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Development of a District-Level Programmatic Assessment Tool for Risk of Measles Virus Transmission

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Abstract

All six World Health Organization (WHO) regions have now set goals for measles elimination by or before 2020. To prioritize measles elimination efforts and use available resources efficiently, there is a need to identify at-risk areas that are offtrack from meeting performance targets and require strengthening of programmatic efforts. This article describes the development of a WHO measles programmatic risk assessment tool to be used for monitoring, guiding, and sustaining measles elimination efforts at the subnational level. We outline the tool development process; the tool specifications and requirements for data inputs; the framework of risk categories, indicators, and scoring; and the risk category assignment. Overall risk was assessed as a function of indicator scores that fall into four main categories: population immunity, surveillance quality, program performance, and threat assessment. On the basis of the overall score, the tool assigns each district a risk of either low, medium, high, or very high. The cut-off criteria for the risk assignment categories were based on the distribution of scores from all possible combinations of individual indicator cutoffs. The results may be used for advocacy to communicate risk to policymakers, mobilize resources for corrective actions, manage population immunity, and prioritize programmatic activities. Ongoing evaluation of indicators will be needed to evaluate programmatic performance and plan risk mitigation activities effectively. The availability of a comprehensive tool that can identify at-risk districts will enhance efforts to prioritize resources

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and implement strategies for achieving the Global Vaccine Action Plan goals for measles elimination.

Keywords

Elimination; measles; outbreak; risk assessment

1. INTRODUCTION

Measles is a highly contagious viral disease that is an important cause of death and disability among children globally.[1] Since the invention and widespread use of a safe, inexpensive, and effective vaccine, progress has been made in the global control of measles.[2] During 2000–2012, annual reported measles incidence decreased 77%, from 146 to 33 cases per million population, and estimated measles deaths decreased 78%, from 562,400 to 122,000, both historically low levels.[1]

In 2012, the World Health Organization (WHO) and its global partners approved the Global Vaccine Action Plan (GVAP), which includes a goal for measles elimination in five of the six WHO regions by 2020.[3] All six WHO regions have set a goal for measles elimination by or before 2020.[1,4] Measles elimination was achieved in the Region of the Americas with the last endemic case reported in 2002, and the Western Pacific Region is approaching measles elimination.[5–7] Despite this progress, on the basis of current performance trends, GVAP targets will not be achieved on time, and additional focused efforts will be needed to achieve the regional elimination goals.[1]

The Measles & Rubella Initiative established the Global Measles and Rubella Strategic Plan for 2012–2020 with goals aligned to the GVAP, and aims to (1) achieve and maintain high levels of population immunity through high coverage with two doses of measles–rubella-containing vaccines, (2) establish effective surveillance to monitor disease and evaluate progress, (3) develop and maintain outbreak preparedness for rapid response and appropriate case management, (4) communicate and engage to build public confidence in and demand for vaccination, and (5) conduct research and development to support operations and improve vaccination and diagnostic tools.[8] To prioritize efforts to implement these strategies and to guide program activities and use available resources efficiently, a need exists to identify areas that are offtrack from meeting programmatic targets and prioritize control efforts in these areas. Regular risk assessments are also important to sustain elimination efforts and to help with the process of verifying measles elimination.

In 2014, with support by a grant from the Bill & Melinda Gates Foundation, the WHO and the U.S. Centers for Disease Control and Prevention (CDC) collaborated to develop a user-friendly tool to assess the performance of measles elimination efforts at the district or subnational level and to identify high-risk districts so that recommended actions can be taken to address programmatic weaknesses and strengthen measles elimination efforts. A similar tool for conducting polio risk assessments was developed recently by partners of the Global Polio Eradication Initiative, and that experience provided an analytical framework as a starting point for the development of a measles risk assessment tool.[9] Our efforts

also built upon existing tools used to calculate population measles-susceptibility profiles, such as the Measles Strategic Planning Tool,[10] a strategic planning tool focused on national-level population immunity that was used to inform national program managers' decision-making process for adopting measles vaccination strategies, and a tool designed by the WHO African Regional Office (AFRO) for rapidly estimating district-level population measles susceptibility among children less than five years of age to guide outbreak response immunization (ORI).[10,11]

This article describes the development of a WHO measles programmatic risk assessment tool intended for monitoring, guiding, and sustaining measles elimination efforts in all six WHO regions. We outline the tool development process; the tool specifications and requirements for data inputs; the analytical framework of risk categories, indicators, and scoring; and the risk category assignment.

