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Brief Report

Characterizing the impact of snowfall on patient attendance at an urban emergency department in Toronto, Canada

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ABSTRACT

Objectives: We sought to determine whether addition of a snowfall variable improves emergency department (ED) patient volume forecasting. Our secondary objective was to characterize the magnitude of effect of snowfall on ED volume.

Methods: We used daily historical patient volume data and local snowfall records from April 1st, 2011 to March 31st, 2018 (2542 days) to fit a series of four generalized linear models: a baseline model which included calendar variables and three different snowfall models with an indicator variable for either any snowfall (>0 cm), moderate snowfall (≥1 cm), or large snowfall (≥5 cm). To evaluate model fit, we examined the Akaike Information Criterion (AIC) and Bayesian Information Criterion (BIC). Incident rate ratios were calculated to determine the effect of snowfall in each model.

Results: All three snowfall models demonstrated improved model fit compared to the model without snowfall. The best fitting model included a binary variable for snowfall (<1 cm vs. ≥1 cm). This model showed a statistically significant decrease in daily ED volume of 2.65% (95% CI: 1.23%–4.00%) on snowfall days.

Discussion: The addition of a snowfall variable results in improved model performance in short-term ED volume forecasting. Snowfall is associated with a modest, but statistically significant reduction in ED volume.

1. Introduction

Accurate modelling of emergency department (ED) arrivals is of great importance for staff and resource planning [1]. Factors such as day of the week, time of day, and holidays are already widely used to vary staffing [2-4]. Adding dynamic variables such as weather could yield significant improvement in forecasting accuracy. Weather is widely felt to impact ED patient volumes, but the nature of this relationship is poorly understood. Studies from Brazil and Singapore on weather variables such as outside temperature did not improve forecasting accuracy of ED patient volumes [2,5,6]. In contrast, a study from the United States found an association between daily maximum air temperature and ED patient volume [4].

Few studies have examined weather factors in colder climates – such as snowfall – where variations are much more diverse. A study from New York City reported that a snowfall day decreases ED visits by 5% [7]. However, this study had only 42 snowfall days during a total of 1316 study days, highlighting the need for local model implementation. Moreover, the authors calculated a simple difference in means rather than accounting for other factors such as day of the week which are known to be significant. They did not look at whether it was better modeled as a continuous, binary or categorized variable.

The primary aim of our study was to determine whether the addition of a snowfall variable improves ED volume forecasting accuracy in our ED. The secondary objectives were to determine (1) the optimal variable characterization and (2) the magnitude of the association between snowfall and daily emergency department arrivals.

2. Methods

2.1. Study setting and design

This is a retrospective observational study using records of daily patient visits at the ED of St. Michael's Hospital, an urban tertiary trauma

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care centre in Toronto, Canada. The ED sees approximately 80,000 patients annually. This study was approved by the St. Michael's Hospital Research Ethics Board.

2.2. Study time period and protocol

The daily number of ED visits from April 1st 2011 to March 31st 2018 (only calendar days with possible snowfall were included) was extracted from the St. Michael's Hospital Enterprise Data Warehouse (LKS-CHART). Total amount of daily snowfall for those same dates was extracted from the Environment Canada website [8]. We then fit a series of four generalized linear models. We modeled daily ED volume as the dependent variable using a Poisson distribution. The following five independent variables were considered as baseline predictor variables and included in all four models: day of the week, month of the year, year, indicator for holiday, and patient volume on the preceding day. We then constructed the following models:

1. Baseline model (includes only baseline variables)
2. Any snowfall (baseline variables plus an indicator variable for any snowfall)
3. Moderate snowfall ≥1 cm (baseline variables plus an indicator variable for snowfall ≥1 cm)
4. Large snowfall ≥5 cm (baseline variables plus an indicator variable for snowfall ≥5 cm)

2.3. Outcome measures and data analysis

To evaluate model fit we calculated the Akaike Information Criterion (AIC) and the Bayesian Information Criterion (BIC). In both cases, a lower number indicates better model fit. To evaluate model diagnostics, we examined model residuals of predicted values compared to actual values. To evaluate the statistical significance of adding any snowfall to the model, we compared the deviance of the model with snowfall to the deviance of the baseline model with a chi-square test.

To determine the effect of snowfall on daily ED volume, we calculated incident rate ratios for the snowfall variables for taking the exponential of the model coefficients. We used the delta method to calculate 95% confidence intervals for the incidence ratios. All analyses were conducted using R v 3.5.1 (r-project.org).

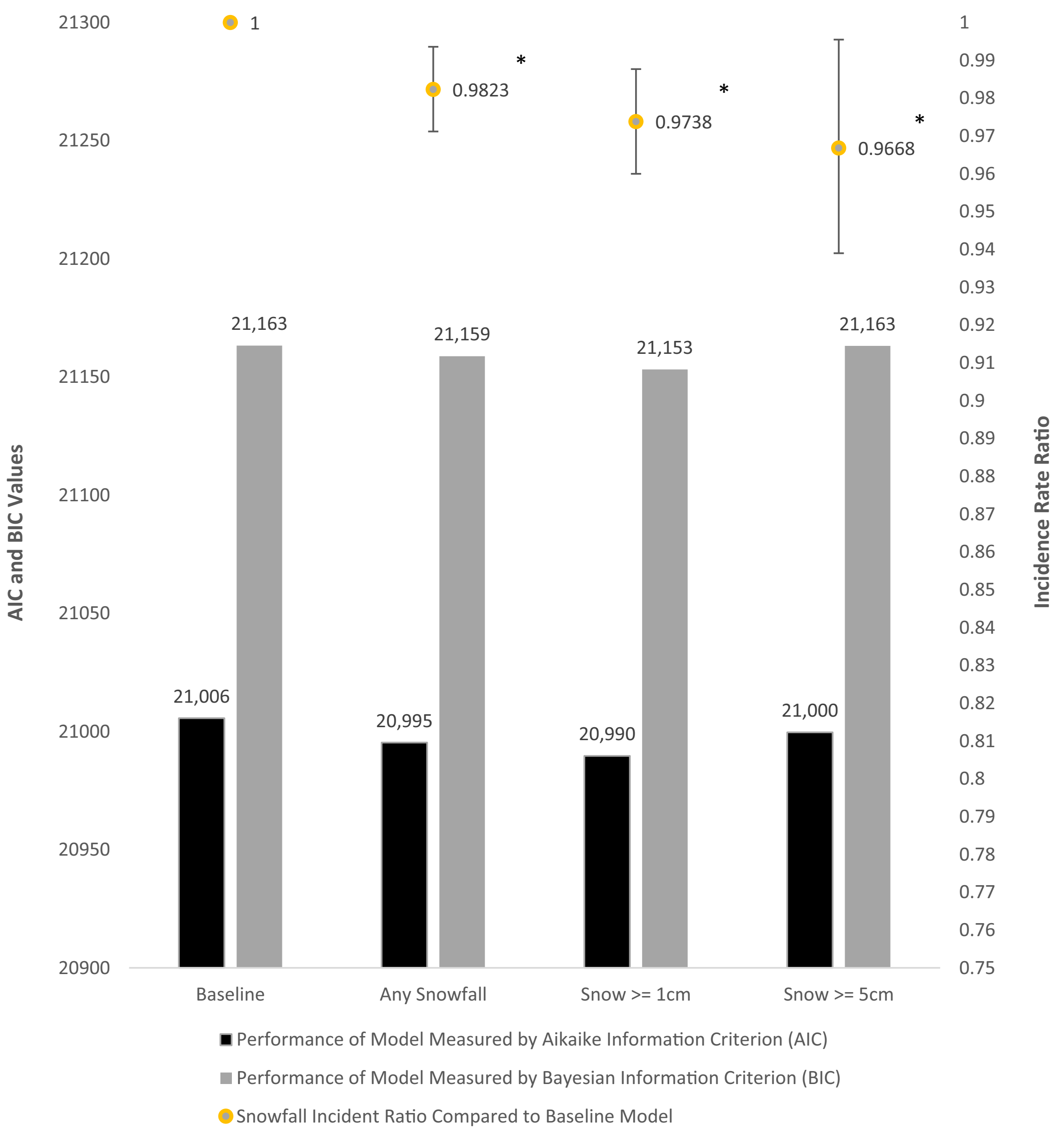

Fig. 1. Comparison of model performance and effect of snowfall at three different thresholds. Error bars represent 95% confidence intervals. *Represent statistically significant effect size of the snowfall variable compared to the baseline model.

3. Results

Two thousand five hundred and forty-two days were included in the analysis with 271 days (10.7%) having received any snowfall, 158 days (6.2%) with >1 cm of snowfall, and 38 days (1.5%) with >5 cm of snowfall. All three models which included a snowfall variable showed an improvement in model fit compared to the baseline model, based on the AIC and BIC values (Fig. 1). The best fitting model, based on the lowest AIC and BIC, was the model with a binary snowfall indicator variable set at a threshold of 1 cm or more snowfall.

All three snowfall models also demonstrated a statistically significant decrease in total daily ED volume on snowfall days (Fig. 1). The best fitting model had a snowfall incidence ratio of 0.97, meaning that days with 1 cm or more of snowfall saw a 2.65% (95% CI: 1.23%–4.00%) decrease in ED volumes corresponding to 5.4 (95% CI: 2.5–8.2) patients per day at our hospital with an average daily volume of 205 patients. The estimated decrease in ED volume from having any snowfall was 1.77% (95% CI: 0.64%–2.88%) and the estimated decrease of having >5 cm of snowfall was 3.32% (95% CI: 0.45%–6.10%).

4. Discussion

Including a snowfall variable in ED volume forecasting improved our static model's accuracy. Better modelling accuracy is desirable and could improve resource matching. This requires a better characterization of several dynamic variables that are likely to affect EDs in different ways. Developing the methodology to model such variables in each ED's local setting is important.

We found snowfall to result in a small, significant decrease in daily ED arrivals, similar to what was reported in the New York study [7]. The greater the snowfall threshold, the greater the impact of the snowfall variable. Reasons for this decrease remain unclear. Past studies have demonstrated an increase in orthopaedic injuries and cardiac arrest with snowfall, but it would appear that this is more than compensated by decreases in attendance for other conditions [9,10]. It is possible that snowfall may deter patients who have lower perceived acuity complaints from presenting to our ED due to poor driving or walking conditions.

Our study has some limitations. The relationship with dynamic variables such as snowfall will vary from ED to ED, but a methodology is proposed here to allow optimal threshold in a local context. Additionally, our study used historical weather data to generate the model as historical forecasted weather data is not available. If a snowfall variable were to be included for prospective forecasting, the level of uncertainty would be greater.

Our study suggests that ED volume forecasting models may benefit from the inclusion of a snowfall variable whenever appropriate. ED patient volume forecasting is increasingly used to improve resource matching. In our context, patient forecasting is used to make short-notice hospital decisions on bed allocation and its use in staffing decision is being explored. In such circumstances, accuracy is highly valued, which is improved by several variables that have small, noticeable impacts, such as snowfall. Further research should prospectively evaluate the elucidated relationship using forecasted rather than historical weather data, how the impact may differ according to type of patient, and implications for resources allocation and patient safety.

Declaration of Competing Interest

None.

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