 10–14 days of rash onset can lead to interventions that will help stop the chain of transmission within a few generations. As the interval between rash onset and case classification increases, so too the risk of increasing the magnitude and geographic extent of transmission increases, as well as the scope of any necessary subsequent intervention.

A second equally important question at the local level relates to surveillance sensitivity: is the surveillance system missing cases? At the local level, the investigator should review health facility outpatient and inpatient logbooks to look for suspected cases of measles and/or fever and rash that may have presented at least 1 month before the outbreak and ideally during the past 12 months. While not usually integrated into routine health facility-based surveillance systems, community-based surveillance can be a rich source of data on cases and mortality. These then can be compared with the above-mentioned list of cases reported in the past 12 months, noting any discrepancies. Any suspected cases that were not reported, or reported and not investigated, should be identified. The investigator should then conduct in-depth interviews with health facility staff and identify the reasons why such cases were not reported or reported but not investigated. If investigations were conducted by staff from a higher (e.g. district or provincial) level, the investigator should also interview staff from those levels that have failed to investigate reported cases to determine the reasons why the cases were not investigated. A non-exhaustive list of common reasons includes:

- lack of financial, physical and/or human resources;
- geographic barriers;
- poor data flow due to inadequate means of communication (e.g. no internet, phone or radio);
- lack of knowledge/training regarding case definitions, reporting needs, data flow;
- lack of standardized forms or specimen collection kits;
- lack of feedback after reporting and/or investigating cases;
- laboratory-related issues such as lack of test kits, other reagents, human resources;
- lack of supervision; and
- no consequences for failing to implement established policy or mandates.

These reasons, while in the causal chain, may not themselves be the root causes of insensitive, untimely and/or incomplete surveillance. Following such responses, the investigator should engage in the series of “why” questions to reveal the root causes underlying these proximate causes of inadequate surveillance performance.

Prior outbreak response

If the outbreak has continued in spite of prior outbreak response activities, the investigator should review all aspects of that outbreak response and fully describe the measures undertaken to understand what potential gaps may have allowed the outbreak to continue and/or expand, including delay of response activities. Health facility outpatient and inpatient logbooks or registers in the affected and neighbouring areas may be reviewed for suspected measles cases and compared with the list of cases reported in the past 12 months, noting any discrepancies. Reasons for not implementing or inadequately conducting recommended procedures and for missing or not investigating reported cases should be explored and followed up with the series of “why” questions to get to the root causes.

WHO Measles Programmatic Risk Assessment Tool

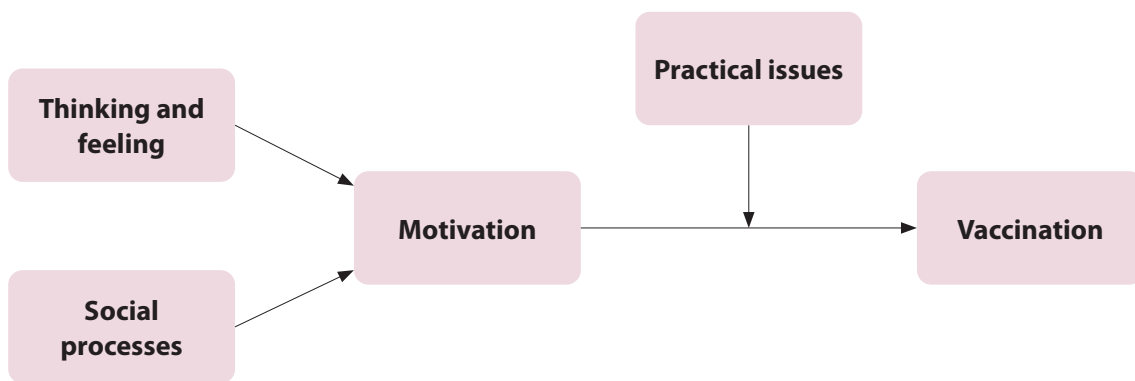
The WHO Measles Programmatic Risk Assessment Tool (46) was developed to help national programmes to identify areas not meeting measles programmatic targets, and based on the findings, guide and strengthen measles elimination programme activities. This Excel-based tool assesses subnational programmatic risk as the sum of indicator scores in four categories: population immunity, surveillance quality, programme performance, and threat assessment. Each subnational area is assigned to a programmatic risk category of low, medium, high, or very high risk based on the overall risk score. Scoring for each indicator was developed based on expert consensus.

