Mathematical Modeling to Optimize Point-of-Care Diagnostic Accuracy for Lassa Fever Control

Poster 034 (ELIC2025429)

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Background

Lassa fever (LF), with a sero-prevalence of 21% and mortality rates of 15–20% in Nigeria, remains a critical public health challenge. Early diagnosis is hindered by non-specific symptoms and limitations in rapid point-of-care (POC) test accuracy, leading to delayed treatment and preventable deaths. This study utilized mathematical modeling to optimize POC diagnostic accuracy, addressing gaps in test sensitivity and coverage to curb transmission.

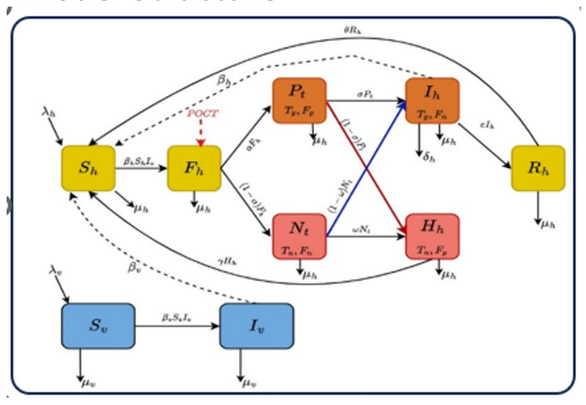
Methods

We adapted a Susceptible-Infectious-Recovered (SIR) compartmental-based model to simulate LF transmission in Ebonyi State, Nigeria. We derived key parameters from literature, including transmission rates, diagnostic positivity/negativity rates (77.4% baseline true positivity), and test coverage. Using scenario analyses we evaluated the impact of varying POC test accuracies (10% and 20% improvements) on disease spread. Geo-spatial and temporal data (2018–2022) informed our model calibration.

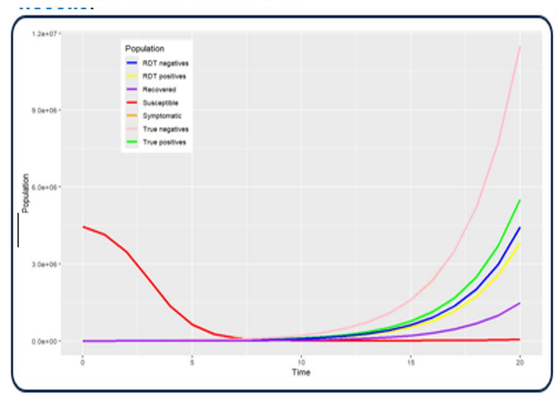
Results

Our modeling revealed that improving rapid diagnostic test (RDT) accuracy directly reduces LF transmission. When test sensitivity increased from 77.4% to 97.4%, we detected 16% more cases, effectively removing these individuals from transmission chains. Even a 10% improvement (to 87.4% sensitivity) identified 4% additional cases. The model demonstrates that higher test accuracy leads to increased identification of infections, and with treatment, progressively shrinks the pool of infectious individuals. Conversely, we found that low testing coverage (<50%) delayed outbreak detection by 2-3 weeks, allowing more unchecked transmission. These results show that optimizing RDT sensitivity is crucial for breaking transmission cycles - with the greatest benefits seen when test accuracy approaches 97%.

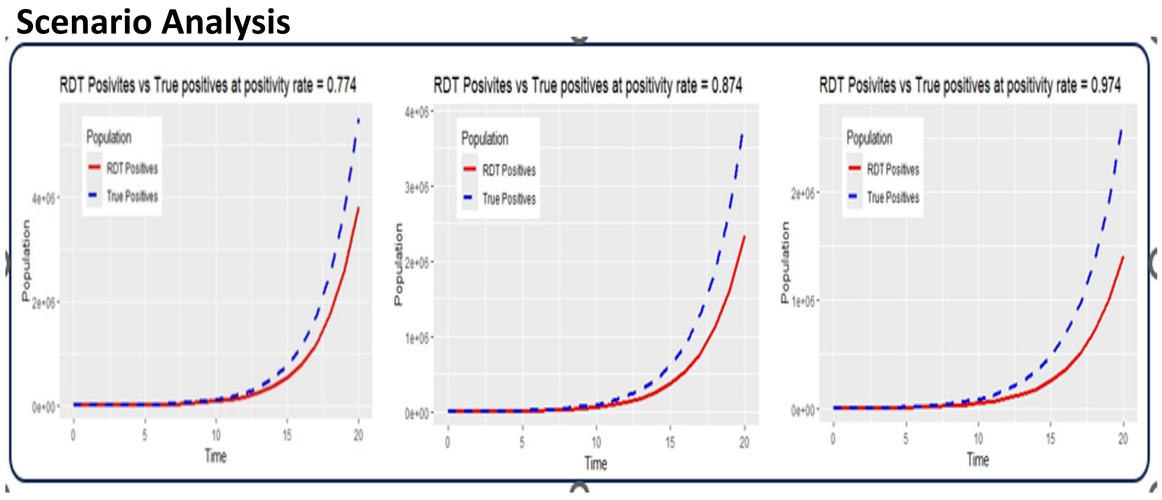
Model Structure



Model Simulation



Scenario Analysis



Conclusions and Recommendations

Optimizing POC diagnostic accuracy is pivotal for interrupting LF transmission. We recommend that the Government of Ebonyi State, and by extension Nigeria, invest in next-generation POC tests with a sensitivity of ≥95%, pre-positioning testings in high-burden regions during peak seasons, and integrating modeling into national surveillance to inform test deployment. These strategies enhance laboratory networks by ensuring timely and accurate diagnostics, ultimately reducing mortality and outbreak risks.

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