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Synergism of Short-Term Air Pollution Exposures and Neighborhood Disadvantage on Initial Stroke Severity

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Abstract

Background and Purpose—Little is known about the relation between environment and stroke severity. We investigated associations between environmental exposures, including neighborhood socioeconomic disadvantage and short-term exposure to airborne particulate matter<2.5μm ($PM_{2.5}$) and ozone (O_3), and their interactions with initial stroke severity.

Methods—First-ever ischemic stroke cases were identified from the Brain Attack Surveillance in Corpus Christi (BASIC) project (2000–2012). Associations between pollutants, disadvantage, and National Institutes of Health Stroke Scale were modeled using linear and logistic regression with adjustment for demographics and risk factors. Pollutants and disadvantage were modeled individually, jointly, and with interactions.

Results—Higher disadvantage scores and previous-day O_3 concentrations were associated with higher odds of severe stroke. Higher levels of $PM_{2.5}$ were associated with higher odds of severe stroke among those in higher disadvantage areas (OR:1.24; 95%CI:1.00–1.55), but not in lower disadvantage areas (OR:0.82; 95%CI:0.56–1.22; *P*-interaction=0.097).

Conclusions—Air pollution exposures and neighborhood socioeconomic status may be important in understanding stroke severity. Future work should consider the multiple levels of influence on this important stroke outcome.

Keywords

ischemic stroke; neighborhood disadvantage; ozone; particulate matter; stroke severity

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DISCLOSURES

None.

Subject Terms

epidemiology

Residential environments have been linked to stroke risk and survival.[1] However, little work has focused on environmental contributions to stroke severity.[2] A few studies have examined the association between air pollution and initial stroke severity and results were contrary to expectations.[3] One possible explanation is the context of exposures may be important. Evidence of synergism between short-term exposure to air pollution and low neighborhood socioeconomic status (SES) has been observed for cardiovascular mortality.[4] Our objective was to investigate associations of neighborhood disadvantage and short-term exposures to particulate matter<2.5μm ($PM_{2.5}$) and ozone (O_3) on initial stroke severity.

METHODS

Incident ischemic stroke cases were ascertained from the population-based Brain Attack Surveillance in Corpus Christi (BASIC) project (2000–2012). Approximately 340,000 people live in Nueces County with the majority residing in the urban city of Corpus Christi. Methods of BASIC have been previously described.[5] Initial stroke severity (National Institutes of Health Stroke Scale (NIHSS) score) was abstracted or retrospectively calculated from medical records using a validated method.[6] Severe stroke (NIHSS≥7) was defined based on the upper quartile of the NIHSS distribution. We identified 12 neighborhood-level Census tract variables reflecting sociodemographic domains of race/ethnicity and wealth/income and created a composite score for neighborhood disadvantage based on individual z-scores.[7] Hourly pollutant data were obtained from a centrally located monitor within the urban population. We focused on same-day $PM_{2.5}$ and previous-day O_3 concentrations based on previous work in this population.[8] For additional details of the exposures, please see http://stroke.ahajournals.org.

Statistical methods

Characteristics of the study population were summarized with descriptive statistics. We *a priori* chose to model stroke severity continuously using linear regression and dichotomously (NIHSS>7) using logistic regression with generalized estimating equations to account for clustering of subjects within census tracts. All models adjusted for demographics and stroke risk factors. Air pollution models additionally adjusted for meteorological and temporal confounders.

Modeling had three stages: 1) main effects of neighborhood disadvantage and each air pollutant separately, 2) main effects of neighborhood disadvantage and each air pollutant together, and 3) adding the interaction between each air pollutant and neighborhood disadvantage. Additionally, models with both air pollutants included were examined. Presence of effect modification was indicated by the significance of the interaction term p-value<0.10. The BASIC project was approved by the University of Michigan Institutional Review Board and each of the Nueces County hospital systems. For complete methodology, please see http://stroke.ahajournals.org.