2. METHODS

2.1. Tool Development Process

In May 2014, WHO and CDC conducted a workshop in Geneva, Switzerland, for a group of experts to review and discuss the development of a global programmatic risk assessment tool to be used by the six WHO regional offices: AFRO, Eastern Mediterranean Regional Office, European Regional Office, Southeast Asian Regional Office, Western Pacific Regional Office (WPRO), and Pan-American Health Organization in the Region of the Americas.

2.2. Tool Specifications and Requirements for Data Inputs

To ensure the programmatic utility of the tool, the specification and requirements for data inputs were defined by expert opinion and the programmatic experiences of each WHO regional office. Fig. 1 summarizes a checklist of data sources required for the measles risk assessment tool.

2.3. Framework of Risk Categories, Indicators, and Scoring

Overall risk was assessed as the sum of indicator scores that fall into four main categories: population immunity, surveillance quality, immunization program performance, and threat assessment. The scoring for each indicator score was based on expert consensus from the Geneva workshop.

2.4. Risk Category Assignment

On the basis of the overall score, the tool assigns each district to a programmatic risk category of low, medium, high, or very high. The cut-off criteria for the risk categories were set at the 50th, 75th, and 90th percentiles of the distribution of all potential scores from all possible combinations of individual indicator cutoffs. All risk indicator data were managed using Excel (Microsoft Corporation) and ArcGIS (ESRI). Prototype tool development used available historical data from three countries (Senegal, Namibia, and the Philippines) to assess risk category assignment results.

3. RESULTS

3.1. Tool Development Process

Initial development of the tool using country examples from WPRO and AFRO was presented at the workshop. The working group discussed and developed consensus on the data input requirements, risk categories, and indicators of the measles programmatic risk assessment tool, and identified potential future applications and use of its results.

3.2. Tool Specifications and Requirements for Data Inputs

To ensure the programmatic utility of the tool, we determined that the tool needs to be user-friendly for national program managers to conduct periodic programmatic assessments to assign risk of measles transmission at the district (second subnational) level. The required data inputs include readily available and routinely collected data from the immunization and surveillance programs as reported by the Ministry of Health. For simplicity and to show improvements in reducing risk over time, the tool requires data from the past three calendar years.

Data inputs for the tool are from the district (second subnational) level; however, if these data are missing, incomplete, or unreliable, then data from the provincial (first subnational) level may be used as a substitute. Required data inputs include administrative vaccination coverage for the first dose of measles-containing vaccine (MCV1), second dose of measles-containing vaccine (MCV2), and first dose of diphtheria, pertussis, and tetanus vaccine or pentavalent vaccine; however, vaccination coverage estimates from population-based surveys, if available, may be substituted for administrative vaccination coverage data. If a supplemental immunization activity (SIA) was conducted during the past three years, data on the target age group and administrative coverage are needed. ORI campaign coverage data can be considered if a preventive SIA was not conducted within the past three years and if the ORI targeted a geographical area that included the entire district. Measles case-based surveillance data, including individual linelisting of cases, are required to calculate surveillance performance indicators; shape files at the district level are needed for mapping districts by risk category. Population estimates or census data are required to calculate population density; local knowledge and expert opinion from national EPI managers are required to identify special populations such as the presence of vulnerable groups.

3.3. Analytical Framework of Categories, Indicators, and Scoring

The indicators determined to have programmatic relevance and importance for inclusion in the tool and their cut-off criteria were determined by expert opinion and the programmatic experiences of each WHO regional office. All indicators in the four risk assessment categories were scored and summed to assign an overall risk score for each district (range of possible scores: 0–100).

Tables I–IV summarize the indicators used for each of the four risk assessment categories, potential corresponding information sources, and rationale for inclusion in the tool. The category of population immunity received the greatest proportion of total possible risk points (40%), followed by threat assessment (24%), surveillance quality (20%), and program

performance (16%). Table I presents the set of indicators used to characterize the population immunity as it relates to overall measles susceptibility and provides details about the criteria and risk point assignment used for each indicator. Vaccination coverage data from the past three years were used to calculate indicators. Vaccination coverage estimates from surveys, if conducted within past three years and including birth cohorts of recent three years, can be used instead of administrative coverage. In countries that do not have measles SIAs as part of their national strategy and are in a postelimination period, zero risk points will be assigned for the population immunity indicators related to SIAs.

