Since January 2020 Elsevier has created a COVID-19 resource centre with free information in English and Mandarin on the novel coronavirus COVID-19. The COVID-19 resource centre is hosted on Elsevier Connect, the company's public news and information website.

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tracted from routinely collected electronic health records providing a highly accessible route to improve personalised disease prognostics in future models.

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PS25.01 (158)

A unified and flexible modelling framework for the analysis of malaria serology data

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**Purpose:** Serology data are an increasingly important tool in malaria surveillance, especially in low transmission settings where the estimation of parasite-based indicators is often problematic. Existing methods rely on the use of thresholds to identify seropositive individuals and estimate transmission intensity, while making assumptions about the temporal dynamics of malaria transmission that are rarely questioned. Here, we present a novel threshold-free approach for the analysis of malaria serology data which avoids dichotomization of continuous antibody measurements and allows us to model changes in the antibody distribution across age in a more flexible way.

**Methods & Materials:** We develop a unified mechanistic model which combines the properties of reversible catalytic and antibody acquisition models, and allows for temporally varying boosting and seroconversion rates. Additionally, as an alternative to the unified mechanistic model, we also develop an empirical approach to analysis where modelling of the age-dependency is informed by the data rather than biological assumptions. Using serology data from Western Kenya, we demonstrate both the usefulness and limitations of the novel modelling framework.

**Results:** The unified mechanistic model 1) eliminates the need to dichotomize continuous antibody measurements into seropositive and seronegative data, 2) removes assumptions about malaria transmission dynamics, 3) adds flexibility in how transmission intensity can be estimated using regression analysis, 4) incorporates age-dependency of the antibody distribution, and 5) allows for joint estimation of malaria transmission intensity from both the reversible catalytic and antibody acquisition models.

**Conclusion:** Our framework makes the best possible use of the data by avoiding the dichotomization of the continuous antibody measurements, a common practice in the analysis of malaria serology data. More importantly, the unified framework allows us to critically assess and evaluate assumptions on the dynamics of biological indicators of malaria transmission using a principled likelihood-based framework.

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PS25.02 (926)

Mathematical modelling of COVID-19: a systematic review and quality assessment in the early epidemic response phase

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**Purpose:** Epidemiological models have played a key role in informing national response strategies for the current COVID-19 pandem. We aimed to identify how mathematical models were employed in the early phase of the pandemic, at a time of great epidemiological uncertainty, as well as to formally assess the quality of models used. Hence we aimed to identify areas for improvement in model-based decision-making for future unknown disease threats.

**Methods & Materials:** A systematic review of mathematical modelling studies estimating the epidemiological impact of COVID-19 (risk of importation/spread) and non-pharmaceutical interventions (NPI) was conducted. We systematically searched PubMed, Embase, and preprints in ArXiv, MedRxiv and bioRxiv. We adopted two published quality assessment frameworks to formally assess the extent in which modelling studies met minimal requirements for incorporation of uncertainty and good modelling practice.

**Results:** In total, 166 articles met our eligibility criteria. The vast majority (129 studies, 78%) of models evaluated the effectiveness of NPIs. NPI effectiveness was predominantly modelled in China and Italy, but varied by global region. Asian studies largely evaluated the impact of quarantine and isolation (64 studies), whereas European modelling studies modelled the impact of containment (15 studies), quarantine of travellers, and the isolation of cases. Early models primarily concerned compartmental, deterministic frameworks using SEIR or variants of SEIR compartments (93 studies, 56%) assuming homogeneous, symptomatic transmission. Incorporation of parameter uncertainty through model calibration (inference of unknown parameters by fitting models to data) and sensitivity analyses were relatively common (66% and 56% of studies respectively), the former mainly using Chinese data. In contrast, inclusion of structural uncertainty (uncertainty in disease characteristics) was relatively uncommon, as was validation of model output to external data.

**Conclusion:** This work allows for the identification of existing challenges in the mathematical modelling of emerging diseases, and emphasises minimal criteria for enhancing reliable model estimation and reporting. Limited availability of epidemiological data in the early phase of a new disease treat challenges model calibration to local, and validation to external data, emphasising the critical importance of enforcing standardised protocols for early epi-data collection, and raising awareness among modellers and decision-makers alike in handling uncertainty.

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PS25.03 (1085)

Real-Time Forecasting of COVID-19 Cases Using Human Mobility in Ontario, Canada

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**Purpose:** To minimize the impact of the COVID-19 pandemic, local public health authorities are often required to make prompt and informed decisions on anticipated case-loads, resource allocation for surveillance and testing, and public health intervention appropriateness. The objective of this research was to develop a near-term forecasting model to predict COVID-19 cases using real-time human mobility information in Ontario, Canada to assist public health authorities with outbreak response.

**Methods & Materials:** We utilized a deep neural network model to generate a short-term forecast of new COVID-19 cases by two weeks from May to August 2021. Variable selection was informed by a recent literature review and our ongoing research associating COVID-19 cases with human mobility, demographic and socio-economic factors. A real-time human mobility statistics consisting of a weekly summary of short and long-distance movement,
demographic characteristics, weather, vaccination coverage, geolocation, and reported COVID-19 cases two weeks prior were included as predictors. We considered weeks as temporal and health regions as geographic units to account for population-level variabilities. We used a holdout method for model validation of over 300 iterations. Average mean squared error (MSE) and 95% confidence interval (CI) along with overlaying forecasted COVID-19 cases over the reported were used to evaluate the overall model fit. The model predictions were summarized as means and 95% CIs.

