Sequential Bayesian assurance for adaptive data collection in mechanistic state-space models

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Introduction and objective

Public health relevance. Repeated serological surveillance is costly, while fixed schedules ignore how uncertainty changes during an epidemic.

Research objective. Develop a sequential Bayesian rule that chooses the minimum new sample size needed to meet a prespecified precision target.

Can a mechanistic forecast decide how many observations should be collected next?

The design uses information from prior rounds and the transmission model instead of applying the same sample size every week.

Results Main finding

85 to 98%
fewer antibody tests than observed testing

0.08
median weekly interval width

80 to 85%
time points meeting the 0.10 target

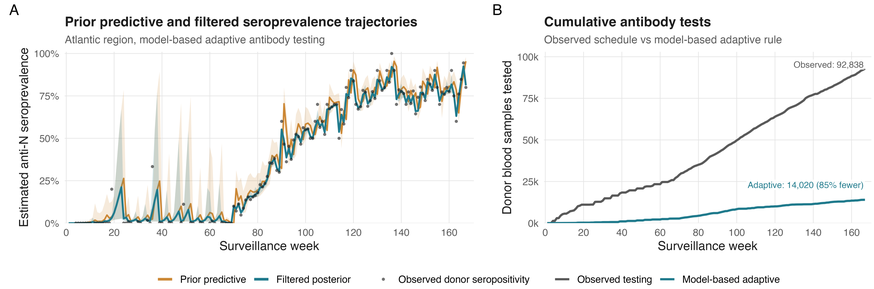
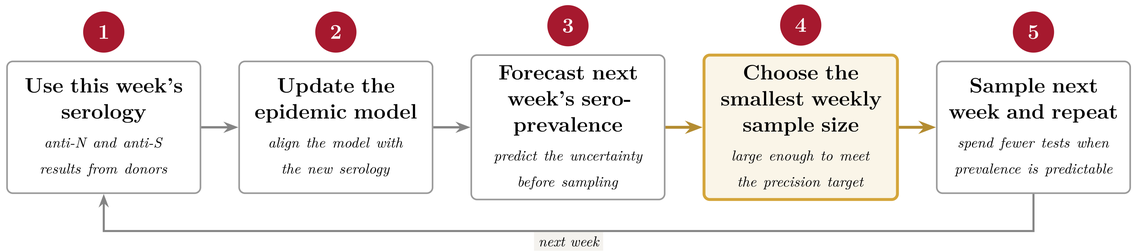


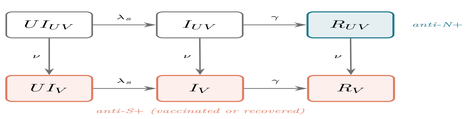
Figure. Model-guided adaptive antibody testing in the Atlantic region.
A: The orange curve shows the model forecast before each week's donor antibody results are incorporated; the teal curve shows the updated estimate after filtering.
Dots show observed weekly anti-nucleocapsid (anti-N) donor seropositivity.
B: Cumulative donor blood samples tested under the observed testing schedule and the model-based adaptive rule.

A stochastic transmission model forecasts next-period seroprevalence. ***Bayesian assurance*** converts that forecast into the ***smallest adequate sample size***.

Methods Adaptive weekly sampling

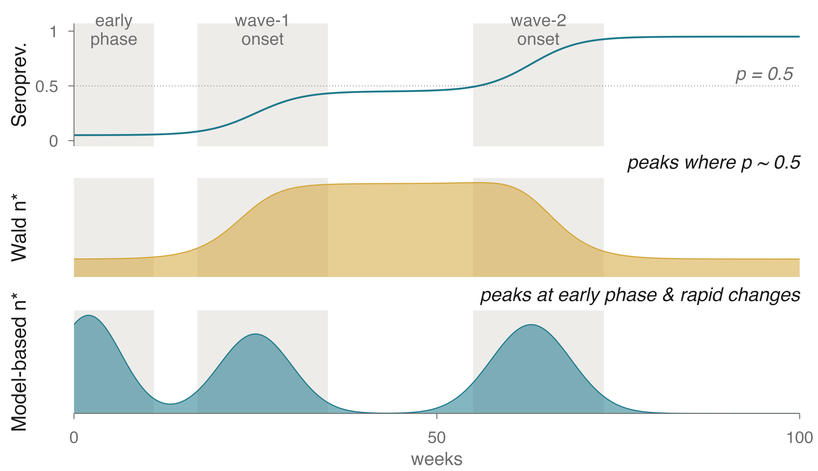


Each decision cycle updates the particle filter, forecasts next-period seroprevalence, evaluates candidate sample sizes, and selects the smallest adequate design.



The transmission model. A mechanistic state-space model links latent epidemic dynamics to repeated anti-N and anti-S observations. The filter carries uncertainty in states and parameters forward without refitting from scratch.

Methods Bayesian assurance sample size



Before collecting the next observations, the design asks how likely a candidate sample size is to produce a posterior interval narrow enough, based on the model forecast and its uncertainty.

Choose the smallest n once that probability reaches q.

The same rule can accommodate multiple data streams and alternative observation models.

Forecast-driven sample sizing converts uncertainty already represented by the model into a concrete operational decision.

Conclusions

- Mechanistic forecasts can guide adaptive surveillance effort
- Sequential assurance selects the minimum new data needed for a precision target
- Large testing reductions were achieved while retaining useful interval precision

Limitations and next steps

- Blood donors are not fully representative of the general population
- Operational constraints such as throughput and batching are not modeled
- Prospective validation is needed before operational deployment

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