Table II presents the set of indicators that assess the ability of a surveillance system to detect and confirm measles cases quickly and accurately. High-quality case-based surveillance is required for detailed case reporting, rapid detection of measles virus circulation, and effective public health and outbreak response activities. For simplicity and to reflect the current status of surveillance quality, surveillance data from the most recent year are used to calculate the performance indicators. Indicators used in the tool might not apply for certain high-income countries that have been measles-free for some time and no longer report the standard surveillance indicators. In such instances, additional evidence to demonstrate measles surveillance sensitivity and quality should be considered and assessment results evaluated on a case-by-case basis for each district. Countries where substantial numbers of measles cases are detected in the private sector will need to demonstrate that these cases are reported to the national surveillance systems and that laboratory results are confirmed by an accredited laboratory. In low- and middle-income countries where measles cased-based surveillance has not been established, the maximum number of risk points will be assigned for all surveillance indicators.

Table III provides the list of indicators used to assess immunization program performance. This category assesses specific aspects of routine immunization (RI) services in addition to trends in coverage of the first and second dose of MCV. Indicators in the threat assessment category include factors that were identified as likely contributors to the potential for measles virus importation and transmission in a population (Table IV).

3.4. Risk Category Assignment

In an effort to choose objective and consistent cut-points for each assessment, risk assignment categories were defined using the 50th, 75th, and 90th percentiles of the distribution of all possible combinations of individual indicator cutoffs. On the basis of the overall score of 100, the tool assigns a “low risk” to districts with an overall score of ≤47, a “medium risk” to districts with scores from 48–54, a “high risk” to districts with scores from 55–60, and a “very high risk” to districts with scores ≥61. For “high risk” and “very high risk” districts/areas, the underlying categories driving the overall risk scores were examined to guide recommended actions to improve the program performance. Fig. 2 shows the results of category assignments generated from the final version of the tool in Senegal, Namibia, and the Philippines. High risk and very high risk districts were identified in the capital regions in all three test countries, which included the Dakar and Metro Manila areas in the expanded areas of Figs. 2(a) and 2(c) for Senegal and the Philippines, respectively, and Windhoek in the center of Namibia as shown in Fig. 2(b). More details of the three

countries used for prototype development and visual and statistical comparisons of risk categories with historical outbreak data are described elsewhere.[12–14]

4. DISCUSSION

The WHO programmatic risk assessment tool for measles was created with the aim to help monitor and guide measles elimination efforts in all six WHO regions. The tool is intended to be used periodically by national program managers to monitor implementation of measles elimination strategies within a country. Data inputs in four categories were combined to assess subnational programmatic risk and incorporated established indicators for monitoring progress toward measles elimination.[15] The results can be used to formulate data-driven recommendations for strengthening measles elimination efforts, mobilizing and prioritizing resources, and focusing programmatic efforts in at-risk districts/areas. Using existing established indicators and readily available data sources ensures that the tool will be relevant and user-friendly. Results can be shown by maps with districts color-coded by risk category. In addition, district risk scores can be displayed by category, allowing for easy interpretation of results and better understanding of what programmatic weaknesses are driving the overall score. Establishing standardized cut-off criteria will allow for comparisons of risk assessment results over time.

The results may be used for advocacy and communication to policymakers, mobilization of resources for corrective actions, management of population immunity, prioritization of programmatic activities, and fostering ownership of measles elimination efforts at the subnational level. Districts identified as high or very high risk by the tool can be prioritized for interventions to strengthen surveillance, increase routine vaccination coverage, update detailed microplans, help guide supervision during SIAs, and assist in planning measles outbreak response activities. A high score can be an indicator for general programmatic weakness and existing immunity gaps to other vaccine-preventable diseases (VPDs); therefore, assessment results could be used to help focus other immunization activities such as VPD surveillance reviews and RI (EPI) reviews. Pilot testing the tool in additional countries and regions will provide examples of its utility in a variety of settings. An electronic version of the tool with automated features is under development with planned availability by early 2016.