- **Population immunity:** Assesses measles susceptibility using subnational vaccination coverage data administered through routine services for MCV1 and second dose measles-containing vaccine (MCV2) and coverage achieved during measles SIAs conducted within the past 3 years. This indicator also includes the proportion of suspected measles cases with unknown vaccination status or who were unvaccinated.
- **Surveillance quality:** Evaluates the ability of a subnational area to detect and confirm cases rapidly and accurately. These indicators include the non-measles discarded rate; the proportion of suspected measles cases with adequate investigation (investigation within 48 hours of notification and inclusion of 10 core variables); the proportion of cases with adequate specimen collection (within 28 days of rash onset); and the proportion of cases for which laboratory results were available in a timely manner.
- **Programme performance:** Assesses specific aspects of RI services, including indicators for trends in MCV1 and MCV2 coverage, dropout rates from MCV1 to MCV2 and from first dose of diphtheria–pertussis–tetanus vaccine (DPT1) to MCV1 based on administrative vaccination coverage data.
- **Threat assessment:** Accounts for factors that might influence the risk for measles virus exposure and transmission in the population. The indicators include: reported measles cases among specific age groups, recent measles cases reported in subnational areas on borders, population density, and presence of vulnerable groups. To ensure programmatic utility of the tool, it is intended to be used annually by national programme managers to monitor implementation of measles elimination strategies within a country. The required data inputs include readily available and routinely collected data from the immunization and surveillance programmes. Results are shown in table and map formats, with subnational areas colour-coded by risk category. In addition, subnational risk scores can be displayed by indicator category, facilitating better understanding of programmatic weaknesses that are driving the overall risk score. Country reports can be created directly from the tool.

Community assessment of demand for immunization services

Understanding social processes, how people think, feel and act in relation to vaccination is vital to inform the development of strategies to generate demand and uptake for the vaccines. Tools to understand the behavioural and social drivers (BeSD) of vaccination include a set of surveys, interview guides and related tools to support assessments and use of quality data on the drivers and barriers to vaccine uptake (45).

The Behavioural and Social Drivers (BeSD) of Vaccination Framework, based on the “increasing vaccination” model (69).



Key considerations for identifying and approaching the target population for insight gathering:

- While health facility or vaccination exit interviews are an easy way to reach parents, this approach naturally biases the sample, limiting insights to parents or caregivers who are already vaccinating their children.
- For an assessment that includes those most vulnerable populations who are not interacting with the health system at all, it will be important to find these families where they live or congregate. The CIFs for measles, AFP or other VPD can provide clues to location or affiliations.
- If possible, look to interview parents selling or shopping in local markets or grocery stores.
- In some areas/countries, single parent households, or where both parents work outside of the home present unique challenges. Consider purposive sampling methodologies to include this group.
- Hesitancy is a motivational state, informed by a range of factors, it will be important to understand underlying reasons for hesitancy to tailor interventions to address it.
- Practical issues include a host of factors such as the convenience and quality of services. Previous experiences of services that were unsatisfactory often lead to dropout in vaccinations. For example, caregivers who have previously been turned away from services without vaccination for any reason (no vaccine was available, not enough children to open a vial, the caregiver did not have the child's homebased record etc.) will be unlikely to return for vaccination.
- To understand practical issues you will want to probe at considerations such as timing of sessions (do sessions start and end on time, are those times convenient for the community), large crowds and time taken at sessions, perceived technical competence of staff, rudeness, cleanliness, places to sit while waiting etc.

- Other practical issues can include transport to vaccination site, distance, convenience of services and operating hours, as well as costs associated with vaccination. The financial cost can include indirect costs, such as lost income due to time off work, transport etc. These insights will offer important considerations for the design and implementation of immunization services.

The questions below offer a guide to understanding the different drivers of measles vaccination in the community which should be adapted to the context of its use (e.g. measles outbreak vs routine immunization).

Questions related to demand side – questions asked in the community, care settings, etc. for individuals or adapted for focus group settings of guardians for children of unknown vaccination status.

