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Cost saving potential in cardiovascular hospital costs due to reduction in air pollution

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HIGHLIGHTS

- Improved methodology chain to estimate potential hospital cost savings for Belgium
- $PM_{2.5\&10}$, NO_2 are significantly associated with cardiovascular emergency admissions.
- Ischemic heart disease and heart rhythm disturbances are significant subcategories.
- 10% reduction in air pollution exposure averts at least €14 M/year on hospital costs.
- Achieving WHO guidelines results in minimum €51 M/year on averted hospital costs.

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ABSTRACT

Objective: We describe a methodological framework to estimate potential cost savings in Belgium for a decrease in cardiovascular emergency admissions (ischemic heart disease (IHD), heart rhythm disturbances (HRD), and heart failure) due to a reduction in air pollution.
Methods: Hospital discharge data on emergency admissions from an academic hospital were used to identify cases, derive risk functions, and estimate hospital costs. Risk functions were derived with case-crossover analyses with weekly average PM_{10}, $PM_{2.5}$, and NO_2 exposures. The risk functions were subsequently used in a micro-costing analysis approach. Annual hospital cost savings for Belgium were estimated for two scenarios on the decrease of air pollution: 1) 10% reduction in each of the pollutants and 2) reduction towards annual WHO guidelines.
Results: Emergency admissions for IHD and HRD were significantly associated with PM_{10}, $PM_{2.5}$, and NO_2 exposures the week before admission. The estimated risk reduction for IHD admissions was 2.44% [95% confidence interval (CI): 0.33%–4.50%], 2.34% [95% CI: 0.62%–4.03%], and 3.93% [95% CI: 1.14%–6.65%] for a 10% reduction in PM_{10}, $PM_{2.5}$, and NO_2 respectively. For Belgium, the associated annual cost savings were estimated at €5.2 million, €5.0 million, and €8.4 million respectively. For HRD, admission risk could be reduced by 2.16% [95% CI: 0.14%–4.15%], 2.08% [95% CI: 0.42%–3.70%], and 3.46% [95% CI: 0.84%–6.01%] for a 10% reduction in PM_{10}, $PM_{2.5}$, and NO_2 respectively. This corresponds with a potential annual hospital cost saving in Belgium of €3.7 million, €3.6 million, and €5.9 million respectively. If WHO annual guidelines for PM_{10} and $PM_{2.5}$ are met, more than triple these amounts would be saved.
Discussion: This study demonstrates that a model chain of case-crossover and micro-costing analyses can be applied in order to obtain estimates on the impact of air pollution on hospital costs.

1. Introduction

After the famous Meuse Valley fog in 1930, the Belgian pathologist Firket was one of the first scientists to demonstrate the harmful effects of air pollution on public health (Firket, 1936, in Nemery et al., 2001). Eighty-five years later, significant improvement has been made in the scientific knowledge regarding the effects of air pollutants on the respiratory and cardiovascular system. Numerous epidemiological studies and reviews have demonstrated an association between cardiovascular diseases and acute and chronic exposures to Particulate Matter (PM) with an aerodynamic diameter <10 μm (PM_{10}) or <2.5 μm ($PM_{2.5}$) (Hansen et al., 2012; Rückerl et al., 2011; Brook et al., 2010) and Nitrogen Dioxide (NO_2) (Carracedo-Martínez et al., 2010; Shah et al., 2013).

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Several international studies and reviews have shown evidence that lowering air pollution exposure leads to less adverse health effects (e.g. Burnett et al., 2014; Pope et al., 2008; Wellenius et al., 2006; WHO Regional office for Europe, 2013). In an era in which the importance of sustainable development and its impact on environment and public health gains more and more recognition worldwide, this outcome forced policy makers to tackle the problem of air pollution. These days, more stringent air quality standards than ever before are applied in the United States (National ambient air quality standards (US EPA, 2015, March 9)), the European Union (Council Directive, 2008/50/EC; The Clean Air Policy Package (European Commission, 2013)) and other countries. Although Belgium still remains one of the most polluted regions in Europe concerning particulate air pollution, it performs relatively well in keeping its air pollution exposure below the European Union air quality guidelines. Despite this observation, adverse health effects still occur at exposure levels well below these guidelines (Beelen et al., 2014). Moreover, the air pollution guidelines published by the World Health Organization (WHO) are stricter and therefore more protective towards public health than the European Union standards (WHO, 2005).

The economic implications of air pollution-related illnesses for society are inevitable but are often overlooked and/or underestimated by policy makers (Landrigan, 2012; Guo et al., 2010; Pervin et al., 2008). However, reductions in air pollution exposure, at every level, are expected to result in a reduction in total external costs. From this perspective, economic data are needed for the debate on priority settings in public health.

In the current study, the aim was to estimate the total averted hospital costs (one component in the total societal cost calculation) in Belgium attributable to a decrease in cardiovascular emergency admissions associated with a short-term reduction in PM_{10}, $PM_{2.5}$, and NO_2. Two reduction scenarios were considered. First, we analyzed the impact of a 10% reduction in short-term air pollution exposure for the study population and extrapolated the effects to a national level. In a second scenario, we assume a reduction of the pollutants towards the levels of the WHO-guidelines and calculate the impact at national level for Belgium. Case-crossover analyses were used (Maclure, 1991) to estimate the impact of air pollutants on emergency admissions for ischemic heart diseases, heart rhythm disturbances, and heart failure. The derived risk functions were used in a hospital cost analysis.

