**Global Measles Incidence and Vaccination Coverage, 2015–2024**

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**Abstract--** Measles remains a significant global public health challenge, with rising incidence in recent years despite the availability of an effective vaccine. This project presents a visualization-driven analysis of global measles incidence from 2015 to 2024, integrating World Health Organization (WHO) regional time trends, country-level burden, laboratory-confirmed cases, vaccination coverage, and dose dropout indicators. Using data from the WHO and UNICEF, the presented visualization--line charts, heatmaps, bar charts, and small multiples—reveal patterns in outbreak timing, geographic disparities, and immunity gaps. The analyses highlight strong regional heterogeneity and consistent associations between lower two-dose vaccination coverage (MCV2) and elevated incidence. These findings underscore ongoing susceptibility within multiple regions and emphasize the continued importance of maintaining high vaccination coverage.

**Index Terms—** Measles, vaccination coverage, MCV1/MCV2, WHO regions, global health surveillance, data visualization

## 1 INTRODUCTION

Measles is among the most contagious human infectious diseases, and despite decades of global vaccination progress, it continues to resurge across multiple world regions. Routine immunization interruptions, vaccine hesitancy, conflict displacement, and impacts from the COVID-19 pandemic have all contributed to widening immunity gaps [1]. In 2019, measles incidence reached a global peak not seen in nearly two decades, with renewed outbreaks occurring again in 2022–2024 [1].

Understanding where and why these patterns occur requires clear and interpretable representations of surveillance data. While WHO and UNICEF make annual incidence and vaccination data publicly available [2], [3], the raw datasets can be difficult to parse due to their scale, geographic span, and year-to-year variability. Visualization methods offer a way to translate this high-dimensional information into interpretable patterns.

This project applies data visualization techniques to characterize global measles trends from 2015 to 2024. We explore global temporal changes, regional disparities, and country-specific burden, integrating vaccination indicators to examine how gaps in two-dose coverage relate to measles resurgence. The aim is to provide an accessible analytical framework that supports epidemiologic insight, policy planning, and communication to diverse public health audiences.

## 2 RELATED WORK

Global measles surveillance is supported primarily by WHO's case-based reporting system, which provides annual country-level incidence values, and by WHO/UNICEF's joint estimates of immunization coverage. While WHO publishes dashboards summarizing outbreaks and vaccination progress [4], these tools generally present each metric separately. Integrating incidence, coverage, and dropout patterns into a single visual analytic workflow remains uncommon.

Research in visualization has emphasized the importance of multi-layered and multi-scale displays for complex global health data. Munzner's Visualization Analysis and Design (2014) outlines principles for perceptually uniform color scales, use of small multiples, and task-oriented narrative structuring [5]. Prior public datasets, including the "Our World in Data" measles series and the TidyTuesday measles project, provide historical visualizations but lack integration with multi-

year vaccination metrics or structured regional comparisons [6].

This project extends these efforts by presenting an integrated visual exploration of incidence, vaccination coverage, and dropout trends across WHO regions, combining temporal, categorical, and geospatial perspectives into a unified analysis.

## 3 METHODS

### 3.1 Data Sources

Data for this analysis were obtained from:

- **WHO Measles Surveillance Reports (2015–2024):** Measles cases, laboratory-confirmed cases, and population denominators per country and WHO region [2].
- **WHO/UNICEF Immunization Coverage Estimates:** Measles-containing vaccination 1 and 2 (MCV1/MCV2) coverage percentages per country and WHO region [3].

The six WHO regional groupings used for geographic classification are as follows: Africa, Americas, Eastern Mediterranean, Europe, South-East Asia, and Western Pacific.

### 3.2 Data Processing

All data processing was conducted in R using the *tidyverse* package. Key steps included:

1. Cleaning and merging incidence files for 2015–2024.
2. Calculating incidence per million population.
3. Standardizing country codes using the *countrycode* package.
4. Joining vaccination coverage and dropout data by country-year.
5. Aggregating incidence to regional and global levels for summary visualizations.
6. Categorizing MCV2 coverage into interpretable bins (0–20%, 20–40%, 40–60%, 60–80%, 80–100%).

