Excess Patient Visits for Cough and Pulmonary Disease at a Large U.S. Health System in the Months Prior to the COVID-19 Pandemic: A Time-Series Analysis.

Joann G Elmore, Pin-Chieh Wang, Kathleen F Kerr, David L Shriger, Douglas E Morrison, Ron Brookmeyer, Michael A Pfeffer, Thomas H Payne, Judith S Currier

Table of Contents

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Abstract

Background: Accurately assessing regional activity of diseases such as COVID-19 is important in guiding public health interventions. Leveraging electronic health records (EHR) to monitor outpatient clinical encounters may lead to the identification of emerging outbreaks.

Objective: To investigate whether excess visits where the word "cough" was present in EHR reason for visit, and hospitalizations with acute respiratory failure were more frequent December 2019 to February 2020, compared with 5 preceding years.

Methods: A retrospective observational cohort was identified from a large U.S. health system with 3 hospitals, over 180 clinics and 2.5 million patient encounters annually. Data from patient encounters from July 1, 2014 to February 29, 2020 were included. Seasonal autoregressive integrated moving average (SARIMA) time-series models evaluated if the observed winter 2019/2020 rates were higher than the forecast 95% prediction intervals. Estimated excess number of visits or hospitalizations in winter 2019/2020 were calculated comparing to previous seasons.

Results: The percent of patients presenting with the EHR reason for visit containing "cough" to clinics exceeded the 95% prediction interval the week of December 22, 2019 and was consistently above the 95% prediction interval all ten weeks through the end of February 2020. Similar trends were noted for emergency department visits and hospitalizations starting December 22, 2019, where observed data in 6 and 7 of the 10 weeks, respectively, exceeded the 95% prediction interval. The estimated excess over the three winter months of 2019-2020, subtracting the maximum or subtracting the average of the five previous seasons from the current season, were 1.6 or 2.0 excess visits for cough per 1,000 outpatient visits, an excess of 11.0 or 19.2 per 1,000 emergency department visits, and an excess of 21.4 or 39.1 /1,000 hospitalizations with acute respiratory failure, respectively. The total number of excess cases above the 95% predicted forecast interval were 168 cases in the outpatient clinics, 56 cases for the emergency department and 18 hospitalized with acute respiratory failure.

Conclusions: A significantly higher number of patients with respiratory complaints and diseases starting late December 2019 and continuing through February 2020 suggests community spread of SARS-CoV-2 prior to established clinical awareness and testing capabilities. This provides a case example of how health system analytics combined with EHR data can provide powerful and agile tools in identifying when future trends in patient populations are falling out of the expectations.

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Word Count: 2,683

Key words: COVID-19 pandemic; electronic health record; time-series analysis; prediction; forecast

ABSTRACT

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INTRODUCTION

Health systems, medical providers, bioinformaticians and researchers worldwide are working tirelessly to understand, contain, and ameliorate the COVID-19 pandemic. During this largest health emergency in a generation, clinicians have anecdotally noted an unusual number of patients with respiratory complaints at the end of 2019 and early 2020, well before COVID-19 was officially categorized by the WHO as a pandemic [1]. It is unclear whether such anecdotal reports are correct or the result of hindsight bias. If correct, the excess could represent typical variation in disease patterns. Alternatively, the excess, especially if it is significantly above prediction intervals based on historical data, could represent undetected and early COVID-19 cases prior to established clinical awareness and testing capabilities for the virus.

In the past decade there has been widespread adoption of electronic health records (EHR) in the United States. However, to date there have been limited efforts to leverage EHRs to support the delivery of high-value medical care or otherwise improve the delivery of health care services [2]. Using EHR data to model and forecast trends has the potential to improve resource management and the preparedness of health systems [3-7], which in turn could improve the quality of medical care. In particular, EHR data paired with analytical tools can potentially identify unusual trends in health care delivery that can alert clinicians and public health experts to critical changes in disease patterns.

The purpose of this paper is to use discrete raw EHR data to evaluate whether there was an excess of patients presenting with symptoms and diseases suggestive of COVID-19 in the months prior to the first known COVID-19 cases in the U.S. health system in March 2020, using words found in chief complaint fields and ICD codes from hospital discharge

diagnoses. Five years of data from a large Los Angeles area health system were analyzed using time series methods to address whether there was an excess number of patients presenting for complaints of cough, or hospitalizations for respiratory ailments. These methods highlight how health care analytics coupled with EHR data can be harnessed for disease surveillance. In particular, surveillance starting from the larger outpatient setting, which is often the tip of the iceberg, can provide an early warning of a public health emergency before patients fill the hospital intensive care units and deaths accumulate.

