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Spatial analysis of exposure to traffic-related air pollution at birth and childhood atopic asthma in Toronto, Ontario

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ABSTRACT

Findings from the Toronto Child Health Evaluation Questionnaire (TCHEQ) study indicate that early childhood exposure to traffic-related air pollution (TRAP) is related to the onset of atopic childhood asthma. To test this hypothesis further, we investigated whether spatial patterns in the birth neighbourhood of TCHEQ subjects with atopic asthma (136 of 909 schoolchildren in grades 1–2) could be explained by TRAP and other risk factors. If a causal relationship exists between early childhood residential exposure to TRAP and the development of atopic asthma, we hypothesise that (1) clusters of current asthma should exist around the place of residence at birth, and (2) accounting for residential concentrations of TRAP at birth should explain some of the autocorrelation. Several high asthma clusters were observed. Adjusting for TRAP completely explained one cluster; elsewhere, clusters were only partially explained by TRAP. Findings suggest that exposure during early childhood to TRAP in Toronto is an important contributor to the development of the atopic asthma phenotype and reveal the likely importance of other risk factors not measured in the fixed effects of the model.

1. Background

Asthma is an important chronic disease of childhood with growing global prevalence. In particular, asthma symptom prevalence is very high in high income countries, including Canada (Asher et al., 2001; Habbick et al., 1999; Manfreda et al., 2001, 2004). The aetiology of childhood asthma remains poorly understood, but research increasingly points toward the importance of exposure to multiple factors, including environmental toxins and respiratory infections during early childhood, as well as social and genetic variables (Marks, 2006; Shankardass et al., 2009).

There is biological and epidemiological evidence that traffic-related air pollution (TRAP) plays a role in the development of asthma (Dell et al., 2014; Martinez, 1999; Zmirou et al., 2004). Although the causal pathway remains unclear, a life course perspective is certainly relevant. While many studies have identified a relationship between asthma and exposure to TRAP in school age children, some studies indicate that exposure during early childhood may be particularly important (Brauer et al., 2007, 2002; Dell et al., 2014; Martinez, 1999; Zmirou et al., 2004). Allergic sensitization has long been recognised as a risk factor for asthma in children (Umetsu and Dekruyff, 2006) and exposure to TRAP has been associated with the development of allergic sensitization (Morgenstern et al., 2008; Nicolai et al., 2003; Nordling et al., 2008; Oftedal et al., 2007).

This analysis was also guided by a conceptual framework that predicts neighbourhood disparities in childhood asthma due to multiple, inter-related fundamental causes (cf. Link and Phelan) operating at the macrosocial (e.g., policies, housing markets) and mesosocial (e.g., neighbourhood) levels (Shankardass and Dunn, 2012). For example, within the city of Toronto, lower income neighbourhoods are subject to higher levels of nitrogen dioxide (NO_2) (Buzzelli and Jerrett, 2007), a component of TRAP that has been associated with asthma onset in other cities (Jerrett et al., 2008).

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It is useful for jurisdictions to examine geographic variation in asthma for planning public health interventions. Multilevel models have been used to examine whether geographic variation in TRAP is associated with the onset of asthma (e.g. Jerrett et al., 2008). In this analysis, we use multilevel models and methods of spatial analysis to examine whether exposure to TRAP during early life helps to explain spatial patterns in atopic asthma, and to highlight specific places where patterns of TRAP and asthma are coincident.

The Toronto Child Health Evaluation Questionnaire (T-CHEQ) study is a multiphase cross-sectional study examining associations between TRAP and asthma in schoolchildren from grades 1 and 2 in Toronto, Ontario, Canada (Dell et al., 2010). A recent nested case-control analysis reported a positive association between lifetime atopic asthma and TRAP exposure based on birth address, cumulative address history and current address (Dell et al., 2014).

To further explore the findings of this earlier study, we examined the spatial relationship between early childhood exposure to TRAP and the place of residence during this period among T-CHEQ subjects. The extent to which exposure explains spatial variation and spatial autocorrelation (i.e., clusters of contiguous areas with especially high or low rates of disease) for current atopic asthma at the birth home is examined using a combination of multilevel modelling and spatial analysis. We hypothesise that if a causal relationship existed between early childhood residential exposure to TRAP and the development of atopic asthma, then (1) clusters of current asthma should exist around the place of residence at birth, and (2) accounting for residential concentrations of TRAP at birth should explain some of the autocorrelation.