**Results:** Our best forecasting model had a mean MSE of 0.53 (95% CI: 0.49 – 0.56). Since May 2021, the overall trend of the reported COVID-19 cases in Ontario closely followed the forecasted cases, about 8% of the reported cases were within 1.5 times the interquartile range (IQR) and all were within the entire range of the distribution of the predictions. Forecasting accuracy also varied by health region characteristics, such a population size and density, remoteness, and reported COVID-19 case volume during the most recent weeks.

**Conclusion:** A near-term prediction of new COVID-19 cases with real-time population-level data could help public health authorities anticipate, plan and monitor disease burden in a population. Such predictions also allow the assessment of population-level health interventions to minimize new COVID-19 cases on a real-time basis and inform prompt decision making.

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**PS25.04 (I189)**

**Forecasting SARS-CoV-2 Incidence in Ontario Municipalities with Statistical and Algorithmic Modeling and Ensembles**

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**Purpose:** In this study, a variety of statistical and algorithmic models were applied to forecast Covid-19 incidence in two Canadian cities, Wellington-Dufferin-Guelph (WDG) and Toronto, Ontario. The purpose of forecasting incidence in the two cities was to explore and compare the predictive capacity of each approach in two regions where daily incidences differ due to population sizes, thus requiring different analytical approaches to inform public health.

**Methods & Materials:** The dataset consisted of daily Covid-19 incidence within WDG and Toronto, Ontario. Data was split into training data (March 13, 2020, to June 17, 2021) and validation data (June 18, 2021, to July 8, 2021). Models fitted to the training data were assessed on validation data. Additionally, the effective reproductive number (Re), holidays, type of variant (i.e., Alpha, Beta, Gamma, Delta), mutation common to a variant detected or no mutation detected as well as the cumulative number of first and second vaccination doses were included as predictors.

Statistical models employed were General Linear Autoregressive Moving Average (GLARMA), Seasonal Autoregressive Integrated Moving Average (SARIMA) and Regression with ARIMA errors. The two machine learning algorithms were Neural Network Autoregression (NNAR) and Random Forest (RF). A hybrid model combining the statistical and algorithmic approaches (ARIMA-Boosted) was also explored. Ensembles combining several of the models were then generated to investigate improvement in predictive performance. Performance was assessed via Root Mean Square Prediction Error (RMSE) and Mean Absolute Scale Prediction Error (MASE).

**Results:** In WDG, regression with ARIMA achieved respectable forecast accuracy (RMSE = 3.50, MASE = 0.71). Ensembles provided a marginal gain in forecast accuracy (RMSE = 3.48, MASE = 0.67) in Toronto, SARIMA modeling had the superior forecasts (RMSE = 8.14, MASE = 0.52), whereas ensembles did not improve accuracy (RMSE = 8.57, MASE = 0.58).

**Conclusion:** Models based on observed associations (i.e., statistical modeling) provided more accurate forecasts than data driven algorithmic modeling (i.e., machine learning) for forecasting epidemic/pandemic trajectory. This finding was consistent in both WDG and Toronto, Ontario. While ensemble forecasts may slightly improve the forecast accuracy, the computational expense did not justify its application in the current examples.

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**Topic 26: Outbreak Response and Control**

**OP26.01 (825)**

**Assessing Effectiveness of Ring Vaccination in Mitigating a Mumps Outbreak on a College Campus**

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**Purpose:** Mumps outbreaks continue to occur in populations that share close social networks. Ring vaccination is a strategy that focuses on vaccinating primary contacts and secondary contacts of an infected individual. While a third dose of the measles-mumps-rubella (MMR) vaccine is recommended by the Centers for Disease Control and Prevention during outbreaks, there are limited studies focusing on the effectiveness of ring vaccination.

**Methods & Materials:** In spring 2019, during a mumps outbreak at a large urban university where two documented doses of MMR are required for matriculation, ring vaccination was used as the university’s primary strategy. To assess the effectiveness, this study compared the attack rates between primary and secondary contacts who had only two doses of documented MMR vaccine and contacts who were ring vaccinated and received a third MMR vaccine. Surveillance and contact tracing efforts during the outbreak were also reviewed.

**Results:** A total of 26 case investigations resulted in 1419 primary and secondary contacts. The attack rate for contacts who had only two documented doses of the MMR vaccine was over three times higher than the attack rate for contacts who were ring vaccinated and received a third dose of MMR vaccine at least two weeks before developing mumps infection (20 per 1000 cases versus 6 per 1000 cases, respectively; p = 0.02).

**Conclusion:** The rate of infection was significantly lower in ring vaccinated contacts. Guidelines that recommend ring vaccination may help prevent larger mumps outbreaks in colleges. Requiring MMR documentation at colleges and universities, using rigorous