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Methodological Innovations in Forecasting the Global Burden of Antimicrobial Resistance: Integrating Predictive Modeling, Scenario Analysis and Data-Driven Insights

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Poster

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Abstract

The global burden of antimicrobial resistance necessitates advanced methodological frameworks in order to capture historical trends and provide reliable future projections. In the Global Research on Antimicrobial Resistance (GRAM) project, which is a joint partnership between the University of Oxford and the Institute for Health Metrics and Evaluation (IHME) at the University of Washington, we used sophisticated epidemiological modeling approach to estimate antimicrobial resistance burden from 1990 to 2021 and forecast outcomes until 2050 across 204 countries and territories. By integrating diverse data sources –including cause-of-death records, hospital discharge data, microbiological surveillance, pharmaceutical sales, antibiotic use surveys, healthcare utilization data and literature reviews –our approach processes 520 million individual records or isolates across 19,513 study-location-years.

The forecasting methodology is built on the Global Burden of Disease (GBD) 2021 study's statistical framework and employs a probabilistic forecasting model that incorporates historical trends, antimicrobial resistance patterns, as well as variations in healthcare systems. This is the first time such extensive methodology was ever employed in the analysis of antimicrobial resistance burden. Such approach employs three distinct scenarios: a reference scenario based on observed trends, a Gram-negative drug development scenario simulating the impact of new antimicrobial agents targeting Gram-negative bacteria, and a better care scenario assuming improvements in healthcare access, infection control and antimicrobial stewardship.

To refine predictions, spatiotemporal Gaussian process regression (ST-GPR) is applied to smooth resistance prevalence estimates across time and geography while addressing data sparsity. Bayesian hierarchical modeling further enhances the robustness of the estimates by integrating historical trends and regional covariate relationships. A decomposition analysis adapted from Das Gupta's framework quantifies the relative contributions of demographic shifts, healthcare improvements and antimicrobial usage changes to the projected antimicrobial resistance burden. Counterfactual scenario modeling is employed to differentiate the burden of resistance, considering both a scenario in which all resistant infections are replaced with susceptible infections and another where infections are entirely eliminated. Monte Carlo simulations are incorporated to quantify uncertainty, generating confidence intervals for projected deaths related to antimicrobial resistance and disability-adjusted life years (or DALYs). Data integration and validation are ensured by benchmarking estimates against historical trends and validating projections using independent epidemiological studies and national surveillance data.

By combining predictive modeling, historical trend analysis and robust uncertainty quantification, this methodological framework establishes a reproducible and scalable approach to global AMR burden estimation. Such forecasting methodology not only informs targeted intervention strategies but also serves as a foundation for broader epidemiological modeling of global health threats, emphasizing the need for continued refinement in predictive epidemiology.

Keywords

predictive modeling, forecasting, antimicrobial resistance

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