METHODS

The study included data for July 1, 2014 to February 29, 2020 from UCLA Health, a large health system with over 2.5 million total outpatient visits and three hospitals (UCLA Medical Center Santa Monica, Resnick Neuropsychiatric Hospital at UCLA, and Ronald Reagan UCLA Medical Center). Health system utilization data between the winter season of December 1, 2019 and February 29, 2020, the months prior to increased public awareness of COVID-19 in the U.S., were evaluated using the previous five years as the comparison period in a time-series analysis. Data were collected using SQL reports from Epic Clarity production databases supporting EHR used throughout UCLA Health.

Analyses included three different care settings: outpatient clinics, emergency departments and hospital. All primary, specialty and urgent care outpatient visits were considered and searched for the word "cough" within the reason for visit, further examining the percentages of patients presenting with cough in the current winter season with forecast predictions based on data for the five preceding years. All patient visits to the emergency departments for cough and data on patients hospitalized with acute respiratory failure for the current winter season were separately examined with the corresponding data for recent years in

the same manner (see **Appendix eTable 7** for list of ICD codes).

Seasonal autoregressive integrated moving average (SARIMA) models were applied on weekly data in SAS from July 1, 2014 through November 30, 2019 to forecast data for December 2019 through February 2020 (see Appendix eTables 1 to 6 and eFigures 1 to 3). These models take into account seasonal effects [8,9] and use maximum likelihood to estimate model parameters based on historical data from July 1, 2014 to November 30, 2019. A winter season is defined as the time period from December 1 to the last day of February the subsequent year. Using the SARIMA model, a forecast of the winter season 2019/2020 was provided. Specifically, a SARIMA(1,0,1)x(1,0,1)$_{52}$ model was used to analyze the outpatient time series, a SARIMA(1,0,3)x(1,0,1)$_{52}$ model was used to analyze the emergency department data, and a SARIMA(1,0,1)x(1,0,1)$_{52}$ model was used to analyze the inpatient data for 'Acute Respiratory Failure'. The autoregressive and moving-average orders were identified by both SCAN and ESACF methods [10].

The 95% prediction intervals for the forecast allowed an assessment of whether the observed data at weekly intervals for winter season 2019/2020 were outside of the time series forecast interval.

For example, for the outpatient clinic visit data, the following $SARIMA(1,0,1) \times (1,0,1)_{52}$ model was used (model parameter estimates are shown in Appendix eTable 1):

$$\left(1-\phi_1 B\right)\left(1-\phi_2 B^{52}\right)\left[X_t-\left(\beta_0+\beta_1 Z_t\right)\right]=\left(1-\theta_1 B\right)\left(1-\theta_2 B^{52}\right)W_t$$

where:

- X_t is the percentage of visits in week t for which cough was a recorded symptom

- B is the backshift operator, $B X_t = X_{t-1}$,

- $W_t \sim wn(0, \sigma_w^2)$ is a white noise process of uncorrelated random variables with mean 0 and variance σ_w^2.

- Z_t is an indicator variable for the months of December to February.

Excess cases per 1,000 visits in the winter 2019/2020 compared to previous seasons were estimated using three methods (see Appendix eTables 8 to 11). First, for a conservative estimate for excess cases, the maximum of the five previous seasons was subtracted from the current season. Second, the average of the five previous seasons was subtracted from the current season. For both methods, the excess percentage was multiplied by the total number of patient visits in the current season to estimate the excess cases for each month. For the third method, the upper limit of the time series 95% forecast interval was subtracted from the observed rate for each of the 13 weeks in the 2019/2020 season to estimate the weekly excess percentages. The weekly excess percentage was multiplied by the weekly patient visits and aggregated to estimate the excess cases.

To visualize the data, the LOESS technique was used to smooth daily data with a smoothing span of 20% (See Appendix eFigure 4 for scatter plots of daily data) [11] with analyses performed in R [12] and figures generated in Microsoft Excel.

Two sensitivity analyses were performed. First, patient insurance status was considered to see if variation in insurance could explain trends over time in the outpatient and emergency department data; the analysis was repeated using only those outpatient clinics that existed for all years of the study period to ensure that changing case mix did not confound our results. Secondly, patients hospitalized with a broader set of respiratory illnesses were investigated: patients hospitalized with ICD codes used in a study of respiratory tract

illnesses associated with influenza,[13] and those with any pneumonia (see Appendix eTable 7 for list of ICD codes). A SARIMA$(2,0,2)\times(1,0,1)_{52}$ model was used to analyze the inpatient data for 'any respiratory tract disease', a SARIMA$(2,0,1)\times(1,0,1)_{52}$ model was used to analyze the inpatient data for 'pneumonia'. Institutional Review Board approval was obtained (UCLA: #20-000528).

