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## Obstetrics

# A forecast of maternal deaths with and without vaccination of pregnant women against COVID-19 in Mexico

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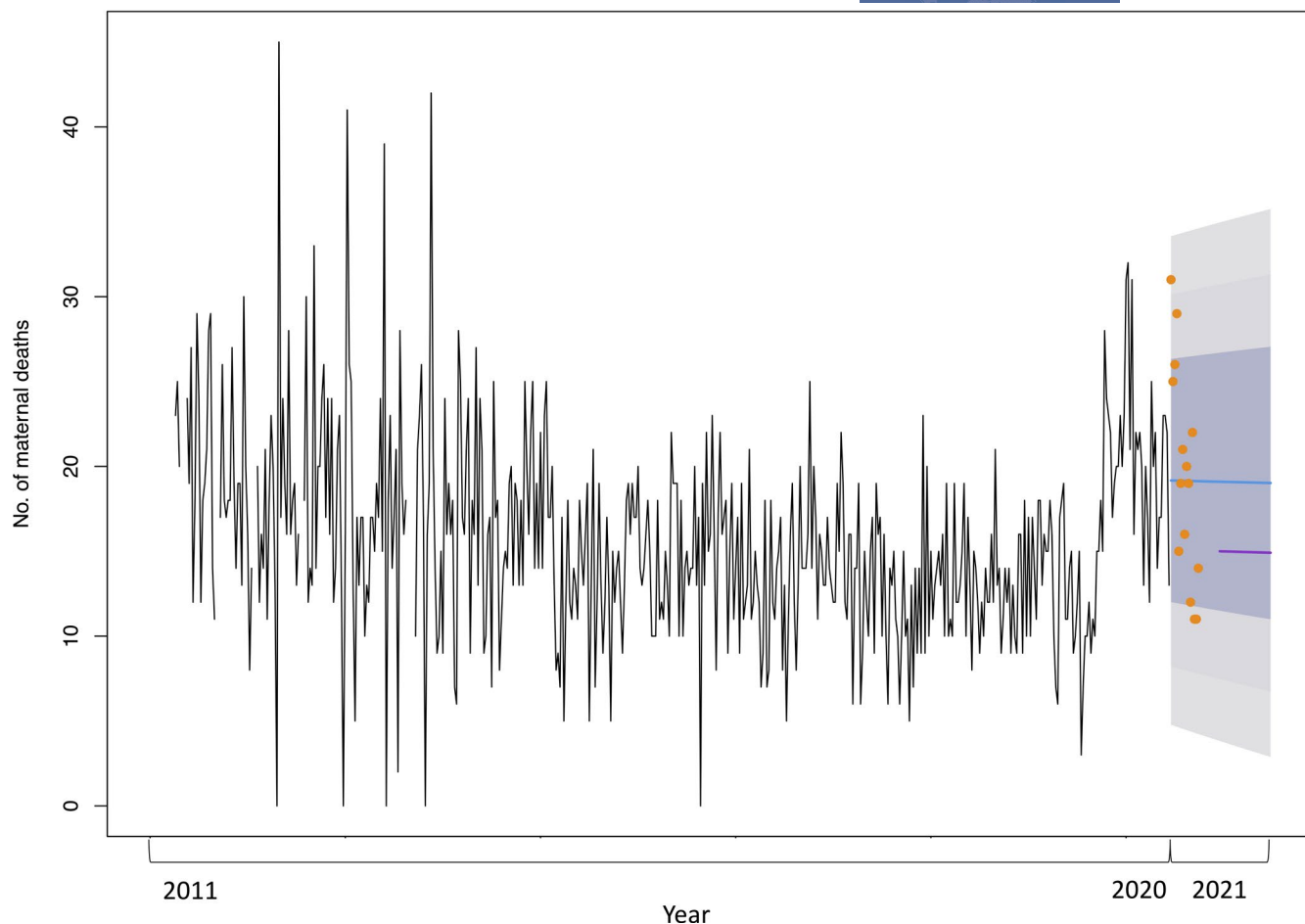
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Pregnant women with coronavirus disease 19 (COVID-19) are at risk of severe morbidity and mortality. With 934 deaths, the maternal mortality ratio (MMR) for Mexico in 2020 was 46.6 per 100 000 live births. COVID-19 was the leading cause of maternal mortality (202 deaths). Respiratory causes represented 31% (286/934) of maternal deaths in 2020, compared to 5% from 2011–2019.<sup>1</sup> Fortunately, the Mexican government launched a universal vaccination program for pregnant women on May 11, 2021.<sup>2</sup>

In the present study, we forecasted excess maternal deaths for the second half of 2021 with and without vaccination of all pregnant women during May and June of 2021. We hypothesized that if current mortality trends continue, the burden of maternal mortality related to COVID-19 in Mexico would not decrease in 2021 in the absence of the vaccination program that was recently initiated. Open data from the Mexican Ministry of Health from 2011–2020<sup>1</sup> were used to forecast weekly death counts from January–December 2021, via an autoregressive integrated moving average (ARIMA)<sup>3</sup> model for univariate time series. Using non-stepwise model selection and assessment of seasonality and stationarity, the best model was chosen according to

the Akaike information criterion. Model performance was evaluated using root mean squared error (RMSE) in the training data (2011–2020) and the test data (first 15 weeks of 2021). Furthermore, the 80%, 95%, and 99% forecast prediction intervals were also calculated. Finally, with the assumption that COVID-19 infection would account for the same proportion of deaths in 2021 as in 2020 (21.6%),<sup>1</sup> we forecasted weekly maternal death counts for 2021 if all pregnant women were vaccinated against COVID-19 during May and June of 2021, which provides 100% mortality protection according to data from clinical trials.<sup>4</sup>

The forecast estimated 993 deaths for 2021 (Fig. 1) and a predicted MMR of 46.5 (95% CI 43.7, 49.5). The RMSE for the ARIMA ([0,1,1] with drift) model was 5.57 and 6.15 in the training and test data, respectively. With a 100% vaccination rate among pregnant women during May and June of 2021, the overall predicted number of deaths for 2021 would decrease to 885, and the MMR would improve to 41.5 (95% CI 38.8, 44.3). Accessibility to vaccines in low- and middle-income countries is a powerful way to limit maternal mortality associated with COVID-19 infection. Our



**FIGURE 1** Forecast of maternal mortality for 2021 in Mexico. The black line represents observed maternal deaths per week from 2011 through 2020 (first bracket). The blue line represents the forecast for 2021 (second bracket). Moreover, the shaded areas outline the 80%, 95%, and 99% prediction intervals. The actual count of maternal deaths for 2021 is highlighted with orange circles. Finally, the purple line represents the forecast for 2021 if all pregnant women were to receive the COVID-19 vaccine between May and June of 2021

study's limitation is that data are provisional. Additionally, incorporating more detailed vaccine characteristics and potential changes in other preventive measures would allow the refinement of our forecast.

#### CONFLICTS OF INTEREST

The authors have no conflicts of interest.

#### AUTHOR CONTRIBUTIONS

MIL-M helped with the conception of the work, data collection, analysis, and interpretation; and helped draft the work, revised it critically, and approved the final version of the manuscript. KGF contributed to the conception of the work, data collection, analysis, and interpretation; and helped draft the work, revised it critically, and approved the final version of the manuscript. MC-Z was responsible for the conception of the work, data collection, analysis, and interpretation; and helped draft the work, revised it critically, and approved the final version of the manuscript. MRR-B, MJR-S, DYC-M, and SA-G helped with the data collection and interpretation, and

helped to draft the work, revised it critically, and approved the final version of the manuscript. MKF contributed to the conception of the work, data collection, analysis, and interpretation; and helped to draft the work, revised it critically, and approved the final version of the manuscript.

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