Identification			
1.1	Name of village, locality/neighbourhood:		
1.2	Reason for selecting the area (slum, minority group, client in a market, etc):		
1.3	Name of nearest health facility	1.4	Name of region/state
1.5	Name of district:	1.6	Date of interviews: DD / MM / YY

Answer or Yes = 1; No = 0		Child number					
		1	2	3	4	5	
Background							
<i>For children 12–23 months of age</i>							
2.2	What is the current age of the child in months?						
2.3	Does the child have a vaccination card?						
2.4	Does the family belong to a high-risk group?						
2.4a	<i>People living in remote areas (e.g. separated by distance or geographical barrier)</i>						
2.4b	<i>People moving for seasonal work/harvest/nomadic</i>						
2.4c	<i>People from other countries or areas, including IDPs and refugees</i>						
2.4d	<i>Religious groups that refuse vaccine</i>						
2.4e	<i>Minority ethnic groups (e.g. marginalized, insular)</i>						
2.4f	<i>Other hard-to-reach* populations (specify):</i>						
2.4g	<i>Other populations with low demand** (specify):</i>						
2.5	If the mother works outside the home, who looks after the child during the day?						
2.5a	<i>Takes with</i>						
2.5b	<i>Older siblings</i>						
2.5c	<i>Grandparent</i>						
2.5d	<i>Nursery childcare</i>						
2.5e	<i>Mothers' cooperative</i>						
2.5f	<i>Other: specify</i>						
2.5	Was the child vaccinated during recent campaigns?						
2.6	Name of facility where the child received the most recent routine vaccination						

Answer or Yes = 1; No = 0		Child number				
		1	2	3	4	5
Immunizations						
3.1	Is the child up to date for routine measles vaccination? (Can be an assessment with yes/no or complete history)					
3.2	For unvaccinated or incompletely vaccination, ask why. (This question can be sensitive and the parent may give a quick “didn’t know” or other answer out of embarrassment. It is best to take time on this question, be sensitive to parent’s situation and probe for additional information)					
3.2a	<i>Vaccine was not available</i>					
3.2b	<i>Lack of money to pay for services</i>					
3.2c	<i>Lack of money for indirect costs (transport etc)</i>					
3.2d	<i>Didn’t know about vaccinations</i>					
3.2e	<i>Didn’t know where to get vaccination</i>					
3.2f	<i>Didn’t know when to get them</i>					
3.2g	<i>Didn’t know other</i>					
3.2h	<i>Lack of time due to work</i>					
3.2i	<i>Lack of time due to other responsibilities</i>					
3.2j	<i>Refusal – religious</i>					
3.2k	<i>Refusal – safety concern</i>					
3.2l	<i>Poor quality of services (probe for what this means)</i>					
3.2m	<i>Other: specify</i>					
3.2n	<i>No answer</i>					
3.3	If the child had any missed or delayed vaccines, did the family receive any reminders or recall for follow up appointment? (yes/no)					
3.3	For families being interviewed in a health care setting, did the staff ask the vaccination status of the child was brought?					
3.3a	<i>If the child was incompletely vaccinated, did they offer vaccination/refer for vaccination?</i>					

* Other hard to reach includes any supply-side barriers not detailed above.

** Other demand-side barriers might include distrust, unaware of vaccination, lack of time or financial barriers.

Outbreak investigation report: proposed outline

A summary report should contain the sections listed below. These sections may be as short as a couple of sentences or a paragraph, or very detailed, depending on the audience. Generally, an internal report can provide all the necessary details in two or three written pages. A write-up for a peer-reviewed journal would be much longer, containing more detail and discussion. The report should contain the elements listed below, regardless of whether the report is internal or external.

Summary: Present an overview of the problem and the findings. Who was affected? What happened? Where and when did the outbreak occur? Why?

Introduction and background: Introduction to the disease or public health problem and appropriate background information like context and environment. For example, population demographics, surveillance data, previous similar outbreaks, description of the area/site/facility, health care system.

Methods: Describe the methods used to investigate the outbreak. This includes case definition and case finding as well as laboratory testing methods.

Findings: Describe the outbreak situation and the context, including the location of the outbreak. Describe the results of the investigation, including laboratory information. Give an epidemiological description (time, place, person) maps and epidemic curve. Provide attack rates and case fatality ratios, by classification information. Which control measures have been implemented? What are the current resources and response capacities? Summary of curative service and case management information as well as vaccination programme?

Recommendations: Wrap-up with lessons learned from this investigation and any recommendations that should or have been made in the following key areas: surveillance and laboratory, case management, vaccination and community sensitization etc. Causes of immunity gaps and assigned and costed action plans to address the programmatic causes for the gaps.

Acknowledgements: Always include acknowledgements to the people and organizations that assisted in outbreak investigation and control.

Supporting documentation: Include documents that were used during the investigation including questionnaires, other forms, WHO guidance, scientific articles.