RESULTS

There were 3,035 ischemic strokes after excluding 92 (geocode) and 276 (air pollution) strokes with missing information. Demographics are described in Table 1. Median initial stroke severity was 4 (IQR:2–7). Those residing in high neighborhood disadvantage areas (90th percentile) were younger, less likely to be non-Hispanic White, and more likely to have diabetes compared to those in low neighborhood disadvantage areas (10th percentile). Median daily levels of $PM_{2.5}$ and O_3 were 7.7µg/m^3 (IQR:5.7–10.6) and 35.7ppb (IQR: 25.5–46.3), respectively.

Greater neighborhood disadvantage was not associated with NIHSS score after adjustment for demographics and stroke risk factors alone or controlling for $PM_{2.5}$ or O_3 (Table 2). However, greater neighborhood disadvantage was associated with greater odds of severe stroke both before and after adjustment for pollution levels (OR=1.27 comparing 90th to 10th percentile of neighborhood disadvantage, 95%CI:1.01–1.60). The association was similar (1.27, 95%CI:1.01–1.59) after adjusting for O_3.

Same-day $PM_{2.5}$ was not associated with NIHSS score or odds of severe stroke (Table 2). However, higher previous-day O_3 levels were associated with greater NIHSS scores and higher odds of severe stroke (mean difference: 0.29, 95%CI:0.06–0.51 and OR:1.17, 95%CI: 1.08–1.26). Neighborhood disadvantage modified the association between $PM_{2.5}$ and odds of severe stroke (P=0.097). In higher neighborhood disadvantage areas (90th percentile), higher same-day $PM_{2.5}$ levels were associated with higher odds of severe stroke (OR:1.24, 95%CI:1.00–1.55), but not in lower neighborhood disadvantage areas (OR:0.82, 95%CI: 0.56–1.22). Mutual pollutant adjustment produced consistent results (results not shown).

DISCUSSION

Living in areas of high compared to low neighborhood disadvantage increased the likelihood of severe ischemic stroke after adjustment for air pollution exposures, even in low pollution areas. We observed a suggestive interaction between neighborhood disadvantage and air pollution exposures such that the association between short-term exposures to $PM_{2.5}$ and severe stroke was only evident in areas of high neighborhood disadvantage. However, higher O_3 levels were associated with severity. This association did not vary by neighborhood disadvantage. These associations were present after accounting for individual-level predictors for severity, suggesting environmental features may explain additional variation in stroke severity.

Plausible explanations for synergism between neighborhood disadvantage and air pollution on stroke severity exist. Those in greater neighborhood disadvantage areas experience more psychosocial stress and violence, which increases susceptibility to air pollution for asthma via oxidative stress and inflammation,[9] and may act similarly for stroke.[10] Greater susceptibility to air pollution could also be due to nutritional deficits from lack of healthy food availability in greater disadvantage areas.[11] Housing without air conditioning, which is more prevalent in disadvantaged areas, may promote more open windows, thus higher infiltration of air pollution.[12] O_3 does not penetrate the indoor environment well,[13] which might explain the lack of synergism for O_3.

Limitations of our study include use of one air pollution monitor. However, $PM_{2.5}$ concentrations are expected to be homogenous across this region and levels measured every 3–6 days at another Nueces County monitor showed high correlations (ρ≥80%) with the study monitor. Census tracts may not accurately capture the neighborhood exposures of interest. Individuals in lower SES areas may seek medical treatment for minor stroke symptoms less frequently than those in higher SES areas. Future studies with more refined pollutant measures across both high and low-SES areas are needed to confirm or extend our findings.

Summary

Air pollution exposures and neighborhood SES may be important in understanding stroke severity. Future work should consider the multiple levels of influence on this important stroke outcome.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

Acknowledgments

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Table 1

Characteristics (n,%) of 3035 Incident Ischemic Strokes in Nueces County, Texas, 2000–2012 Overall and by High/Low Neighborhood Disadvantage (90th vs. 10th percentiles).

