Traffic-Related Air Pollution and Asthma Hospital Readmission in Children: A Longitudinal Cohort Study

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Objective To examine the association between exposure to traffic-related air pollution (TRAP) and hospital readmission for asthma or bronchodilator-responsive wheezing.

Study design A population-based cohort of 758 children aged 1-16 years admitted for asthma or bronchodilator-responsive wheezing was assessed for asthma readmission within 12 months. TRAP exposure was estimated with a land use regression model using the home address at index admission, with TRAP dichotomized at the sample median (0.37 $\mu g/m^3$). Covariates included allergen-specific IgE, tobacco smoke exposure, and social factors obtained at enrollment. Associations between TRAP exposure and readmission were assessed using logistic regression and Cox proportional hazards models.

Results The study cohort was 58% African American and 32% white; 19% of the patients were readmitted within 12 months of the original admission. Higher TRAP exposure was associated with a higher readmission rate (21% vs 16%; $P = .05$); this association was not significant after adjusting for covariates (aOR, 1.4; 95% CI, 0.9-2.2). Race modified the observed association; white children with high TRAP exposure had 3-fold higher odds of asthma readmission (OR, 3.0; 95% CI, 1.1-8.1), compared with white children with low TRAP exposure. In African American children, TRAP exposure was not associated with increased readmission (OR, 1.1; 95% CI, 0.6-1.8). In children with high TRAP exposure, TRAP exposure was associated with decreased time to readmission in white children (hazard ratio, 3.2; 95% CI, 1.5-6.7) compared with African American children (hazard ratio, 1.0; 95% CI, 0.7-1.4). African American children had a higher readmission rate overall.

Conclusion TRAP exposure is associated with increased odds of hospital readmission in white children, but not in African American children. *(J Pediatr 2014;164:1396-402)*.

Asthma is the most common chronic disease in children,[1] affecting approximately 7.1 million US children.[2] Asthma-related admissions due to exacerbations represent 5.6% of all hospital admissions for children.[3] The estimated annual cost of environmentally mediated childhood asthma in the US is $2.2 billion.[4] Various factors are known to be associated with asthma morbidity, including race, viral infections, allergen exposure (in atopic individuals), medication adherence, and traffic-related air pollution (TRAP) exposure.[5,6]

TRAP is a complex mixture of carbon monoxide, carbon dioxide, hydrocarbons, oxides of nitrogen, particulate matter, and mobile source air toxics.[5] Studies in southern California and Cincinnati have suggested that diesel exhaust particles (DEP) compose a substantial portion of particulate matter in urban areas, and that DEP levels have significant spatial variability.[7,8] Previous studies have shown that DEP, which are predominately of ultrafine size (<0.1 μm), are associated with decreased forced expiratory volume in 1 second and forced vital capacity in adult volunteers with asthma.[9]

In urban areas, traffic emissions are the predominant source of intraurban variability in air pollutants, and land use regression (LUR) models have been shown to explain much of this variability.[10,11] In Cincinnati, Ohio, estimated DEP, using a LUR model, has been associated with infant wheezing,[12] as well as with nighttime coughing in children.[13]

A previous systematic review found sufficient evidence to infer a causal relationship between TRAP exposure and exacerbation of asthma symptoms in children.[5] The evidence linking TRAP to asthma health care utilization was insufficient to determine causality, however. In particular, the review noted that key limitations of the TRAP and asthma health care utilization literature

CCHMC	Cincinnati Children's Hospital Medical Center
DEP	Diesel exhaust particles
ECAT	Elemental carbon attributed to traffic
EMR	Electronic medical record
GCARS	Greater Cincinnati Asthma Risks Study
LUR	Land use regression
TRAP	Traffic-related air pollution

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included a reliance on ecological association studies and a relative absence of individual-level covariates beyond age and sex.[5] Although subsequent studies have found associations between TRAP exposure and asthma-related health care utilization,[14-16] those studies either lacked individual-level covariates or were conducted in subspecialty clinic settings.

The overall objective of the Greater Cincinnati Asthma Risks Study (GCARS) is to examine racial disparities in readmission for asthma and bronchodilator-responsive wheezing in children. In the present study, we sought to examine the association between TRAP exposure and asthma readmission within 12 months. Our prospective cohort design provided an opportunity to address previous study limitations with extensive individual-level information on demographic factors, allergen sensitization, and medication use.

