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Long-term exposure to traffic pollution and hospital admissions in London

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ABSTRACT

Evidence on the effects of long-term exposure to traffic pollution on health is inconsistent. In Greater London we examined associations between traffic pollution and emergency hospital admissions for cardio-respiratory diseases by applying linear and piecewise linear Poisson regression models in a small-area analysis. For both models the results for children and adults were close to unity. In the elderly, linear models found negative associations whereas piecewise models found non-linear associations characterized by positive risks in the lowest and negative risks in the highest exposure category. An increased risk was observed among those living in areas with the highest socioeconomic deprivation. Estimates were not affected by adjustment for traffic noise. The lack of convincing positive linear associations between primary traffic pollution and hospital admissions agrees with a number of other reports, but may reflect residual confounding. The relatively greater vulnerability of the most deprived populations has important implications for public health.

1. Introduction

A large body of evidence from daily time-series studies has found short-term associations between a range of ambient air pollutants, including those of primary traffic origin, and emergency hospital admissions for cardiovascular and respiratory conditions (WHO, 2013). Evidence for associations with long-term exposure to traffic pollutants, in contrast, is rather mixed (HEI, 2010; WHO, 2013). A systematic review on studies published between 1950 and 2007 found none reporting positive associations between chronic exposure to nitrogen dioxide (NO_2) or nitrogen oxides (NO_x) and cardiovascular or respiratory morbidity and concluded that, due to the small number of studies, evidence on these pollutants was insufficient to make solid conclusions (Chen et al., 2008). In 2010, a report on traffic-related air pollution and health also concluded that the epidemiologic evidence relating to the associations between long-term exposure to primary traffic exposures, for example nitrogen oxides, and health was largely inconclusive (HEI, 2010).

To address this question studies of traffic-related pollution within cities are needed. Population-wide small-area studies which use routinely collected register data have the relative advantage over most cohort studies of individuals of having a larger sample size and greater representativeness, although they are likely to be more vulnerable to residual confounding from unmeasured area and individual-level factors. Previous ecological studies of environmental exposures in London, however, have successfully used small-area methods (Halonen et al., 2015a, 2015b; Hansell et al., 2013).

Therefore, as part of a research programme into the health effects of traffic pollution in London (TRAFFIC study (King's College London, 2014)), we conducted a within-city small-area study of the associations between long-term exposure to primary traffic pollution and hospital admissions for cardiovascular and respiratory diseases for the whole of London between 2003 and 2010. We hypothesized that long-term average pollution contributes to

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exacerbations of existing health conditions resulting in additional hospital admissions observable at the small-area. We used a dispersion model to estimate at a fine spatial scale long-term exposure to six primary traffic pollutants including metrics for exhaust and non-exhaust related primary particles that have rarely been used in previous studies. In addition to the commonly used linear models we used piecewise linear models that relax the assumption of linearity across the whole exposure range.

2. Methods

2.1. Study area

Our study area comprised all postcode areas within the M25 motorway with over nine million inhabitants. Each postcode is nested within a Census Output Area (COA) that was the spatial unit of analysis ($n = 27{,}731$). Mean population of COAs is 300 (>40 households) (Office for National Statistics, 2014). We included 27,686 COAs with complete information for the exposures, health outcomes, and possible area-level confounders.

2.2. Health outcomes

We selected the first emergency hospital episode in each of the years 2003–2010 recorded in the Hospital Episode Statistics provided by the Health and Social Care Information Centre (HSCIC). We used emergency rather than all (including elective) admissions to better capture exacerbations of disease as opposed to planned visits due to existing diseases. The outcome groups were (ICD-10): all cardiovascular diseases (I00-I99), coronary heart disease (I20-I25), heart failure (I50), stroke (I61, I63, I64), all respiratory diseases (J00-J99), obstructive respiratory diseases (J12-J18 and J20-J22) and infections of the lower respiratory tract (J40-J46). Cardiovascular outcomes were analysed in two age groups: 45–74 and $\geq$ 75 years old, and respiratory outcomes in three age groups: 0–14, 15–64, and $\geq$65 years old. We used the sum of admissions across 2003–2010 within each COA. Of all HES admission records in England from 2003 to 2010, 4.2% did not have a valid postcode and were excluded. Annual mid-year population estimates at COA-level by sex and 5-year age band from the Office for National Statistics (ONS) were used to calculate admission rates. The study uses SAHSU data, supplied from ONS; data use was covered by approvals from the National Research Ethics Service - reference 12/LO/0566 and 12/LO/0567 - and by Health Research Authority Confidentially Advisory Group (HRA-CAG) for Section 251 support (HRA - 14/CAG/1039); superseding National Information Governance Board and Ethics and Confidentiality Committee approval (NIGB - ECC 2-06(a)/2009).