RESULTS

Outpatient Clinic Data

The data encompass 9,501,091 outpatient clinic visits, with the average number of clinic visits increasing over time (e.g., 314,832 visits from December 1, 2014 to February 28, 2015 winter season to 511,687 for the winter season 2019-2020). The expected cyclical increase in patients presenting with reports of cough each winter is observed for all six years studied (**Figure 1A,** see also Appendix eFigure 1a). The percent of patients presenting for complaint of a cough was within the prediction intervals in early and mid-December 2019. Starting the week of December 22, 2019, the data exceed the 95% prediction interval and consistently exceed the 95% prediction interval each week through the end of February 2020 (**Figure 2)**.

The estimated total excess visits for cough over the three winter months of 2019-2020 were 739 (1.6/1,000 visit) when compared with the highest historical monthly value, 1,047 (2.0/1,000 visit) when compared with the average monthly value for all five years of historical controls, or 168 excess visits above the 95% prediction interval forecast by the time-series analysis (**Table 1**, see also Appendix eTable 8).

Table 1. Outpatient and emergency department visits for cough and hospitalizations for acute

respiratory failure by years of winter season (December to February)

Calendar Year	Outpatient				Emergency Department				Hospitalization			
	Total Visit	Cough			Total Visit	Cough			Total Stay	Acute Respiratory Failure		
		N	%	cases per 1,000		N	%	cases per 1,000		N	%	cases per 1,000
2014 - 2015	314,832	929	0.30%	3.0	24,127	853	3.54%	35.4	11,016	680	6.17%	61.7
2015 - 2016	391,089	1,499	0.38%	3.8	25,977	1134	4.37%	43.7	10,925	760	6.96%	69.6
2016 - 2017	405,620	1,671	0.41%	4.1	25,505	1072	4.20%	42.0	10,831	827	7.64%	76.4
2017 - 2018	425,686	1,670	0.39%	3.9	27,022	1429	5.29%	52.9	10,640	830	7.80%	78.0
2018 - 2019	446,673	1,635	0.37%	3.7	25,555	1263	4.94%	49.4	10,646	996	9.36%	93.6
2019 - 2020	511,687	2,938	0.57%	5.7	26,748	1708	6.39%	63.9	9,903	1,138	11.49%	114.9
Estimated excess cases per 1,000 visits[a]	1.6, 2.0				11.0, 19.2				21.4, 39.1			
Estimated excess cases[a]	739, 1047				229, 514				210, 387			
Total # Weeks Observed Data Above the 95% Prediction Interval	10 / 13 (100% of weeks after Dec 22, 2019)				6 / 13 (60% of weeks after Dec 22, 2019)				7/13 (70% of weeks after Dec 22, 2019)			
Estimated excess cases above the 95% prediction interval[b]	168				56				18			

a. Two methods were used to estimate the excess cases per 1,000 visits and excess cases in the 2019-2020 winter season (December 2019, January 2020, and February 2020) compared to previous seasons. First, for a conservative estimate for excess cases per 1,000 visits, using percentages we subtracted the maximum of the five previous seasons with the current season. Second, we subtracted the average of the five previous seasons from the current season. For both methods, we multiplied the excess percentage by the total number of patient visits in the current season to estimate the excess cases.

b. For this third method, we subtracted the upper limit of the time series 95% forecast interval from the observed rate for each of the 13 weeks in the current season to estimate the weekly excess percentages (Data not shown in table). We multiplied the weekly excess percentage by the weekly patient visits and aggregated these numbers to estimate the excess cases.

Emergency Department Visits

The emergency department data encompass 574,813 visits from July 1, 2014 to February 29, 2020, with an average of 25,822 visits per winter season. Similar to outpatient visits for cough, seasonal variation in the proportion of emergency department visits for cough was observed (**Figure 1B**). An excess above the time-series 95% prediction interval was noted

starting December 22, 2019; 6 of the 10 weeks exceeded the 95% prediction interval (**Figure 3**). The estimated total excess in patient visits to the emergency departments for cough over the winter season 2019/2020 using the three methods were 229 (11.0/1,000 visit), 514 (19.2/1,000 visit), or 56 (**Table 1**, Appendix eTable 9).

Hospitalized Patients

There were 247,774 patients admitted to our three hospitals from July 1, 2014 to February 29, 2020, with the average number of admissions each winter season of 10,660. The percent of patients with a discharge diagnosis of acute respiratory failure were higher in December 2019, January 2020 and February 2020 when compared with all 5 historical control years (**Figure 1C,** see also Appendix table 10). The observed percent of patients who had acute respiratory failure during the subsequent hospitalization exceed the time-series 95% prediction interval for patients admitted starting the week of December 22, 2019; 7 of the 10 weeks of observed data were above the 95% prediction interval (**Figure 4**). The estimated excess number of patients hospitalized with acute respiratory failure were 210 (21.4/1,000 visit), 387 (39.1/1,000 visit), or 18 (**Table 1**).