Methods

GCARS, a population-based, prospective, observational cohort, collected data from children aged 1-16 years admitted for asthma or bronchodilator-responsive wheezing to Cincinnati Children's Hospital Medical Center (CCHMC), an urban tertiary care hospital, between August 2010 and October 2011. The cohort also included children admitted to a nearby satellite inpatient facility beginning in November 2010. Given data from the Ohio Hospital Association indicating that nearly 85% of all asthma admissions of children aged 1-16 years within our 8-county primary service area occur at CCHMC facilities,[17,18] our accrued admission sample can be considered population-based. Children not admitted to CCHMC tended to be older and to live farther from the main hospital in less urbanized areas.[17]

Patients were identified by use of the evidence-based clinical pathway for acute asthma or bronchodilator-responsive wheezing by the admitting physician. The pathway includes medications, delivery devices, education, and a standardized bronchodilator weaning protocol followed by respiratory therapists. Quality assurance data show that the order set is used for >98% of children admitted to CCHMC with asthma. Children who were removed from the asthma pathway before discharge, who had significant respiratory or cardiovascular comorbidities (eg, cystic fibrosis, congenital heart disease), who resided outside of the 8-county primary service area, or whose primary caregiver did not understand written or spoken English were excluded from the sample (roughly 2% of those otherwise eligible). The CCHMC Institutional Review Board approved this study.

During the enrollment period, 1547 patients were admitted for asthma, 1312 (85%) of whom met our inclusion criteria (**Figure 1**; available at www.jpeds.com). Of the 1312 eligible children, 774 (59%) enrolled in the study. Eighty-one children (6%) were admitted when research staff were not available, 53 children (4%) had no parent or guardian available to provide consent, and consent could not be provided for 56 children (4%) owing to a high census or competing patient care priorities. In the 346 children (26%) who refused to participate in the study, the most common reasons given were discomfort with the blood draw or disinterest in participating in research. Two children withdrew participation during the study. Recruitment was for 14 months, and included parts of 2 summer and autumn seasons.

To assess rates of loss to follow-up and potential readmissions to sites other than CCHMC, a random 25% subsample of the 774 children was contacted by telephone at approximately 12 months after the index admission. If the family could not be reached at that time, then the child's current home address was identified using the electronic medical record (EMR) and/or public records. Almost all (95.9%) of the children in this random subsample were confirmed to have maintained residence in CCHMC's primary service area. None of those reached by telephone (n = 164; 84% response) reported an admission for asthma or wheezing to a hospital other than CCHMC during the follow-up period.

Asthma Readmission Outcome

Our primary outcome, readmission to the hospital within 12 months of enrollment, was captured using the *International Classification of Diseases, 9th Revision, Clinical Modification* classification codes for primary or secondary discharge diagnoses (493.XX or 786.07 for asthma or wheezing, respectively) recorded in the hospital billing data. Outcome accuracy was verified by a review of the EMR to ensure that each readmission event met the same inclusion and exclusion criteria as the index admission.

TRAP Exposure

Exposure to TRAP was estimated by applying a previously developed and validated LUR model[12,19] to the reported primary residence of the enrolled child. The LUR methodology used to derive TRAP exposure estimates has been described previously.[12,19] In brief, ambient air sampling was conducted on a rotating basis at 27 sampling sites in the greater Cincinnati area between 2001 and 2006. The average daily concentration of elemental carbon was determined at each site. The final LUR model, including elevation, truck traffic within 400 meters, and length of bus routes within 100 meters, provided an estimate of elemental carbon attributed to traffic (ECAT), a specific component of TRAP related primarily to diesel exhaust.[8,12,19] For this study, we used the average daily ECAT exposure as a surrogate for the TRAP mixture.

For estimating TRAP exposure for each enrolled patient, the primary home address at the time of the index admission was geocoded using ArcGIS version 9.3 (ESRI, Redlands, California). Using the previously described LUR model, a TRAP estimate was assigned to each patient's address. Children living outside of the air pollution modeling area (n = 16) were excluded from the analyses.

Covariates

During the index admission, a research assistant verbally administered a questionnaire, and serum samples were collected. The child's race was ascertained by caregiver report