Evaluation of the impact of ORI campaigns

An impact evaluation takes longer than a process evaluation, because it requires measuring the effect on disease control and/or RI services. Information from pre-ORI assessments can be used as a baseline for comparisons with similar assessments after ORI. The programmatic impact of the vaccination strategies, including ORI, may be measured and compared by considering age-specific incidence. Case-based measles surveillance, with laboratory confirmation of measles infection, is the reference standard for evaluating programme impact. In settings with less mature surveillance systems the case-based data may have a lower yield.

Quasi-experimental studies, such as interrupted time series (ITS) analyses, which are assessing measles incidence repeatedly overtime, before and after the vaccine campaign, are commonly used. Two complementary measures estimate the public health impact of vaccines (70), the vaccine-preventable disease incidence (VPDI) and the number needed to vaccinate (NNV).

VPDI is the incidence of measles preventable by the vaccine. It measures the number of cases averted per unit of persons vaccinated (generally 100 000) and per unit of time (usually 1 year). VPDI is the difference between the incidence in unvaccinated group minus the incidence in the vaccinated group, which is also mathematically equivalent to the incidence in the unvaccinated \times VE. The latter formulation emphasizes that VPDI is a measure that incorporates both VE – which is a measure of how well a vaccine works – and the background disease incidence, a measure of the burden of the target disease.

$$\text{VPDI} = \text{Incidence}_{(\text{unvaccinated})} - \text{Incidence}_{(\text{vaccinated})} = \text{Incidence}_{(\text{unvaccinated})} \times \text{VE}$$

NNV quantifies the number of people or doses needed to prevent one case of measles. The formula is presented below. The number 100 000 is used in the formula because it is the standard for the calculation of incidence rates. The length of follow up for the calculation of VDPI is usually 1 year.

$$\text{NNV} = \frac{100\,000 / \text{VPDI}}{\text{Length of follow up for the calculation of VDPI}}$$

Rapid convenience monitoring

The most important objective of rapid convenience monitoring (RCM) is to find unvaccinated children in order to vaccinate them. Additional goals are to identify reasons for non-vaccination and plan and execute rapid corrective action. RCM data provide information on the general performance of the SIA and suggest how to refine strategies for reaching the hardest-to-reach children. RCM is a pass/fail assessment of the areas surveyed, not a coverage assessment. RCM data are collected using methods that are not designed to be representative of the population targeted for the SIA and, therefore, do not produce valid coverage estimates. RCM should be used while the ORI activity is still ongoing (referred to as intra-ORI RCM), and at the end of the ORI (referred to as post-ORI independent monitoring).

Intra-ORI RCM should start with an inhouse monitoring, selecting geographic areas such as a neighbourhood or village, where unvaccinated target-age children are more likely to be found. Pick a direction at random, and begin with the first household. If the household has eligible children, complete the inhouse monitoring form, indicating if the children received a vaccination during current ORI and eventually the reasons for being unvaccinated. Continue the survey until 15 households with at least one eligible child per household has been interviewed. The assessment should be complemented by out-of-house monitoring in areas where children may congregate (i.e. market, playground, etc.); document the immunization status on up to 10 ORI-eligible children. Finally, a *school monitoring* should be considered when a significant proportion of the ORI target age groups are enrolled in schools and when schools are used as temporary vaccination posts.

Post-ORI independent monitoring – immediately after all ORI vaccination activities have been completed – it is critical to conduct independent monitoring using the RCM methodology in all areas where initial data (coverage, intra-ORI RCM) or local knowledge suggests poor coverage. The main objective of post-ORI independent monitoring is to find unvaccinated children so that they can be targeted during mop-up activities 1–2 weeks after the ORI. In addition, such monitoring provides independent and critical information on ORI performance that would be very useful for future vaccination activities. See WHO's *Planning and implementing high-quality supplementary immunization activities for injectable vaccines: using an example of measles and rubella vaccines* for a more comprehensive description (10).

Desk review

Instructions

Review each information source listed in the first column. Record the date of the information source (e.g. March 2021), key recommendations that relate to the EPI system and measles-specific recommendations, as well as the status of each. Understanding the status of each recommendation may require discussion with colleagues, or review of available data.