Sensitivity Analyses

The above findings were qualitatively unchanged when clinic and ED visits were analyzed by insurance class and clinic visits were restricted to clinics that treated patients in all years of the study period (see Appendix eFigures 5 to 7). The percent of patients with a discharge diagnosis of any respiratory tract disease or of any pneumonia were also higher in December 2019, January 2020 and February 2020 when compared with prior years (see Appendix eTable 11).

DISCUSSION

A significantly higher number of patients presented to outpatient clinics and emergency departments in this health system with a complaint of cough starting the last week of December 2019 and continuing through January and February 2020. These findings translate into hundreds of additional patients seeking outpatient medical attention in this health system for the respiratory symptom of cough this winter. A significant excess in the number of patients hospitalized with acute respiratory failure during this same time period was also noted. It is possible that some of this excess represents early COVID-19 disease before clinical recognition and testing, information that may help epidemiologists better understand the spread of this pandemic. If only some of these excess visits are due to COVID-19, this could still represent community spread of SARS-CoV-2 during that time because a substantial proportion of individuals infected have no symptoms or mild symptoms and do not seek medical care [14,15] , making cryptic spread of the disease within a community likely.

Electronic health records (EHRs) are widely adopted but have not been used to their fullest potential to deliver high-value care [16-18].   This work demonstrates the potential of using EHR data for symptom or disease surveillance. A strength of this study is the use of raw EHR data that are already collected in most health care systems to answer the simple question: Were patients presenting with reports of "cough" at excess numbers in the months before the first known case of COVID-19 in this health system?   In addition, this study considers data from three separate locations of patient care contained in the EHR: the outpatient setting, the emergency department, and the hospital.   For many diseases,

data from the outpatient setting can provide an early warning to emergency departments and hospital intensive care units (ICU) of what is to come. By leveraging time-series analysis to calculate prediction intervals of expected patients, outlier numbers of patient visits can be quickly identified.

While asymptomatic transmission and community spread of COVID-19 are possible explanations for the observed excess patient encounters, other reasons and limitations need to be considered. The study was performed in a single health system and only the word "cough" searched. While the term "cough" is possibly more specific to COVID-19 than other symptoms such as "fever" or "aches", this search method has imperfect specificity and sensitivity as it does not include the full spectrum of COVID-19 symptoms [19-25]. The health system patient mix could have changed over the study period, but sensitivity analyses did not find evidence of this.   It is possible that the findings are due to lung injury from e-cigarettes (vaping), but this explanation is doubtful because the CDC reported a continued decline after September 2019 [26].

Another limitation is not knowing for certain whether and what percent of excess patient visits were due to influenza. An increase in influenza positive test results and emergency department visits for influenza-like illnesses was noted in Los Angeles County and the U.S. during the 2019-2020 winter season when compared with prior years [27, 28].   The incidence of influenza-like illness symptoms in the U.S. peaked earlier in 2019 when compared with previous years [28], with the 2019-20 season peak at a similar level as the 2017-18 season peak. This suggests that some of the observed incidence was due to influenza rather than COVID-19.   However, the analysis shows an excess of patients above the forecast 95% prediction interval based on five previous seasons.

It is plausible that some of the excess visits might be due to SARS-CoV-2 as studies of rapid sentinel surveillance and genome sequencing suggest community transmission of SARS-CoV-2 much earlier than initially thought.   Studies in the U.S. and France find evidence for cryptic spread of the virus as early as December 2019/January 2020, before community surveillance was actively implemented [29 – 32]. Especially early in outbreaks, existing methods for case identification may not capture incident infections; thus, novel and complementary methods using EHR data such as reported here may play an important role.

Heightened media attention to the coronavirus pandemic could influence patients to seek medical care for cough-related concerns and should be considered [33]. Such data can complement these EHR data approaches. Using data from Google Trends [34] the popularity of "cough" as a search term in the U.S. was slightly higher from late December 2019 through January 2020 when compared with the average national popularity in the four previous years (see Appendix eFigure 8). Popularity of searches for "cough" increased substantially in mid-March, corresponding to the sharp increase in "coronavirus" Google news searches. While there was almost no mention of a COVID-19 type illness by United States media in December 2019 and little mention in January 2020, substantial media attention was present in February 2020. Therefore, this limitation is pronounced for February 2020, but less concerning for the earlier months.

In summary, health system analytics combined with EHR data can be harnessed to quickly identify changes in underlying patient populations.   This study identified a significant excess of patients with COVID-19 disease type presentations starting the last week of December 2019 and continuing through February 2020, a time period before availability of

testing or even consideration for clinical diagnosis of COVID-19 by providers. A unique feature is the evaluation of three different stages of health care settings, and thus expanding surveillance beyond just reporting the number of patients in emergency departments or hospital ICU beds to include consideration of 9.5 million outpatient clinic records. The CDC Outpatient Influenza-like Illness Surveillance Network (ILINet) currently monitors patients presenting with fever and a cough and/or a sore throat in the U.S [35]. Data from the outpatient clinic setting is usually a harbinger of what is to come to hospital emergency departments and intensive care units.