### 3.3 Visualization Techniques

To reflect the multi-dimensional nature of measles epidemiology, several visualization approaches were used:

- **Global Line Chart:** Summarizes decade-long international trends while comparing mean incidence.
- **Bar Charts:** Compares average incidence across WHO regions and top ten countries with highest burden.
- **Heat Maps**: Highlights temporal clustering of regional and country-level (top 10) outbreaks.
- **Lab-Confirmed Ratio Bar Charts:** Compares the proportion of lab confirmed cases across regions and ten countries with the lowest ratios.
- **Faceted Line Charts:** Visualizes MCV1–MCV2 dropout percentage over time by region.
- **MCV2 Coverage Binned Chart:** Shows incidence distributions across discrete vaccination coverage groups.
- **Dual-Axis Line Chart:** Aligns regional incidence with MCV2 coverage trajectories to explore susceptibility patterns.

Sequential palettes were used for incidence to maintain perceptual ordering, while categorical palettes distinguished regional trends. Heatmaps were designed with consistent low-to-high gradients for interpretive clarity.

## 4 RESULTS

### 4.1 Global Incidence Trends

The global trend shows clear outbreak cycles. Incidence steadily declined from 2015 to a trough around 2017 before surging to a major global peak in 2019. Pandemic-era reductions in population movement contributed to a temporary drop in 2020–2021, but incidence increased sharply again from 2022 to 2024, indicating renewed susceptibility worldwide.

### 4.2 Regional Comparisons

Regional averages reveal substantial disparities. The Western Pacific Region had the highest overall incidence across the decade, with Africa showing persistently elevated moderate-to-high levels. Europe demonstrated notable outbreak surges in 2018–2019 and again in 2024. The Region of the Americas maintained low

incidence throughout, consistent with longstanding elimination status, though isolated outbreaks did occur.

The regional heatmap further illustrates the timing of these outbreaks, capturing intense clusters in Europe and the Western Pacific during key years.

### 4.3 Country-Level Burden

The highest-burden countries included Mongolia, Madagascar, Kyrgyzstan, Somalia, Yemen, Liberia, Kazakhstan, Azerbaijan, Romania, and Ukraine. These nations experienced intense outbreaks, often triggered by a combination of suboptimal vaccination coverage, conflict-related disruptions, or health system instability. The top 10 country heatmap showed that outbreaks tend to occur in short, intense waves rather than consistently year-to-year.

### 4.4 Laboratory Confirmed Cases

Regional patterns showed substantial variation in the proportion of measles cases that were laboratory confirmed. The Americas reported the highest confirmation ratios, reflecting strong surveillance and testing capacity, whereas Africa and South-East Asia had the lowest proportions, suggesting more limited access to laboratory verification.

At the country level, the lowest confirmation ratios were observed in South Sudan, Tonga, Equatorial Guinea, Namibia, Nigeria, and Liberia. These low ratios indicate that most suspected cases were not laboratory verified, highlighting gaps in diagnostic capacity or reporting completeness in settings with weaker health infrastructure.

### 4.5 Vaccination Coverage and Dropout

MCV1–MCV2 dropout patterns varied greatly by region. Africa exhibited the highest dropout levels, though with some improvement in recent years. South-East Asia showed consistent reductions in dropout percentages, reflecting strengthened immunization systems. Europe and the Americas maintained relatively low dropout rates.

A clear relationship emerged between vaccination coverage and incidence. Countries with 0–20% MCV2 coverage experienced incidence levels several times higher than those with 60–80% coverage. This negative association highlights the importance of high two-dose coverage in preventing widespread outbreaks.

### 4.6 Combined Incidence–Coverage Dynamics

Paired regional trends revealed that rising incidence in Africa and Eastern Mediterranean regions often coincided with stagnation or declines in MCV2 coverage. Europe experienced outbreaks despite relatively steady coverage, indicating that immunity gaps—rather than coverage alone—may drive episodic surges.

## 5 DISCUSSION

The integrated visualization approach used in this project demonstrates how combining multiple surveillance dimensions can illuminate complex epidemiologic patterns. While global incidence patterns illustrate broad outbreak cycles, regional and country-level views reveal distinct vulnerabilities. Visualization methods such as small multiples, heatmaps, and segmented bar charts effectively highlight these differences.

The findings reinforce core public health principles: high two-dose vaccination coverage is essential, dropout rates matter, and immunity gaps—even in high-coverage settings—can precipitate significant outbreaks. The resurgence of measles across Europe and Western Pacific regions emphasizes the importance of not only vaccination programs but also consistent public health infrastructure, early detection, and outbreak response capacity.

## 6 FUTURE WORK

Future enhancements to this project could include:

- Developing an interactive dashboard for real-time exploration.

- Adding geographic maps to complement aggregated regional displays.
- Applying predictive modeling to identify countries at highest near-term risk.
- Automating data refresh pipelines to support continuous monitoring.

These extensions would expand the analytical utility of the tools developed here and support ongoing surveillance and prevention efforts.

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