

Acute Childhood Asthma in Galway City from 1985-2005: Relationship to Air Pollution and Climate

Abstract:

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Abstract

We examine the relationship of air pollution and climatic variables to asthma admission rates of children in Galway city over a 21 year period. Paediatric asthma admissions were recorded from 1985-2005, and admission rates per thousand calculated for pre-school (1-4 years), school aged (5-14 years) and all children (1-14 years) on a monthly and annual basis. These data were compared to average monthly and annual climatic variables (rainfall, humidity, sunshine, wind speed and temperature) and black smoke levels for the city. Simple correlation and Poisson Generalized Additive Models (GAM) were used. Admission rates each month are significantly correlated with smoke levels (p=0.007). Poisson GAM also shows a relationship between admissions and pollution (p=0.07). Annual smoke levels impact more on admission rates of preschoolers (p=0.04) than school age children (p=0.10). These data suggest that air pollution is an important factor in the epidemiology of acute childhood asthma.

Introduction

The last 40 years have seen an epidemic of childhood asthma through the developed world that is largely unexplained. The prevalence of asthma increased throughout the latter three decades of the twentieth century¹, and more recently has shown evidence of reaching a plateau³ and beginning to decline¹. Whilst numerous theories have been advanced, no unifying hypothesis has been agreed³. Admission rates for asthma appear to correlate well with the prevalence and severity of asthma¹.

Over the past 20 years in Galway, asthma admission rates increased steadily to a peak in 1995 and thereafter diminished dramatically. The severity of asthma in those admitted appears unchanged, and there is an increased willingness to treat in the community and prescribe prophylactic therapy⁵. A similar series of observations across the UK suggested widespread use of inhaled steroids was responsible for the reduction in asthma admissions⁶. However, it is unlikely that worsening treatment caused the initial rise. A survey in general practice in the UK documented a reduction in consultation rates, not only for asthma, but for all respiratory illnesses across the same timeframe⁸. Could an environmental change be responsible? Paediatric epidemiological studies show that exposure to pollution has a detrimental effect on lung function in children, which is reversed when they move to a cleaner area⁸. In Galway we have a well-defined city population, a single acute paediatric unit, an environment where the major sources of air pollution are vehicular traffic and domestic heating, and 21 years of measurements of asthma admissions, air pollution, and climatic variables. We decided to explore the long-term link, if any, between air pollution, climatic variables, and acute asthma in children.

Methods

Galway is a city on the west coast of Ireland with a population of 72,000, and an area of 22 Km². A single hospital provides maternity and paediatric services for the area. The children's unit provides services for a child population of approximately 11,000 who reside in the city, with a further 35,000 in surrounding area. There are no heavy industries in the locality, the prevailing wind is Atlantic south-west to west, and the climate is temperate with relatively heavy rainfall. Domestic heating is provided by coal (81%) and oil-fired central heating. The sale of bituminous coal was banned in 2000. Background urban air pollution was monitored in Galway city on a daily basis from 1983 to 2005. Three sites within 1km of the centre were used. Black smoke (BS) concentrations were measured using the Organization for Economic Cooperation and Development (OECD) method. Black smoke concentration measurements are a measure of small particulate pollution, typically less than 2 microns; well below the respirable threshold. Daily levels of black smoke were obtained from 1985-2005, and converted to monthly and annual averages. Daily records of humidity, wind speed, temperature, rainfall and sunshine for the city were provided by the National Meteorological Service; data were also aggregated to monthly and annual averages. There were few missing data; where readings were missing monthly averages were calculated from available information.

Asthma admissions were retrieved from the paediatric unit register and Hospital Inpatient Enquiry System. Previous comparisons of the unit register and HIPE during studies in 1990, 1997, and 2004 showed good agreement. Given the difficulty of differentiating virus-associated wheeze from asthma in infants, we excluded children under one year of age. Raw numbers of asthma admissions for children with a Galway city address were converted to a rate per 1000 by using census data from 1986, 1996, 2002 and 2006 to define the population. Since the child population is relatively small, admissions (33-90 annually) were aggregated on a monthly and then annual basis for analysis. Relationships between admission rates and climatic and pollution variables were examined by simple correlation. A gamma distribution based Generalised Additive Model (GAM)^{9,10} with a log link function was then employed to explore in detail the association between the monthly admission rates, black smoke concentrations and climatic variables. The study was approved by the hospital ethics committee.

Results

The entire data set, with variables for each month (n=252) of the 21 years, was examined initially by simple correlation. Monthly asthma admissions correlated weakly but significantly with smoke levels (Spearman's rank correlation of r =0.17, p=0.007). There is evidence of a positive association between asthma admissions and black smoke levels for the 1-4 year olds (p=0.04) and a positive trend for 5-14 year olds separately (p=0.10). There appears to be a stronger association between black smoke and admissions rates in ages 1-4, thus explaining the intermediate significance of the combined 1-14 years analysis. Using the GAM no statistically significant climatological effect on the monthly admission rates was found. There was evidence of a positive association between asthma admissions and particulate concentrations for all subjects (1-14 years) (p=0.075). Figure 1 depicts the smooth fitted temporal trend in monthly asthma admission counts after using GAM to account for the effects of black smoke and seasonal variation. Once these are allowed for there is insufficient evidence for a residual trend.