Harnessing larger electronic health data systems to monitor outpatient visits for the growing and diverse set of symptoms associated with COVID-19 should be considered [21-25].

This SARS-CoV-2 pandemic highlights the urgent need to support development of agile health care analytics that enable real-time symptom and disease surveillance [36]. Lessons learned from this pandemic will hopefully lead to better preparation to quickly provide warnings and track the next pandemic.

Figure 1. Percent of Outpatient and Emergency Department visits for cough and hospitalizations for acute respiratory failure from July 1, 2014 to February 29, 2020. (Vertical reference lines align to the first day of each month.)

Figure 1A. Outpatient Clinic Visits for Complaints of Cough from July 1, 2014 to February 29, 2020.

Figure 1B. Emergency Department Visits for Cough from July 1, 2014 to February 29, 2020.

Figure 1C. Hospitalizations for Acute Respiratory Failure from July 1, 2014 to February 29, 2020.

Figure 2. Time series analysis of outpatient data. 2A. Forecast, with 95% prediction intervals, of expected rates of outpatient presentations for cough (based on time-series analyses of the 5 previous years), with observed data for each week shown for December 1, 2019 to February 29, 2020. Figure 2B. Time series analysis of outpatient data.

Figure 3. Time-series Analysis of Emergency Department Visits for Cough. Figure 3A. Forecast, with 95% prediction intervals, of expected rates of emergency department presentations for cough (based on time-series analyses of the 5 previous years), with observed data for each week shown for December 1, 2019 to February 29, 2020. Figure 3B. Time series analysis of Emergency Department data.

Figure 4. Time Series Analyses of Hospitalizations for Acute Respiratory Failure. Figure 4A. Forecast, with 95% prediction intervals, of expected rates of patients hospitalized with acute respiratory failure (based on time-series analyses of the 5 previous years), with observed data for each week shown for December 1, 2019 to February 29, 2020. Figure 4B. Time series analysis of hospitalization data.