Characteristic	Overall (n=3035)	Low Neighborhood Disadvantage (n=320)	High Neighborhood Disadvantage (n=313)
Age, median(Q1-Q3), yrs	70(59–80)	73(62–82)	69(58–78)
Female	1558(51.3)	164(51.3)	157(50.2)
Race/Ethnicity			
Non-Hispanic White	1258(41.5)	240(75.0)	20(6.4)
Mexican American	1609(53.0)	73(22.8)	268(85.6)
African American	168(5.5)	7(2.2)	25(8.0)
National Institutes of Health Stroke Scale, median(Q1-Q3)	4(2–7)	4(2–7)	4(2–7)
Medical History			
Atrial fibrillation	398(13.1)	46(14.4)	36(11.5)
Coronary artery disease	924(30.4)	104(32.5)	96(30.7)
Diabetes mellitus	1235(40.7)	88(27.5)	161(51.4)
High cholesterol	975(32.1)	103(32.2)	83(26.5)
Hypertension	2292(75.5)	233(72.8)	235(75.1)
Excessive alcohol use	198(6.5)	16(5.0)	25(8.0)
Smoking History			
Current	637(21.0)	62(19.4)	75(24.0)
Former	374(12.3)	52(16.3)	36(11.5)

Table 2

Results of linear and logistic models of initial stroke severity (NIHSS score) with environmental exposures.

	Continuous NIHSS*			Dichotomous NIHSS ≥7*†		
	Mean Diff.	95% CI	*P*	OR	95% CI	*P*
Single Exposure Models//						
Neighborhood disadvantage§	0.18	−0.36–0.72		1.19	0.96–1.48	
Same-day $PM_{2.5}$†‡	−0.02	−0.50–0.47		1.03	0.85–1.25	
Previous-day O_3†‡	0.29	0.06–0.51		1.17	1.08–1.26	
Same-day $PM_{2.5}$						
Dual Exposure Models†//						
Neighborhood disadvantage§	0.30	−0.26–0.86		1.27	1.01–1.60	
$PM_{2.5}$†‡	0.01	−0.50–0.48		1.03	0.86–1.25	
Exposure Interaction Models†‡§#						
$PM_{2.5}$ - Low neighborhood disadvantage	−0.24	−1.20–0.72		0.82	0.56–1.22	
$PM_{2.5}$ - High neighborhood disadvantage	0.20	−0.48–0.87		1.24	1.00–1.55	
$PM_{2.5}$ - Neighborhood disadvantage interaction			0.513			0.097
Previous-day O_3						
Dual Exposure Models†//						
Neighborhood disadvantage§	0.28	−0.29–0.85		1.27	1.01–1.59	
O_3†‡	0.29	0.06–0.51		1.17	1.08–1.26	
Exposure Interaction Models†‡§#						
O_3 - Low neighborhood disadvantage	0.29	0.02–0.56		1.23	1.11–1.36	
O_3 - High neighborhood disadvantage	0.28	0.01–0.56		1.12	1.01–1.24	
O_3 - Neighborhood disadvantage interaction			0.969			0.164

CI:Confidence Interval; NIHSS:National Institutes of Health Stroke Scale; OR:Odds ratio; O_3:Ozone; $PM_{2.5}$:Particulate matter<2.5μm

*All models adjustment:age, sex, Mexican American ethnicity, African American race, history of atrial fibrillation, coronary artery disease, diabetes, hypertension, and smoking status

†Pollutant models additional adjustement:temperature, relative humidity, day, and season

‡ 10μg/m^3 or 10ppb greater $PM_{2.5}$ or O_3 exposure, respectively

§ Higher score represents more neighborhood disadvantage, comparing 90th to 10th percentile

// Single exposure models:air pollutant or neighborhood disadvantage score; dual exposure models:both air pollutant and neighborhood disadvantage score

Exposure interaction models:both air pollutant and neighborhood disadvantage score and their interaction