Cost of near-roadway and regional air pollution–attributable childhood asthma in Los Angeles County

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Background: Emerging evidence suggests that near-roadway air pollution (NRP) exposure causes childhood asthma. The associated costs are not well documented.
Objective: We estimated the cost of childhood asthma attributable to residential NRP exposure and regional ozone (O_3) and nitrogen dioxide (NO_2) levels in Los Angeles County. We developed a novel approach to apportion the costs between these exposures under different pollution scenarios.
Methods: We integrated results from a study of willingness to pay to reduce the burden of asthma with results from studies of health care use and charges to estimate the costs of an asthma case and exacerbation. We applied those costs to the number of asthma cases and exacerbations caused by regional pollution in 2007 and to hypothetical scenarios of a 20% reduction in regional pollution in combination with a 20% reduction or increase in the proportion of the total population living within 75 m of a major roadway.
Results: Cost of air pollution–related asthma in Los Angeles County in 2007 was $441 million for O_3 and $202 million for NO_2 in 2010 dollars. Cost of routine care (care in absence of exacerbation) accounted for 18% of the combined NRP and O_3 cost and 39% of the combined NRP and NO_2 cost; these costs were not recognized in previous analyses. NRP-attributable asthma accounted for 43% (O_3) to 51% (NO_2) of the total annual cost of exacerbations and routine care associated with pollution. Hypothetical scenarios showed that costs from increased NRP exposure might offset savings from reduced regional pollution.
Conclusions: Our model disaggregates the costs of regional pollution and NRP exposure and illustrates how they might vary under alternative exposure scenarios. The cost of air pollution is a substantial burden on families and an economic loss for society. (J Allergy Clin Immunol 2014;134:1028-35.)

Key words: *Air pollution, asthma, cost of illness, urban growth, vehicle emissions, willingness to pay*

Approximately 36 million persons in the United States live within 300 feet of a 4-lane highway, railroad, or airport.[1] Emerging evidence suggests that near-roadway air pollution (NRP) exposure causes childhood asthma.[2-5] A causal relationship implies that any subsequent asthma exacerbation, regardless of its precipitating trigger, can be attributed to NRP exposure.[6] In urban areas in Southern California, NRP exposure might account for a substantial proportion of all air pollution–related exacerbations in children, which are commonly estimated on a population level only for regional pollutants.[7-9]

There has been little study of the costs of NRP-related health effects,[10,11] which can be substantial.[12] There are 3 categories of costs associated with these effects: direct costs are payments for health care; indirect costs reflect opportunity costs, such as lost wages; and willingness to pay (WTP) to avoid the burden of asthma quantifies negative quality-of-life consequences.[13] Population estimates of asthma-related costs have generally not quantified the day-to-day experience of asthma, because no robust studies had appropriately measured it.[14-16]

We developed a model of annual cost of childhood asthma that integrated novel methods from economics and epidemiology: WTP to avoid asthma morbidity[17] and risk assessment for children with NRP-caused asthma.[7] We evaluated the cost of pollution-related childhood asthma in Los Angeles County (LAC) in 2007 and the hypothetical cost per year of pollution-related childhood asthma under alternative levels of regional pollution and exposure to NRP.

LAC has a high prevalence of childhood asthma,[18] dense traffic corridors, and high levels of regional air pollutants, such as ozone (O_3), nitrogen dioxide (NO_2), and particulate matter. These regional levels are expected to continue to decrease as a result of regulatory efforts.[19] Although a reduction in regional pollution should decrease the cost of asthma, the net effect when that reduction is combined with a change in the proportion of the population living near a major roadway is not obvious. Based on the results of a previously published evaluation of pollution-related asthma exacerbations in LAC,[7] we have now estimated (1) the childhood asthma-related costs attributable to regional and near-roadway pollution in 2007 and (2) the savings that might result from a 20% regional pollution reduction combined with a 20% increase or decrease in the proportion of families living in proximity to a major roadway relative to 2007 levels.[7]

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Abbreviations used
CRF: Concentration response function
ED: Emergency department
LAC: Los Angeles County
NRP: Near-roadway air pollution
NO_2: Nitrogen dioxide
O_3: Ozone
WTP: Willingness to pay

METHODS

Pollution-attributable asthma outcomes

The selection of pollutants, estimation of population exposure, concentration response functions (CRFs), and pollution-associated burden of asthma have been described previously.[7] Briefly, we examined the effects of O_3 and NO_2 because each has a well-established causal relationship with asthma exacerbations.[20,21] In Southern California NO_2 can be used as a proxy for general regional pollution (exclusive of O_3), including particulate matter, elemental carbon, and nitric acid, all of which are associated with respiratory health effects.[22,23] O_3 is relatively uncorrelated with other regional pollutants in the Los Angeles air basin.[23,24] We avoided double counting pollution-attributable exacerbations by evaluating each pollutant separately.