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Supplementary Files

Figures

Percent of Outpatient and Emergency Department visits for cough and hospitalizations for acute respiratory failure from July 1, 2014 to February 29, 2020. (Vertical reference lines align to the first day of each month.) 1A. Outpatient Clinic Visits for Complaints of Cough from July 1, 2014 to February 29, 2020. 1B. Emergency Department Visits for Cough from July 1, 2014 to February 29, 2020. 1C. Hospitalizations for Acute Respiratory Failure from July 1, 2014 to February 29, 2020.
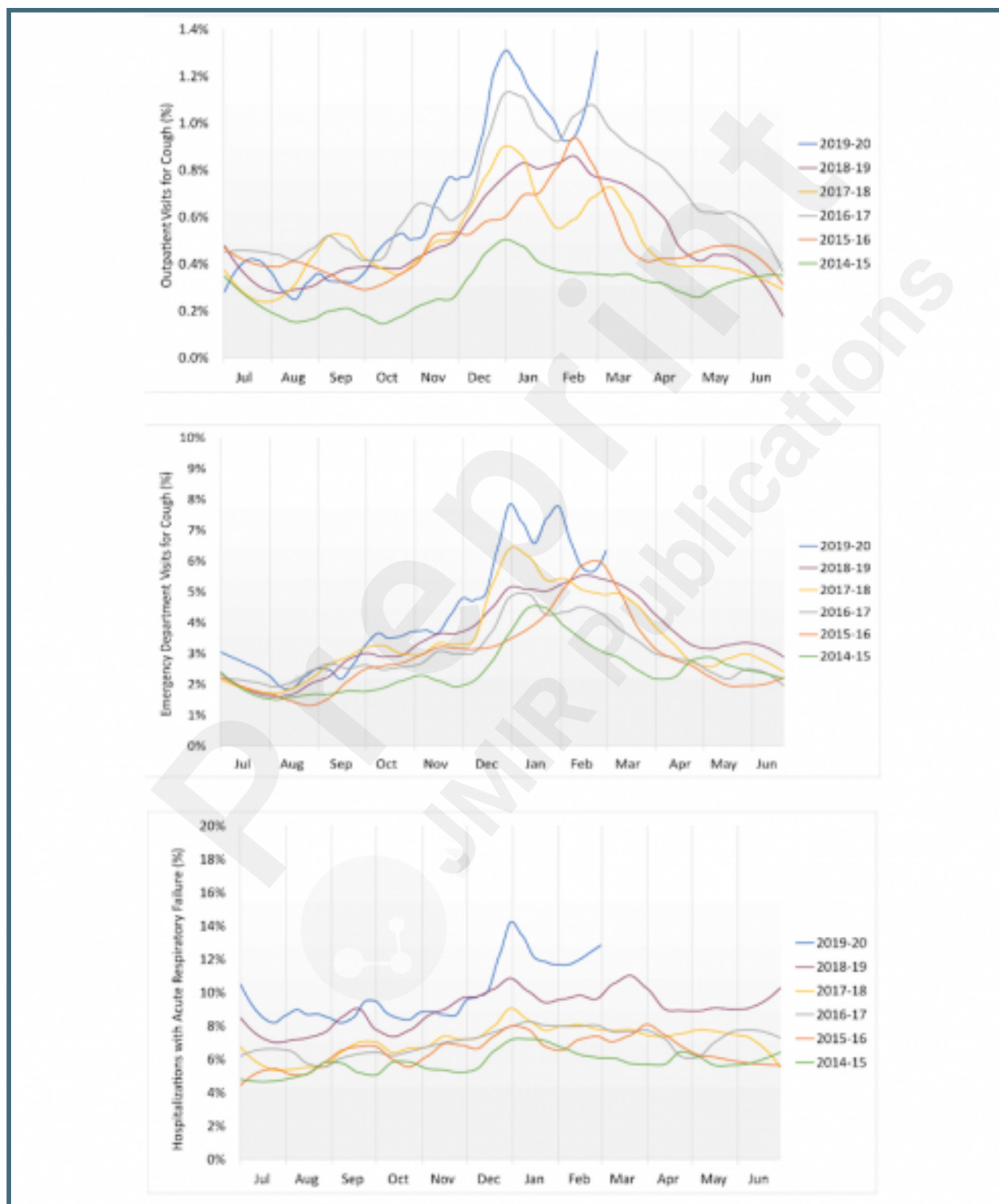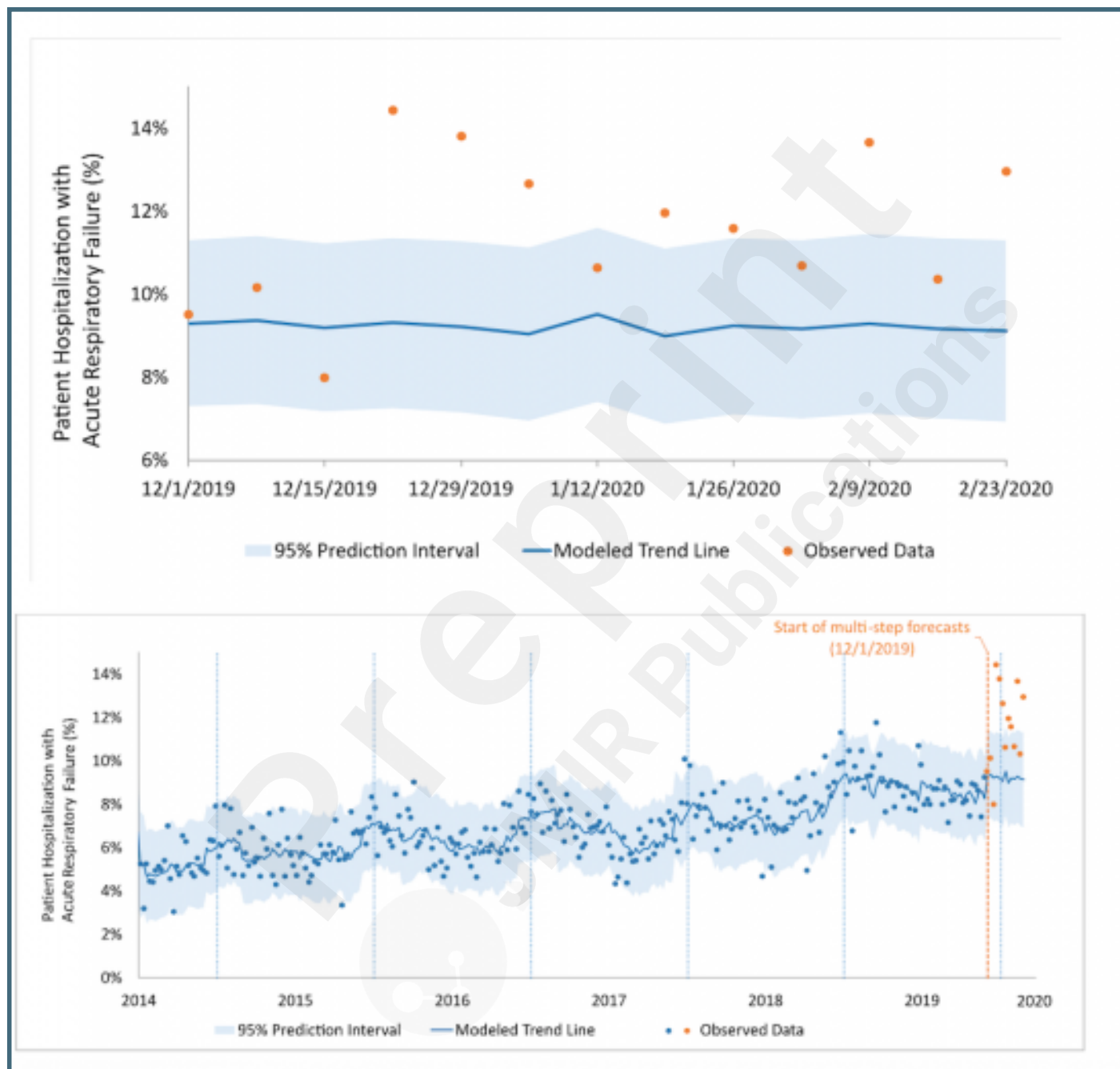
Time series analysis of outpatient data. 2A. Forecast, with 95% prediction intervals, of expected rates of outpatient presentations for cough (based on time-series analyses of the 5 previous years), with observed data for each week shown for December 1, 2019 to February 29, 2020. 2B. Time series analysis of outpatient data.
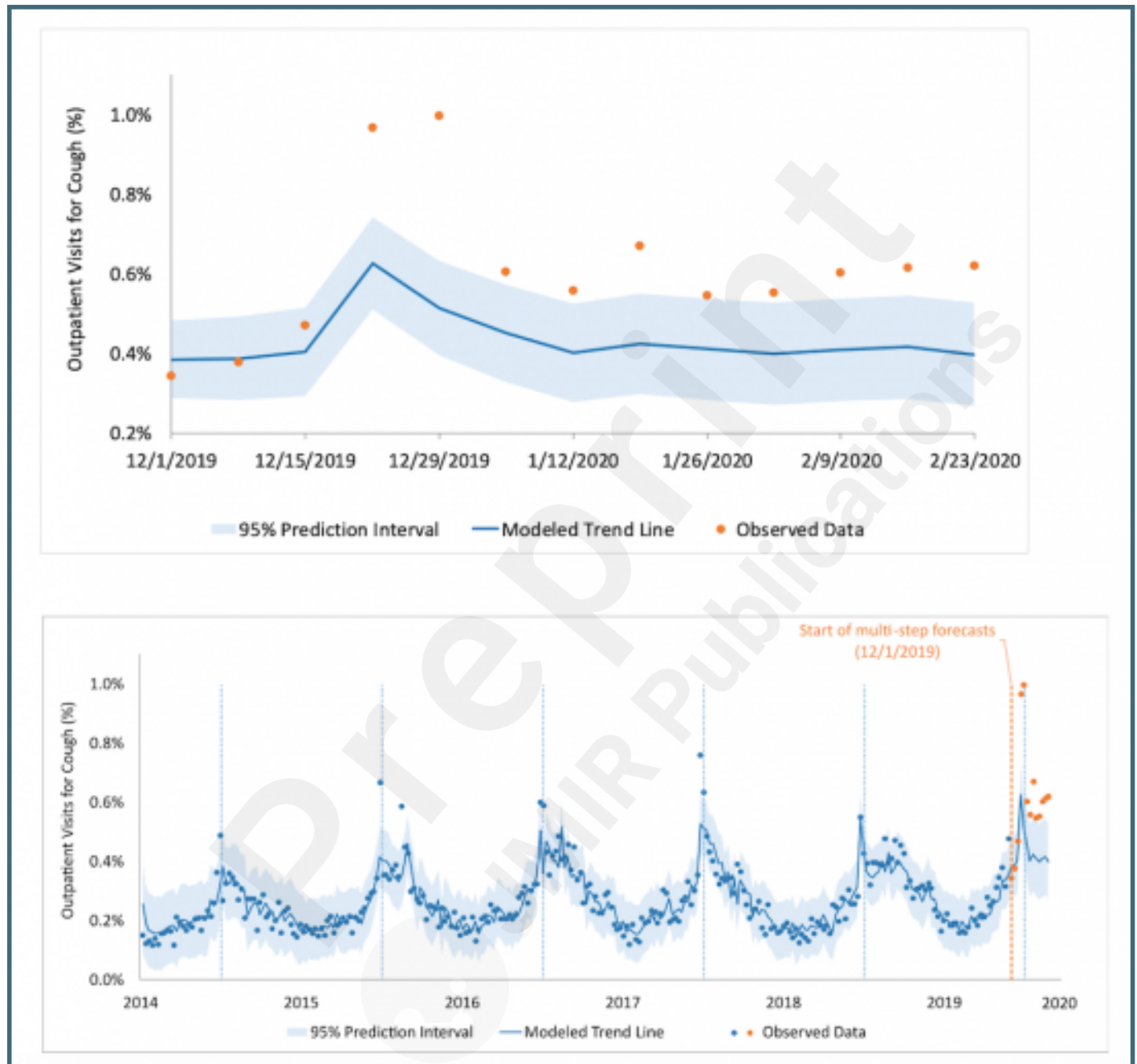
Time-series Analysis of Emergency Department Visits for Cough. 3A. Forecast, with 95% prediction intervals, of expected rates of emergency department presentations for cough (based on time-series analyses of the 5 previous years), with observed data for each week shown for December 1, 2019 to February 29, 2020. 