2.3. Exposures

We used the KCL urban dispersion model (Beevers et al., 2013; Kelly et al., 2011) to estimate average annual concentrations (2003–2010), as follows: 1) six primary traffic pollutants: nitrogen oxides (NO_x), nitrogen dioxide (NO_2), as well as exhaust (tailpipe emissions) and non-exhaust (brake and tyre wear and resuspension) related primary $PM_{2.5}$ and PM_{10} (aerodynamic diameter <2.5 and < 10 μm, respectively); and 2) five pollutants reflecting the contribution of regional/urban background pollution: $PM_{2.5}$, PM_{10} and ozone (O_3) from which we calculated coarse fraction of PM_{10} ($PM_{10\text{-}2.5}$) and oxidative gases (O_x, i.e. NO_2+O_3) (Williams et al., 2014) The modelling was based on Atmospheric Dispersion Modelling System (ADMS) v.4 and road source model v.2.3, which incorporates hourly meteorological measurements, empirically derived NO–NO_2–O_3 and PM relationships, and information on source emissions from the London Atmospheric Emissions Inventory (LAEI) (Greater London Authority, 2008). For NOx and NO_2, modelled data have been evaluated against measurement data from monitoring sites with an annual data capture of >75%. Minimum number of sites was 62 in 2003, and maximum number was 100 in 2008. The model performed well when validated against measurements: a comparison of observed vs. modelled concentrations provided high spearman correlation coefficients (r): for NOx r varied between 0.79 and 0.92, and for NO_2 between 0.85 and 0.93. More detailed information about the modelling procedure and model validation can be found elsewhere (Beevers and Dajnak, 2015). Spatial resolution of the model was 20 × 20 m; estimates for each postcode address centroid were based on interpolation between model grid points. COA-level exposure was calculated as the mean of: 1) annual mean concentrations at all postcode address centroids within a COA, and 2) overall study years.

2.4. Statistical analyses

Adjacent small areas tend to be more alike than those further apart. To model these spatial dependencies we used ecological Poisson regression specified in a Bayesian framework that was implemented through the Integrated Nested Laplace Approximation (INLA) approach (Rue et al., 2009) using R 3.1.0 package R-INLA (www.r-inla.org) (Martino and Rue, 2010; R Core Team, 2014). We included age and sex standardised expected numbers of admissions as offsets in the models and accounted for (i) spatial residuals through a conditional autoregressive structure which assumes dependencies between neighbouring areas, and (ii) spatially unstructured variability through an area specific random effect. Minimally informative priors were specified on all the parameters in the model: Gaussian distributions centred on zero and characterised by a precision (1/variance) equal to 0.00001 for the regression coefficients; Gaussian distributions on the two random effects, both centred on zero and characterised by a lognormal (0.5, 0.00005) on the logarithm of the precision.

First we used linear Poisson regression models to determine associations between pollutants and cause-specific hospital admissions. Linear models are most commonly used and thus results can be more reliably compared with prior findings. However, the associations between air pollutants and health outcomes are not necessarily linear. To overcome this issue, categorical variables based on percentiles of the exposure are often used that do not account for changes in the estimates of epidemiological risk (RR/OR) within each category. As a compromise between the two approaches we used piecewise linear models that relax the assumption of linearity of any association across the whole range of exposures. These models use pre-defined exposure categories (here characterised by approximately equal exposure range in each) and assume a (potentially different) linear effect within each category. Models were adjusted for COA-level confounders: quintiles of socioeconomic deprivation; tertiles of proportion of COA population of black and South Asian ethnicities; proxy for smoking (annual smoothed age and sex standardised relative risk of lung cancer mortality (ICD-10: C33-C34)) (Hansell et al., 2013); and daytime road traffic noise ($L_{Aeq,\ 16\ h}$). The Carstairs index (Morgan and Baker, 2006) was used as small-area level composite measure of socioeconomic deprivation. Deprivation and ethnicity data were derived from the UK Census 2011, provided by the ONS, and cancer data are derived from national cancer registries and were supplied by the ONS. Annual daytime (from 7:00 to 22:59) road traffic noise levels were modelled at geometric centroids of ~190,000 postcode locations in London using the TRAffic Noise EXposure (TRANEX) (Gulliver et al., 2015) model with 0.1 dB(A)