The baseline exposure for all scenarios was the 2007 population-weighted proportion of LAC children living near a major roadway and the 2007 levels of regional pollution.[7] A CRF for NRP was based on residence within 75 m of a major roadway, a proxy for NRP exposure relevant for Southern California.[5,9] Major roadways included freeways, highways, or major arterial roads (functional road classes FRC01, FRC03, and FRC04 from the TeleAtlas MultiNet roads network[7]). In the first scenario we estimated total asthma-associated costs of having 17.8% of the population living near major roadways by constructing a hypothetical in which this population's NRP exposure was reduced to background levels. We examined the costs imposed by the NO_2 and O_3 levels observed in LAC in 2007 compared with their mean values in cleaner comparison cities in the Southern California Children's Health Study that year (Scenarios 1A and 1B, respectively). The 2007 baseline measures of 24-hour NO_2 across census tracts in LAC ranged from 6.2 to 31.4 ppb (population-weighted mean, 23.3 ppb). In Scenario 1A we calculated the effect of a reduction in population-weighted NO_2 exposure to 4 ppb across all census tracts. The 2007 baseline measures of 8-hour daily maximums for O_3 across LAC ranged from 30.5 to 55.6 ppb (population-weighted mean, 39.3 ppb). In Scenario 1B we reduced the population-weighted O_3 exposure to 36.3 ppb. This first scenario generates the full asthma burden of the combined effects of NRP and regional pollution in LAC compared with that seen in cleaner communities.

To illustrate the change in costs with respect to the 2 components of pollution-attributable asthma, we constructed hypothetical scenarios in which a decrease in levels of each regional pollutant was combined with either a 20% decrease (second scenario) or a 20% increase (third scenario) in the population percentage exposed to NRP. Because 17.8% of LAC children live near a major roadway, a change of 20% constitutes 3.56 percentage points. The hypothetical reductions in NO_2 and O_3 concentrations are plausible and based on projections from the current air quality plan for Southern California.[19] Health effects and their costs were estimated for a single year. When calculating outcomes in the hypothetical scenarios, we assumed that changes in the prevalence of asthma and resulting exacerbations were fully realized and instantaneous. These assumptions allowed us to compare costs across all of the scenarios and avoided the need for discounting.

For each scenario, we used the near-roadway CRF to estimate the prevalence of asthma cases attributable to NRP in a given year.[9] We estimated 3 types of exacerbations among children in LAC for 1 year[7]: regional pollution-triggered outcomes among children with NRP-attributable asthma (Fig 1, Box 3); outcomes triggered by other factors among children with NRP-attributable asthma (Fig 1, Box 2); and regional pollution-triggered outcomes among children with asthma caused by factors other than NRP ("other-cause asthma"; Fig 1, Box 6). Asthma exacerbation–related outcomes included bronchitis episodes, hospital admissions, emergency department (ED) visits, doctor's office visits, and school absences for respiratory illness (for O_3 only). Bronchitis, which was defined as a productive cough lasting 3 months or more, is a sensitive marker of NRP-attributable asthma exacerbations[25] and is distinct from viral or bacterial bronchitis. We estimated the annual frequency of each outcome attributable to these regional pollutants by using published CRFs for Southern California children when available or other appropriate CRFs when not. Tables E1-E3 in this article's Online Repository at www.jacionline.org provide details on CRFs and baseline rates.

Direct and indirect costs of an exacerbation

For each outcome, we estimated the direct cost of goods and services and the indirect cost of caregivers' lost wages. For the direct costs of health care, we used the amount charged rather than the amount paid because amounts charged are not confounded by insurance status. All costs were expressed in 2010 dollars,[26] and sources are summarized in Table E2.

Direct costs of hospitalization and ED visits were calculated as the sum of facilities' and physicians' charges.[27,28] The direct cost of an office visit was estimated by using the national mean charge for a physician's office visit.[29] The direct cost of asthma inhalers (rescue and controller medications) was the average of the price for each inhaler category weighted by the typical use of each category.[30] The average price for each category of drug was the weighted mean of the name brand and generic prices.[31,32]

The indirect costs for office visits, ED visits, and hospitalizations were the value of the caregiver's time spent traveling,[33] waiting,[34] and receiving care[27,35,36] and were taken from secondary databases and peer-reviewed publications. We used 1 workday (8 hours) as the time for a school absence and valued time at the average wage rate.[37] Although this is the standard approach to valuing indirect costs, it overlooks the fact that caregivers of asthmatic children sometimes leave the labor force to provide care.[38] These caregivers face lower expected lifetime earnings even when they do return to the labor force.[39]

Direct and indirect costs of routine care

Children with asthma need more routine care than other children. These fixed costs of asthma (Fig 1, Box 1) include medication use and treatment for excess ear and sinus infections, an asthma-related comorbidity. The expected quantity for each outcome was estimated for children aged 0 to 17 years in LAC by using the peer-reviewed literature and secondary databases (see Table E2).[30,40,41] Costs were calculated by using the same approach as for exacerbations.

Direct and indirect costs of a bronchitis episode

Each bronchitis episode includes 5 potential costs: school absences,[42] antibiotic prescriptions,[43-46] office visits,[47,48] ED visits,[47,48] and inpatient hospital stays.[47,48] We estimated the number of office visits, ED visits, and hospital stays as the mean rate for children with asthma using the 2007 Medical Expenditure Panel Survey. These estimates are significantly lower than some reported rates.[49]

WTP

Bronchitis and asthma substantially affect quality of life.[13,49,50] The value of this effect is quantified as the WTP to avoid this burden by using contingent valuation. A contingent valuation study offers participants a hypothetical health-related product, quotes prices, and inquires about WTP. Surveys must be designed to elicit values specific to desired health outcomes and to ensure valid responses.[16] To meet these criteria, we used the results of a contingent valuation study conducted in California among families with asthmatic children.[17]

The WTP study[17] was designed to estimate a WTP beyond the household's current expenditures and included "debriefing" questions to ensure that the WTP was based on a desire to reduce the pain and suffering of asthma. Thus the estimate is specific to asthma and additive to the other costs. The