Limitations of the tool include its dependence on the quality of the data inputs. For example, poor-quality data for administrative vaccination coverage will produce unreliable risk assignments within a country. The tool was not designed to be predictive of measles outbreaks but rather to assess the level of risk for measles transmission in a district/area if virus were to be introduced, using key programmatic indicators. Comparisons of risk categories with historical outbreak data were performed in three countries used for prototype development, and the results showed correlation between districts with high scores and the occurrence of measles transmission during the following year in two of the three countries.[12–14] Even if the tool has limited value in predicting outbreaks, results of the risk assessment can be used to guide measles elimination strategies and identify programmatic areas that require strengthening.

As countries get closer to measles elimination, outbreaks among older children and young adults are likely to occur during outbreaks with sustained measles virus transmission. The assessment tool accounts for this potential population susceptibility by including data for reported confirmed or measles-compatible cases among those aged 5–14 years and ≥15 years. This indicator for risk of measles susceptibility among older population was placed in the threat category, rather than the population immunity category, primarily because of the lack of available historical vaccination records among older populations or the presence of natural immunity due to previous infection. Moreover, rather than factoring in many years of historical data, which would lock some districts into the same category over time despite recent improvements, the tool uses recent data, allowing for the recommended remedial actions based on the assessment to be relevant and easily reflected in future assessments, providing encouragement to improve the program.

Future development of revised versions of this tool may be warranted if additional indicators become standardized in reporting, such as those in RI programs, and changes of epidemiological profiles occur in regions as they move closer to achieve measles elimination. The availability of a comprehensive tool that can identify districts with high scores will enhance efforts to prioritize resources and implement strategies for achieving the GVAP goals for measles elimination by 2020.

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Data Inventory	Assessment Year	Data Prior to Assessment Year		
Immunization unit		Year 1	Year 2	Year 3
1. Population estimates	√	√	√	√
2. Administrative MCV1 coverage data[1]		√	√	√
3. Administrative MCV2 coverage data[1]		√	√	√
4. Administrative DPT1 coverage data				√
5. SIA administrative coverage data[1,2]		√		
8. Identify vulnerable populations[3]		√		
9. Shape file of country (district level and for each year if different)	√	√	√	√
Surveillance unit				
1. Case-based measles surveillance data				√
2. Surveillance data dictionary (or explanation of coding for each variable)		√		

Fig. 1.

Checklist of data sources required for the measles programmatic risk assessment tool: DPT1 = first dose in series for diphtheria, pertussis, and tetanus vaccination; MCV1 = first dose in series for measles-containing vaccination; MCV2 = second dose in series for measles-containing vaccination; SIA = supplementary immunization activity. (1) Vaccination coverage estimates from surveys if conducted within past three years and includes birth cohorts of recent three years that can be used to replace administrative coverage. (2) Outbreak response immunization (ORI) campaign coverage data can be considered if an SIA was not conducted within the past three years and if the ORI targeted a geographical area that included the entire district. (3) Presence of vulnerable groups includes any of the following: (i) migrant population, internally displaced population, slums, or tribal communities; (ii) communities resistant to vaccination (i.e., religious, cultural, philosophical reasons); (iii) security and safety concerns; (iv) areas frequented by calamities/disasters; (v) poor access to health services because of terrain/transportation issues; (vi) lack of local political support; (vii) high-traffic transportation hubs/major roads or bordering large urban areas (within and across countries); (viii) areas with mass gatherings (i.e., trade/commerce, fairs, markets, sporting events, and high density of tourists).

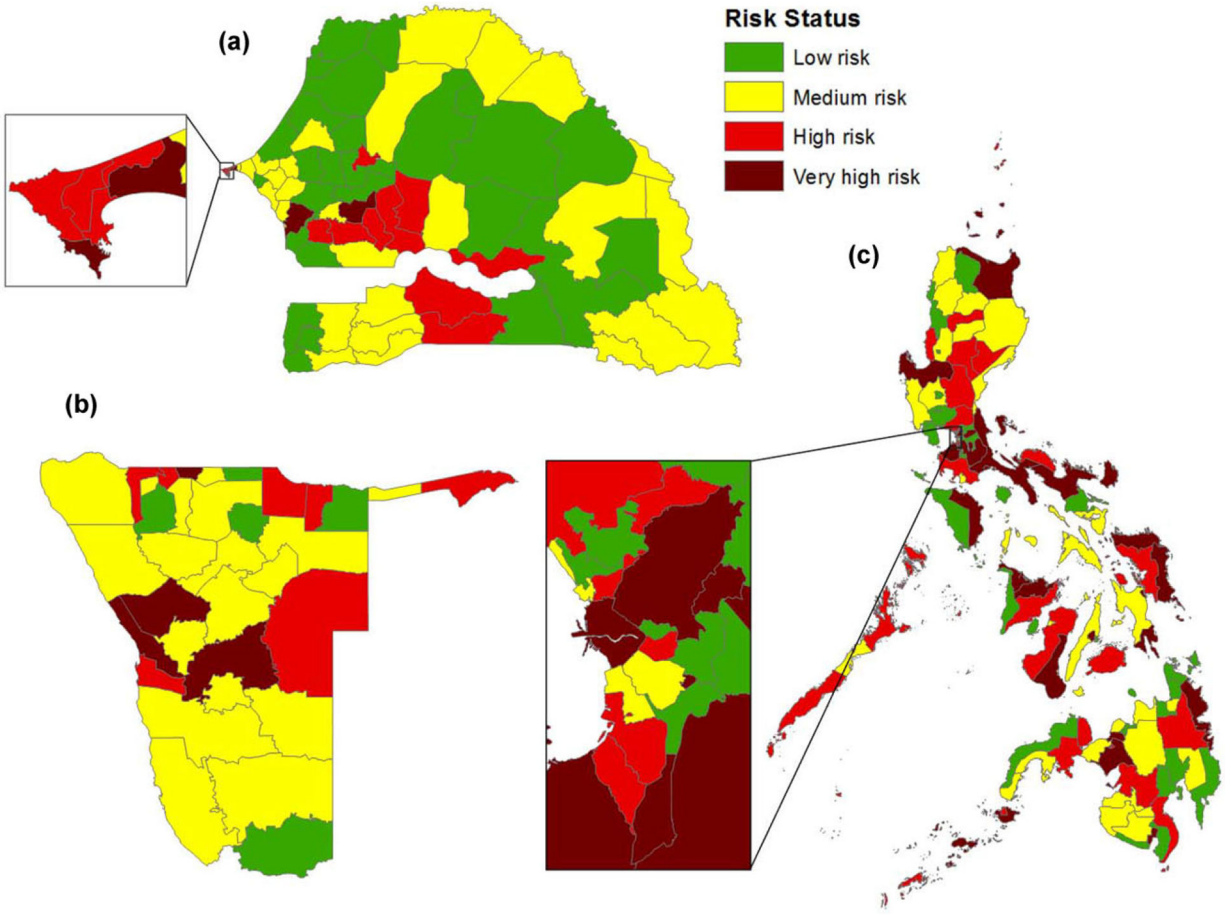

Fig. 2.

Measles risk assessment profiles in: (a) Senegal 2006–2008, (b) Namibia 2006–2008, and (c) the Philippines 2010–2012.

Table I.

Population Immunity Indicators Used in the World Health Organization Measles Programmatic Risk Assessment

Population Immunity Indicators (Information Source(s))	Rationale	Cut-Off Criteria (Risk Points)	Comments
District MCV1 coverage (administrative coverage reports, survey coverage estimates)	Quality of RI for first dose of MCV	≥95% (+0) 90–94% (+2) 85–89% (+4) 80–84% (+6) <80% (+8)	• Calculate the average administrative coverage from the past three years to assign risk point. • If coverage survey estimates available at district level (conducted within past three years and includes birth cohorts of recent three years) can replace administrative coverage.
Proportion of neighboring districts with <80% MCV1 (administrative coverage reports, survey coverage estimates)	Provides context about geographical gaps in immunity	<50% (+0) 50–74% (+2) ≥75% (+4)	• Assess representativeness of immunity gap in surrounding area of a district. • If coverage survey estimates available at district level (conducted within past three years and includes birth cohorts of recent three years) can replace administrative coverage. • Also consider districts from bordering countries if data are available.
District MCV2 coverage (administrative coverage reports, survey coverage estimates)	Quality of RI for second dose of MCV	≥ 95% (+0) 90–94% (+2) 85–89% (+4) 80–84% (+6) <80% (+8)	• Calculate the average administrative coverage from the past three years to assign risk point. • If MCV2 was introduced in the past three years, then only use the years with reported coverage. • If MCV2 has not been introduced, then give maximum score. • If coverage survey estimates available at district level (conducted within past three years and includes birth cohorts of recent three years) can replace administrative coverage.
Measles SIA conducted within the past three years (administrative SIA coverage reports, survey coverage estimates)	Raises population immunity beyond RI	Yes, ≥95% coverage (+0) Yes, 90–94% coverage (+2) Yes, 85–89% coverage (+4) Yes, <85% coverage/no coverage data (+6) No SIA(+8)	• Assess SIA administrative coverage to assign risk point. Districts with routine MCV1 and MCV2 administrative coverage (>95%) receives 0 points. • If no nationwide SIA was conducted in the past three years but an outbreak response immunization (ORI) campaign was performed for an entire district, report coverage to assign risk point. • If post-SIA coverage survey estimates available at district level can replace administrative coverage. • If measles SIAs not part of national strategy, assign 0 risk points (i.e., countries in postelimination period or high-income countries)
Target age group of measles SIA conducted within the past three years (administrative SIA coverage reports)	Suggests a larger susceptible population if narrow age group targeted	Wide age group (+0) Narrow age group (+2) No SIA (+2)	• Narrow age group is defined as <5 birth cohorts (9–59 m or less). Wide age group is defined as > 5 birth cohorts (greater than 9–59 m). Districts with >95% for both routine MCV1&2 receive 0 risk points. • If measles SIAs not part of national strategy, assign 0 risk points (i.e., countries in postelimination period or high-income countries).
Years since the last measles SIA (administrative SIA coverage reports)	Indicates a buildup of susceptible population	≤1 year (+0) 2 years (+2) ≥3 years(+4)	• Districts with >95% for both MCV1&2 receive 0 risk points. • If measles SIAs not part of national strategy, assign 0 risk points (i.e., countries in postelimination period or high-income countries).