3B. Time series analysis of Emergency Department data.
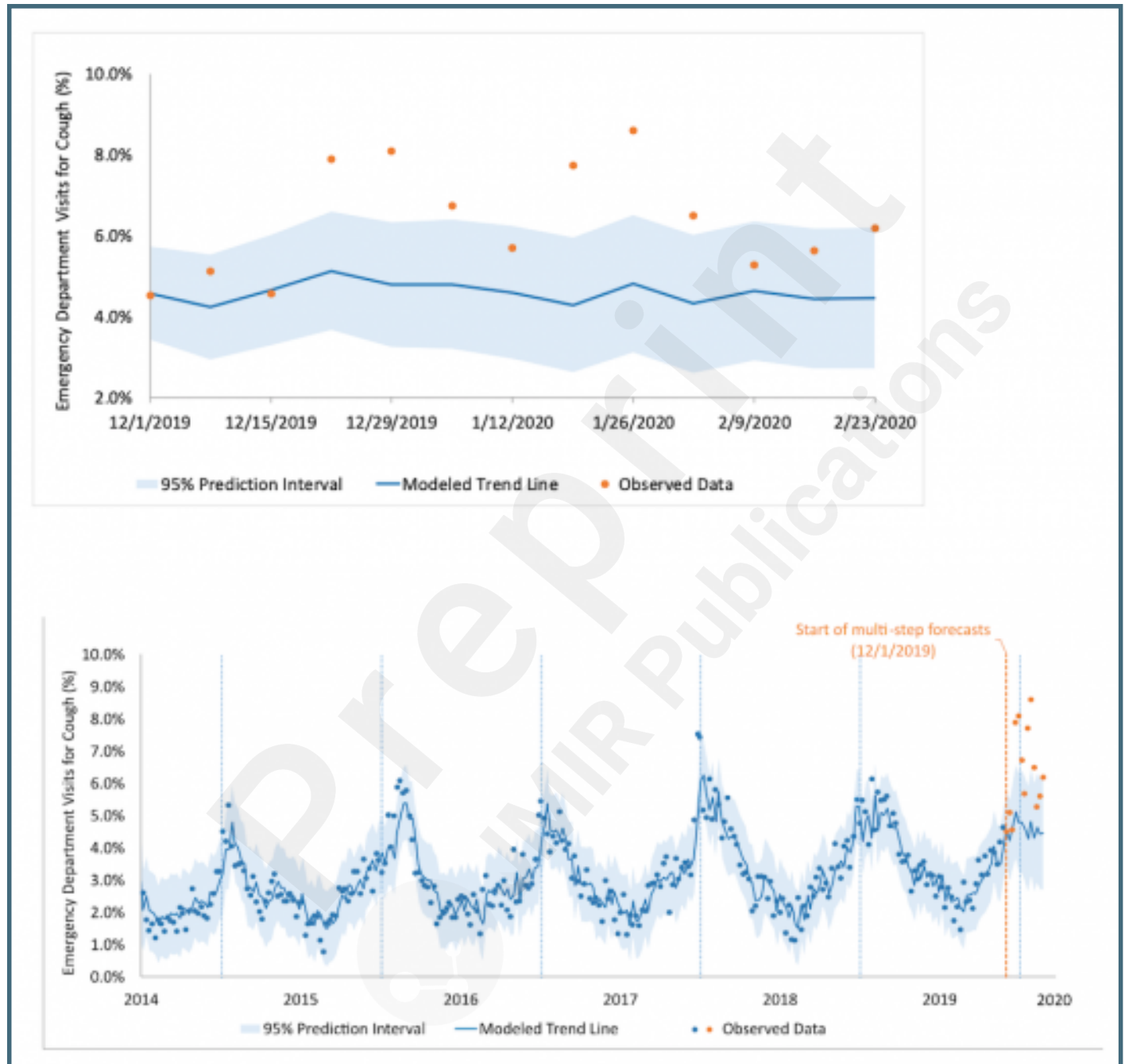
Time Series Analyses of Hospitalizations for Acute Respiratory Failure. 4A. Forecast, with 95% prediction intervals, of expected rates of patients hospitalized with acute respiratory failure (based on time-series analyses of the 5 previous years), with observed data for each week shown for December 1, 2019 to February 29, 2020. 4B. Time series analysis of hospitalization data.

Multimedia Appendixes

Electronic Appendix.
URL: https://asset.jmir.pub/assets/1997358f0101e75e51c77e9c442dd890.docx