Information source (Use most recent)	Purpose of the information source	Most recent period	Key findings/ recommendations	Measles specifics	Status of key findings/ recommendation
Health system					
Health sector review reports	Review the implementation of national health sector plans to assess sector performance and to agree on actions to address constraints in implementation or to improve performance.				
Joint external evaluations (JEE)	Assess country capacities to prevent, detect and rapidly respond to public health risks whether occurring naturally or due to deliberate or accidental events.				
Health system strengthening (HSS) application (Gavi)	Application for Gavi investment in health system strengthening directed towards improving coverage and equity through key strategic focus areas (data, supply chain, leadership and management, demand promotion).				

Information source (Use most recent)	Purpose of the information source	Most recent period	Key findings/ recommendations	Measles specifics	Status of key findings/ recommendation
EPI system					
Country multi-year plan (cMYP)/national immunization strategy	National-level multi-year plan for the EPI system. Includes budget.				
EPI review	Comprehensive assessment of the strengths and weaknesses of an immunization programme at national, subnational and service-delivery levels.				
Surveillance review	Comprehensive assessment of the strengths and weaknesses of disease surveillance system at national, subnational levels.				
Gavi joint appraisal (JA)	Review of the implementation progress and performance of Gavi support to the country, and of its contribution to improved immunization outcomes.				
Tailoring immunization programme (TIP) assessments	Understand enablers and barriers to vaccination particularly in undervaccinated or hesitant populations. Interventions to address barriers often defined, implemented and evaluated.				
Missed opportunities for vaccination (MOV) assessment	Assessment to demonstrate the magnitude and identify causes of missed opportunities for vaccination.				
Effective vaccine management assessment	Generates performance indicators and criteria scores for individual facilities, for each level of the supply chain, and for the entire supply chain.				
Data quality assessment	Evaluate different aspects of the immunization monitoring system at district and health unit levels.				

Information source (Use most recent)	Purpose of the information source	Most recent period	Key findings/ recommendations	Measles specifics	Status of key findings/ recommendation
Post-introduction evaluation, especially for measles vaccine	To understand the effect of the introduction of a vaccine into the existing immunization system.				
Reaching every district/Reaching every child planning and monitoring	Microplanning and monitoring of immunization coverage at subnational and operational levels.				
Vaccination coverage surveys	Population-based surveys of vaccination coverage. Can be national, subnational or for defined intervention (i.e. post-SIA).				
SIA results	Reports or other documentation of monitoring and evaluation of SIAs. Can include post-campaign coverage survey.				
Community-based surveys or assessments (e.g. KAPB surveys)	To understand provider and/or client knowledge, attitudes, practices and beliefs (behaviours) (KAPB) related to vaccination.				
Partner assessments (e.g. Gavi full country evaluations)	Understand and quantify the barriers to and drivers of immunization programme.				
Law, policy and governance					
Immunization laws	To understand the laws, legislation and policy governing the immunization programme.				
Operational-level EPI policies and guidelines	To understand operational-level information provided to health care workers managing and implementing the EPI.				
National immunization technical advisory group reports	Reviews of evidence and recommendations for operation of EPI system.				
Immunization coordination committee reports					

Summary of desk review

	Recommendation	Implementation status	Barrier for non-implementation	Comments
Programme management and financing				
Human resources and management				
Vaccine supply, quality and logistics				
Service delivery				
Disease surveillance				
Demand generation				
Monitoring				

ANNEX 12

Resources to inform development of strategies to address immunization system barriers

	Programme management and financing	Human resources	Vaccine supply and logistics	Service delivery	Monitoring coverage and AEFI	Immunization demand	Disease surveillance
Resources, references							
Global Routine Immunization Strategies and Practices (GRISP) (🌐)	●			●	●	●	
Reaching Every District (🌐)	●	●	●	●	●	●	
Reducing missed opportunities for vaccination (MOV): intervention guidebook (🌐)	●	●	●	●		●	
Improving vaccination demand and addressing hesitancy (🌐)						●	
Vaccination in the second year of life (2YL) (🌐)	●	●		●	●	●	
School-based immunization (🌐)	●	●		●	●		
Vaccination in humanitarian emergencies (🌐)	●	●	●	●	●	●	
Engagement of the private sector in immunization service delivery (🌐)	●	●	●	●	●		
Summary of WHO position papers on routine vaccines: (🌐) Table 3 (Recommendations for delayed or interrupted routine vaccines); Table 4 (Vaccination of health care workers)	●						
Periodic intensification of routine immunization (PIRI) (🌐)	●	●	●	●	●	●	
Safety and acceptability of multiple injections (🌐)							
Tailoring immunization programmes (🌐)	●			●		●	
Immunization Academy training videos (🌐)	●	●	●	●	●	●	●

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