This study might be valuable for policy makers, as the estimated risk functions contribute to the quantification of air pollution related cardiovascular diseases and the hospital cost calculations might guide subsequent cost-benefit analyses.

2. Methods

2.1. Data

2.1.1. Emergency admissions

Hospital discharge data on emergency admissions from January 1st 2007 until July 1st 2012 were obtained from UZ Brussels (University Hospital Brussels, Belgium). UZ Brussels is an academic general hospital founded by the Vrije Universiteit Brussel in 1977. The hospital has 721 beds and admits approximately 30,000 patients a year. The emergency department is open 24 h a day treating approximately 65,000 patients a year.

Patients at interest were identified with the following primary discharge diagnoses (International Classification of Diseases, Ninth Revision, Clinical Modification, ICD-9-CM): 1) ischemic heart disease (ICD-9-CM 410–414 and 429), 2) heart rhythm disturbances (ICD-9-CM 426–427), and 3) heart failure (ICD-9-CM 428). These diagnoses were selected because a significant short-term association between air pollution and these diagnoses has been confirmed in other settings in earlier research (Burnett et al., 2014; Pope et al., 2006, 2008; Wellenius et al., 2006). To be able to focus on acute events and eliminate elective admissions, only admissions through the emergency department were considered in the current study (Zanobetti and Schwartz, 2006).

For the identified patients, hospital data of interest were extracted from the Minimal Clinical Dataset (MCD). The registration of MCD is obligatory for each hospital in Belgium. We extracted the primary discharge diagnoses (ICD-9-CM), length of stay, date of admission, and severity of illness (SOI) for each patient. According to the APR-DRG classification SOI is defined as “the extent of an organ system derangement or physiologic decompensation of a patient”. SOI is based on a variety of demographic, clinical, physiological and laboratory variables (Averill et al., 1997). SOI has four levels (minor, moderate, major, and extreme) but was categorized into two levels in this study: 1) minor–moderate severity and 2) major–extreme severity. In addition we extracted personal characteristics as gender, age, and zip code of residence (municipality). Age was categorized into three categories: sixty years old or less, between 61 and 75 years old, and older than 75 years.

Ethical approval for the study was obtained by the Ethics Committee of UZ Brussels (B.U.N.143201215726).

2.1.2. Hospital costs

Hospital costs consisted of emergency and hospital claims at individual level from UZ Brussel. These are registered in the Minimal Financial Dataset and contain all claims for drugs, clinical biology, medical imaging, technical interventions, honoraria, and other claims charged to patients (co-payments), health insurances, and/or other insurances. To calculate the total hospital cost, a fixed price per day was added according to the year of admission. This day price is based on an additional fixed amount that Belgian sickness funds pay directly to the hospitals. It covers the financing of non-medical hospital activities such as capital expenditures and investments for housing and medico-technical facilities, hotel function, and nursing care. For this study the weighted average per diem prices (across Belgian hospitals) was used (Cleemput et al., 2012). All costs were converted into 2011 euros using the Belgian health care inflation rates published by the Belgian Directorate-General Statistics and Economic information.[1]

2.1.3. Exposure data

Daily average PM_{10}, $PM_{2.5}$, and NO_2 concentrations were obtained from the Belgian Interregional Environment Agency. In Belgium (33,990 km^2), the number of monitoring stations in use has increased over the years, but is relatively stable since 2008. In 2012, there were 66 monitoring stations for PM_{10}, 38 for $PM_{2.5}$, and 89 for NO_2. Data from monitoring stations are combined with land cover data obtained from satellite images (Corine land cover data set) in a spatial temporal interpolation method (Kriging) described by Janssen et al. (2008). This provides interpolated air pollutant concentration estimates on a 4×4 km^2 grid, which are then used to calculate population-weighted averages per municipality. For each patient, the weighted average of the municipality in which he/she was living at the time of hospitalization was used as the patient's air pollution exposure. Previous studies have demonstrated that PM_{10} estimates correlate well with individual exposure, as assessed by carbon load in macrophages (Jacobs et al., 2010). Validation statistics of the interpolation tool gave a temporal explained variance (R^2) for hourly average $PM_{2.5} > 0.80$ (Maiheu et al., 2013). Meteorological data and influenza epidemics were taken into account when estimating the exposure–response functions. Daily mean air temperature and relative humidity measured at the station in Uccle (Brussels, Belgium) were provided by the Belgian Royal Meteorological Institute. An index of human discomfort, apparent temperature incorporating relative humidity, was calculated by using a standard formula (Kalkstein and Valimont, 1986; Steadman, 1979). Data on influenza epidemics in Belgium were provided by the National Influenza Centre (Scientific Institute of Public Health, WIV-ISP, 2015, March 13).

[1] http://statbel.fgov.be/nl/statistieken/cijfers/economie/consumptieprijzen/index_search/.