Population Immunity Indicators (Information Source(s))	Rationale	Cut-Off Criteria (Risk Points)	Comments
Proportion of suspected measles cases who are unvaccinated or have unknown vaccination status (case-based surveillance data)	Suggests clusters of susceptible population	<20% (+0) ≥20% (+6)	• Calculate proportion of suspected measles cases who are unvaccinated with MCV or have unknown vaccination status from the past three years to assign risk point. • Limit calculation to only those who are age-eligible for MCV1 and older. • If no suspected measles cases were reported over the past three years, then give maximum score.

MCV1 = first dose in series for measles-containing vaccination; RI: routine immunization; MCV2 = second dose in RI series for measles-containing vaccination; SIA = supplementary immunization activity.

Table II.

Surveillance Quality Indicators Used in the World Health Organization Measles Programmatic Risk Assessment

Surveillance Quality Indicators (Information Source(s))	Rationale	Cut-Off Criteria (Risk Points)	Comments
Nonmeasles discarded rate (case-based surveillance data)	Relates to surveillance sensitivity	≥2 per 100,000 (+0) <2 per 100,000 (+4) <1 per 100,000 (+8)	• Assign risk point using annual measles case-based surveillance data from most recent year. • For countries that have introduced rubella vaccine, use nonmeasles, nonrubella discarded rate.
Proportion of measles cases with adequate investigation (case-based surveillance data)	Relates to quality and sensitivity of surveillance	≥80% (+0) <80% (+4)	• An adequate investigation is defined as a case investigated within 48 hours of notification that includes all 10 core variables: (1) case identification, (2) date of birth/age, (3) sex, (4) place of residence, (5) vaccination status or date of last vaccination, (6) date of rash onset, (7) date of notification, (8) date of investigation, (9) date of blood sample collection, and (10) place of infection or travel history.[15] • If no investigations were conducted, then give maximum score.
Proportion of measles cases with adequate specimens collection (case-based surveillance data)	Relates to quality and specificity of surveillance	≥80% (+0) <80% (+4)	• Adequate specimen collection is defined as serum collection within 28 days of rash onset. • Exclude epidemiologically linked cases. If no specimens were collected, then give maximum score.
Proportion of measles cases with laboratory results available in a timely manner (case-based surveillance data)	Relates to laboratory surveillance system performance	≥80% (+0) <80% (+4)	• Timeliness is defined as 10 days from the date of specimen collection to the date of laboratory report of results. • If no specimens were received, then give maximum score.

Table III.

