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Effects of climate and fine particulate matter on hospitalizations and deaths for heart failure in elderly: A population-based cohort study

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ABSTRACT

Background: There are limited data on the effects of climate and air pollutant exposure on heart failure (HF) within taking into account individual and contextual variables.

Objectives: We measured the lag effects of temperature, relative humidity, atmospheric pressure and fine particulate matter ($PM_{2.5}$) on hospitalizations and deaths for HF in elderly diagnosed with this disease on a 10-year period in the province of Quebec, Canada.

Methods: Our population-based cohort study included 112,793 elderly diagnosed with HF between 2001 and 2011. Time dependent Cox regression models approximated with pooled logistic regressions were used to evaluate the 3- and 7-day lag effects of daily temperature, relative humidity, atmospheric pressure and $PM_{2.5}$ exposure on HF morbidity and mortality controlling for several individual and contextual covariates.

Results: Overall, 18,309 elderly were hospitalized and 4297 died for the main cause of HF. We observed an increased risk of hospitalizations and deaths for HF with a decrease in the average temperature of the 3 and 7 days before the event. An increase in atmospheric pressure in the previous 7 days was also associated with a higher risk of having a HF negative outcome, but no effect was observed in the 3-day lag model. No association was found with relative humidity and with $PM_{2.5}$ regardless of the lag period.

Conclusions: Lag effects of temperature and other meteorological parameters on HF events were limited but present. Nonetheless, preventive measures should be issued for elderly diagnosed with HF considering the burden and the expensive costs associated with the management of this disease.

1. Introduction

It has already been shown through multiple lines of evidence that climate is changing across the planet, largely as a result of human activities (Intergovernmental Panel on Climate Change, 2013). Global temperature is warming. Climate is more variable and unpredictable. Donat et al. (2013) predict that days and nights will be warmer, not to mention an increase in the occurrence and the duration of heat waves. In some parts of the world as in the province of Quebec, Canada, winters will remain cold and extreme cold snaps will occur despite the

Abbreviations: AIC, Akaike information criterion; BIC, Bayesian information criterion; CAs, Census agglomerations; CHDs, Coronary heart diseases; CMAs, Census metropolitan areas; CNS, Central nervous system; CSDs, Census subdivisions; CTs, Census tracts; CVDs, Cardiovascular diseases; DAs, Dissemination areas; GEE, Generalized estimating equation; HF, Heart failure; ICD, International classification of diseases; INSPQ, *Institut national de santé publique du Québec*; km, Kilometer; kPa, Kilopascal; NAPS, National Air Pollution Surveillance; ORNL DAAC, Oak Ridge National Laboratory Distributed Active Archive Center; $PM_{2.5}$, Fine particulate matter; QICDSS, Quebec Integrated Chronic Disease Surveillance System

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global warming (Ouranos, 2015).

Natural environment of the province of Quebec is characterized, among others, by the vastness of the landscape. With an area of 1,667,441 square kilometers (km), the province of Quebec extends to nearly 2000 km from south to north and 1500 km from east to west. As a result of its extensive area and the relief of the territory, Quebec has several distinct climate areas and ecosystems. In the center of Quebec, average temperatures vary from − 16 °C in winter to 12 °C in summer whereas it fluctuates from − 8 °C to 20 °C in the south of the province (Ouranos, 2015).

Climate changes affect, above all, vulnerable populations, including individuals with chronic diseases, elderly and disadvantaged people (Basu and Samet, 2002; Kenny et al., 2010; Doyon et al., 2008). Extreme temperatures, such as extended heat waves or cold snaps, increase morbidity, mortality and health resource utilization for heart failure (HF) when combined with an advanced age and a low-income neighbourhood (Hawkins et al., 2012). Moreover, several atmospheric pollutants sensitive to weather conditions are affected by the global warming (Luber and Lemery, 2015). These air pollutants can exacerbate cardiovascular diseases (CVDs) and, according to Luber and Lemery (2015), are associated with an increase in emergency visits, hospitalizations and premature deaths.

Sensitivity to extreme climate is apparent in the field of CVDs, a research thematic prioritized in a recent report published by the National Institute of Environmental Health Sciences (Portier et al., 2010). There are multiple evidences of the negative impact of meteorology as well as air pollution on HF hospital admissions and mortality (i.e., Goggins and Chan, 2017; Das et al., 2014; Qiu et al., 2013; Gotsman et al., 2010; Inglis et al., 2008; Kolb et al., 2007). However, to our knowledge, there is no study that investigates the impact of meteorological parameters and fine particulate matter on morbidity and mortality for HF at a neighbourhood scale considering both individual and contextual factors.

In this study, we measured the effect of several meteorological parameters on the occurrence of a hospitalization or death for the main cause of HF in elderly, aged 65 years and older, known to be diagnosed with this condition in Quebec (Canada) over a ten-year period (2001 – 2011). The main objective was to evaluate the effect of mean temperature, relative humidity and atmospheric pressure as well as air pollutant $PM_{2.5}$, on HF negative outcomes controlling for several contextual and individual covariates. This is particularly relevant for purposes of surveillance in public health in a context of climate changes.

2. Methods

To measure the association between climate, $PM_{2.5}$ exposure and the occurrence of HF events, a population-based retrospective cohort study was conducted.

2.1. Study population

Individuals of 65 years and older hospitalized for HF, either as a primary or secondary cause between April 1st 2001 and December 31st 2011 without any hospitalization for this motive (all diagnostic positions) in the previous five years, were identified in the Quebec Integrated Chronic Disease Surveillance System (QICDSS) database to build the cohort study. The index date corresponds to the date of entry into the cohort, defined as the date of the discharge from this HF hospitalization. Individuals were excluded if they moved out between their entry into the cohort and the occurrence of the outcome of interest or the end of the study period.

To homogenize the study cohort and minimize selection bias, the first hospital admission for HF without any hospitalization for this cause in the previous five years was used. The aim of using a buffer of five years was to include individuals at the beginning of the symptomatic phase of their disease, when it is sufficiently serious to necessitate a hospitalization.

Health data of individuals included in the cohort were obtained from the QICDSS database. The QICDSS created by the *Institut national de santé publique du Québec* (INSPQ) is an innovative chronic disease surveillance system developed to monitor several chronic diseases in the province of Quebec. The QICDSS data are derived from the linkage of five health administrative databases managed by the Ministry of health and social services (*Ministère de la santé et des services sociaux*) and the provincial health insurance board (*Régie de l'assurance maladie du Québec*). It contains information on all individuals covered by the Quebec universal public health insurance plan that had at least one diagnosis or criteria of the studied chronic diseases. The five data sources are the health insurance registry, the hospitalization database, the physician billing claims database (including emergency department visits, outpatient visits and community physicians' visits), the pharmaceutical claims database (for people of 65 years and older), and the vital statistics death database (Blais et al., 2014; Vanasse et al., 2016).

2.2. Geographical areas

Dissemination areas (DAs) can be used as proxy for life conditions in neighbourhoods especially for health adverse events associated with extreme summer heat in Quebec (Ngom et al., 2013; Bélanger et al., 2016). However, in the present study, it was impossible to use this proxy due to the large number of DAs with only one or no HF event. Census tracts (CTs) and census subdivisions (CSDs) were used instead of DAs given that they cover larger populations.

CTs usually have a population between 2500 and 8000 inhabitants. They are located in census metropolitan areas (CMAs) and in census agglomerations (CAs) that have a core population of 50,000 or more (Statistics Canada, 2015a). As to CSDs, they designate municipalities or areas that are deemed to be equivalent to municipalities for statistical reporting purposes (e.g., Indian reserve) (Statistics Canada, 2015b).

People in the cohort were assigned to CTs and CSDs with the six-digit postal codes of residence available in the QICDSS database. The matching between CTs/CSDs and postal codes was made using the postal codes conversion file of Statistics Canada (Statistics Canada, 2015c). Overall, 1367 CTs and 761 CSDs were under study (the population ecumene is presented in Fig. 1), corresponding to 112,793 people.

2.3. Study outcomes and confounders

The health outcomes of interest were the time before the occurrence of a hospitalization (primary diagnosis only) or death (main cause) for HF from the index date. HF diagnosis was identified in the QICDSS database using the International Classification of Diseases (ICD). In Quebec, the transition of ICD-9 to ICD-10 occurred in April 2006 for the inpatient data and in January 2000 for the data related to death. Hence, HF diagnosis was identified according to either ICD-9 or ICD-10, depending on which version was being used on a given date (ICD-9 code 428.xx and ICD-10-CA (Canadian enhancement) code I50.xx).

The potential confounders were selected a priori based on substantive prior knowledge (Roger, 2013; Khatibzadeh et al., 2013; He et al., 2001). The potential confounders considered were: age, sex, presence of hypertension, diabetes or coronary heart disease (e.g., myocardial infarction), mean number of outpatient consultations or emergency hospitalizations (primary diagnosis) for CVDs in the last 12 months, mean number of prescription drugs related to the cardiovascular and renal systems in the last 12 months, mean number of prescription drugs related to the central nervous system (CNS) in the last 12 months, week day (Monday to Friday vs. Saturday or Sunday), residential area (CMA of Montreal: > 1 million inhabitants, other CMAs: 100,000 to 1 million inhabitants, CAs: 10,000 to 100,000 inhabitants, and small towns as well as rural areas: < 10,000 inhabitants), and material and social deprivation index. These variables