2. Methods

2.1. The Toronto setting

The City of Toronto is a large, urban centre (population ~2.5 million) in the Province of Ontario, Canada. Toronto is the most populous municipality in Canada and among the most populous in North America. It is noted for having a culturally and socio-economically diverse population (Justus, 2004). In addition to a grid of major roadways, there are several highways and expressways that transect Toronto. Highway 401 travels from west to east to the north of the downtown core, and is one of the busiest roadways in the world (Beckerman et al., 2008). This and other highways and expressways that lie within the City are outlined in Fig. 1.

2.2. Overview of T-CHEQ study

The T-CHEQ sample used in this analysis has been described elsewhere in detail (Dell et al., 2014). In brief, during the first phase of the study in 2006, parents of 5619 children in the first and second grade at 231 public schools completed a 20-min, self-administered questionnaire about the health and demographic characteristics of their child. Questions included the International Study of Asthma and Allergies in Childhood (ISAAC) survey on history of asthma, rhinitis and eczema, and questions about medication use. Data were also collected on age and sex, and family income, which was transformed into a derived variable for income adequacy based on the following Statistics Canada classification of [income, number of persons in the household]: Lowest income= < $15,000, 1–2 or < $20,000, 3–4 or < $30,000, 5+; Lower middle income=$15,000–$29,999, 1–2, or $20,000–$39,999, 3–4, or $30,000–$59,999, 5+; Upper middle income=$30,000–$59,999, 1–2, or $40,000–$79,999, 3–4; and Highest income=$60,000+, 1–2, or $80,000+, 3+. Modifications were made to the ISAAC methodology to capture an ethnically diverse study population, and analysis indicates similarity with the general Toronto population in distribution of sex, household income, dwelling type and household size, environmental tobacco smoke exposure, and asthma and wheeze prevalence based on census data and population-based national surveys (Yang et al., 2011).

A stratified random sample of 1497 families involved in the first phase of the study participated in the second phase (response rate 90.9%), including 704 subjects with a history of asthma or wheeze

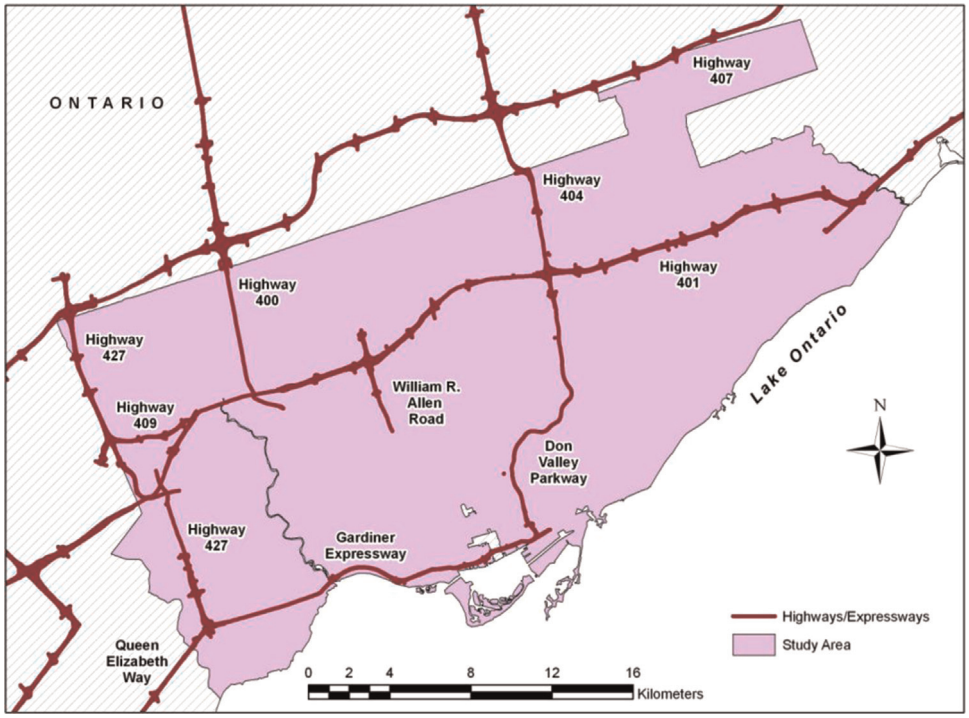

Fig. 1. Toronto, Ontario-study setting and highways/expressways.