Program Performance Indicators Used in the World Health Organization Measles Programmatic Risk Assessment

Program Performance Indicators (Information Source(s))	Rationale	Cut-Off Criteria (Risk Points)	Comments
Trends in MCV1 coverage (administrative coverage reports, survey coverage estimates)	Addresses sustainability of vaccination coverage	Increasing or same (+0) ≤10% decline (+2) >10% decline (+4)	• Assess administrative coverage and assign risk point for slope/trend in the past three years. • If coverage survey estimates available at district level (conducted within past three years and includes birth cohorts of recent three years) can replace administrative coverage.
Trends in MCV2 coverage (administrative coverage reports, survey coverage estimates)	Addresses sustainability of vaccination coverage	Increasing or same (+0) ≤10% decline (+2) >10% decline (+4)	• Assess administrative coverage and assign risk point for slope/trend in the past three years. • If coverage survey estimates available at district level (conducted within past three years and includes birth cohorts of recent three years) can replace administrative coverage. • If MCV2 has not been introduced, then give maximum score.
MCV1–MCV2 drop-out rate (administrative coverage reports, survey coverage estimates)	Indicates failure to complete the measles vaccination schedule	≤10% (+0) > 10% (+ 4)	• Assign risk point using administrative coverage data from most recent year. • If coverage survey estimates available at district level (conducted within past three years and includes birth cohorts of recent three years) can replace administrative coverage. • If MCV2 has not been introduced, then give maximum score.
DPT1–MCV1 drop-out rate (administrative coverage reports, survey coverage estimates)	Indicates failure to start measles vaccination schedule after beginning RI schedule	≤10% (+0) > 10% (+ 4)	• Assign risk point using administrative coverage data from most recent year. • If coverage survey estimates available at district level (conducted within past three years and includes birth cohorts of recent three years) can replace administrative coverage. • First dose of pentavalent vaccination (Penta1) may substitute DPT1 if used in country.

DPT1= first dose in series for diphtheria, pertussis, and tetanus vaccination; RI: routine immunization; MCV1 = first dose in RI series for measles-containing vaccination; MCV2 = second dose in RI series for measles-containing vaccination.

Table IV.

Threat Assessment Indicators Used in the World Health Organization Measles Programmatic Risk Assessment

Threat Assessment Indicators (Information Source(s))	Rationale	Cut-Off Criteria (Risk Points)	Comments
≥1 measles case reported among children less than five years (case-based surveillance data)	Signifies risk for further transmission	No (+0) Yes (+4)	• Assign risk point using annual measles case-based surveillance data from most recent year. • Include confirmed, epidemiologically linked, and clinically compatible cases and exclude discarded cases.
≥1 measles case reported among persons 5–14 years (case-based surveillance data)	Signifies risk for further transmission	No (+0) Yes (+3)	• Assign risk point using annual measles case-based surveillance data from most recent year. • Include confirmed, epidemiologically linked, and clinically compatible cases and exclude discarded cases.
≥1 measles case reported among persons ≥15 years (case-based surveillance data)	Signifies risk for further transmission	No (+0) Yes (+3)	• Assign risk point using annual measles case-based surveillance data from most recent year. • Include confirmed, epidemiologically linked, and clinically compatible cases and exclude discarded cases.
Population density (population census data)	Higher risk for transmission in densely populated areas	0–50/km^2 (+0) 51–100/km^2 (+1) 101–300/km^2 (+2) 301–1,000/km^2 (+3) >1,000/km^2 (+4)	• Assign risk point using population census data from most recent year and divided by district area (extracted from shape files used for mapping).
≥1 measles case reported in a bordering district within the past 12 months (case-based surveillance data)	Cross-border transmission has greatest risk for importation	No (+0) Yes (+2)	• Assign risk point using annual measles case-based surveillance data from most recent year. • Include confirmed, epidemiologically linked, and clinically compatible cases and exclude discarded cases. • Consider all land borders; for island borders, refer to local knowledge whether frequent population movement occurs with neighboring district. • Consider cross-country borders if data are available.
Presence of vulnerable groups (local knowledge from national EPI manager)	Groups that are often undervaccinated or play a role in transmission	No vulnerable groups (+0) One risk point for each vulnerable group present (up to maximum of +8)	Assign one risk point for the presence of each of the following: (1) migrant population, internally displaced population, slums, or tribal communities; (2) communities resistant to vaccination (i.e., religious, cultural, and philosophical reasons); (3) security and safety concerns; (4) areas frequented by calamities/disasters; (5) poor access to health services because of terrain/transportation issues; (6) lack of local political support; (7) high-traffic transportation hubs/major roads or bordering large urban areas (within and across countries); (8) areas with mass gatherings (i.e., trade/commerce, fairs, markets, sporting events, and high density of tourists)