Looking at the subgroups, however, using GAM, the residual smooth time trend in the admission rates was significant for both preschoolers ($p=0.04$) and school age children ($p<0.001$); both exhibiting a peak around 1995 (Figure 2). This implies an impact of factors other than pollution. The time trends for the two age groups differ in terms of estimated behaviour before and after this peak. After allowing for an influence of air pollution, pre-schoolers had an additional 20% rise after 1995 not attributable to pollution, whereas in school age children the rise in admissions to the peak may largely be accounted for by pollution, but the fall was 40% greater than that attributable to it. Data were then aggregated on an annual basis over the 21 year period. There was little year on year variation in climatic variables-temperature, windspeed, rainfall, sunshine, humidity. This is seen in Figure 3. The annual admission rates and black smoke values are shown in Figure 4, which clearly shows an association between black smoke and admission rate.

Discussion

Our data show a strong association between black smoke levels and admission to hospital with childhood asthma. The association between smoke and acute admissions is more evident when plotted annually. Though the hypothesis is biologically plausible, these changes could be coincidental. The reason for the rise and fall in black smoke from the mid-nineties is probably a combination of changes in domestic and vehicular fuel use. Coal sales changed little from 1985 to 1995, suggesting that the rise in black smoke came from other sources. The predominant coal supplier in the area noted a trend to the use of smokeless coal in Galway in the mid 1990s. More stringent emission standards for bituminous coal were implemented in 1995, so coal supplied in Galway after that year had both lower sulphur content and lower smoke emissions. Sale of bituminous coal was banned in 2000, and this was associated with a further small reduction in smoke levels.

Therefore some of the fall in smoke levels from 1995 is due to a cleaner coal. Short-term (30-minute periods) analysis of particulate matter in Galway show that peaks agree well with peaks in traffic flow, suggesting much of the air pollution is traffic related (unpublished data). The rise in smoke levels up to 1995 coincided with a growth in registered vehicle numbers in the county (from 44,000 to 108,000) and the proportion of diesel-powered vehicles (from 18% to 35%), indicating that vehicular traffic was a factor in elevating smoke levels. The fall in smoke levels from 1995 occurred despite the further growth in traffic volume and increased proportion of diesel engines, suggesting reduced vehicle emissions were important. We suspect that reduced diesel emissions, consequent on reduced sulphur content and more stringent emission standards implemented in the mid-1990s, were a key factor¹¹. We are unable to apportion the relative contributions of domestic and traffic sources to the increased, and then reduced, black smoke levels, as chemical analyses of the black smoke samples over this period are not available. Pollution, viral infection, and allergens all contribute to airway inflammation and narrowing. Analysis of annual data minimises the influence of seasonal climatic allergic and infectious variables. Black carbon can penetrate to alveoli where it is taken up by alveolar macrophages¹². These irritant particles linger in the lung. They are likely to have a greater detrimental effect in the lungs of children, because of their narrower airway calibre, more rapid respiratory rate, and relatively greater minute volume¹³. Air pollution as an explanation for the epidemic of childhood asthma has been dismissed¹⁴, partly on the basis of comparative studies in areas of high and low pollution¹⁵. However, the study of a pollution may not be sufficiently precise; air that looks black and heavily polluted may have little impact on respiratory morbidity if the particles are large or non-irritant. Categorisation of air pollution on the basis of particle size (e.g. PM10, 2.5, 1.0) is crude.

Other factors such as mineral and free radical content, surface area, and number of particles are not captured in a simple weight. Black smoke as an indicator of air pollution is imperfect, but is acknowledged as a good marker of diesel pollution¹⁶. Detrimental effects of black carbon may relate more to particle numbers and total surface area than simple mass¹⁷. Diesel exhaust particles are more irritant to the lung¹⁸ and more likely to trigger allergic sensitisation¹⁹. Diesel as a contributor to air pollution in the West increased steadily from the 1960s, assuming a leading role in the 1980s and increasing steadily to the end of the century²⁰; the time course of the childhood asthma epidemic. Looking at age group specific effects, air pollution appears to have a greater impact on admission rates for pre-school children than school age children. This is consistent with the physiologic predisposition of smaller children to the detrimental effects of pollution. Prophylactic treatment has probably had little impact on admissions of the pre-school group since inhaled steroids are less effective in this group. The reduction in admissions after the peak is possibly offset by the greater risks of admission noted in pre-school children generally since the introduction of on call co-op services in primary care.

We observed an additional decrease in admissions trends in time in school age children in our statistical modelling (in Figures 2) after accounting for the meteorological and black smoke effects. This is consistent with an effect of improved prophylactic therapy in school aged children in the community, co-incident with the dissemination of agreed guidelines⁶. The lack of significance of the residual time trend when the two cohorts are combined is due to these differing behaviours on either side of the peak cancelling each other out. In conclusion, we have shown an association between a measure of childhood asthma morbidity and black smoke in Galway city. We hypothesise that regulatory changes in the nature of coal and diesel, and more stringent vehicular emission rules have improved air quality and contributed to the reduced incidence of hospital admissions.

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Comments: