Association of Neighborhood Socioeconomic Status With Outcomes in Patients Surviving Stroke

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Abstract

Objective
To examine associations between neighborhood socioeconomic status (nSES) and 90-day poststroke outcomes.

Methods
The Brain Attack Surveillance in Corpus Christi Project is a population-based surveillance study in Nueces County, Texas. Patients with strokes were identified between 2010 and 2016 via active and passive surveillance and enrolled in the study. nSES index is a standardized composite of 2010 Census tract–level income, wealth, education, and employment (median −4.56, interquartile range −7.48 to −0.46). The 90-day outcomes were ascertained via interview: functional status measured by the average of 22 activities of daily living/instrumental activities of daily living (range 1–4), biopsychosocial health by the Stroke-Specific Quality of Life scale (range 0–5), and depressive symptoms by the 8-item Patient Health Questionnaire (range 0–24). Associations between nSES and outcomes were estimated using confounder-adjusted generalized estimating equations with an nSES × NIH Stroke Scale score interaction term.

Results
Seven hundred seventy-six survivors made up the analytical sample (52.96% male, 62.24% Mexican American, 52.96% ≥64 years old). Higher compared to lower nSES (mean difference comparing 75th to 25th percentile of nSES) was associated with better function (−0.27, 95% confidence interval [CI] −0.49 to −0.05), better biopsychosocial health (0.26, 95% CI 0.06–0.47), and fewer depressive symptoms (−1.77, 95% CI −3.306 to −0.48) among those with moderate to severe strokes. Among those with minor strokes, higher nSES was associated with better function (−0.13, 95% CI −0.24 to −0.02).

Conclusions
nSES may influence poststroke recovery. Studies should identify neighborhood characteristics that contribute to poststroke outcomes, particularly in moderate to severe stroke survivors.

Glossary

ADL = activities of daily living; **BASIC** = Brain Attack Surveillance in Corpus Christi; **CI** = confidence interval; **IADL** = instrumental ADL; **ICF** = International Classification of Functioning, Disability, and Health; **NIHSS** = NIH Stroke Scale; **nSES** = neighborhood socioeconomic status; **PHQ-8** = Patient Health Questionnaire Eight; **SS-QOL** = Stroke-Specific Quality of Life.

Stroke is a leading cause of long-term functional impairment in the United States.[1] By 2050, the prevalence of stroke is expected to more than double as the US population ages.[2] Consequently, the number of stroke survivors living with functional impairment will increase significantly.[2] Given the public health importance and high prevalence of strokes, multiple medical, psychosocial, and physical predictors of poststroke disability and quality of life have been elucidated.[3] As theorized by the World Health Organization's International Classification of Functioning, Disability, and Health (ICF) (figure 1), poststroke disability is a function of the interactions between individual impairment and the surrounding built and social environment.[4] Among studies examining the effects of the neighborhood environment on disablement, a wide variety of neighborhood characteristics have been associated with self-reported disability independently of individual person-level characteristics. One key feature is neighborhood socioeconomic status (nSES).[5]

Studies have shown that living in a lower-nSES neighborhood is associated with higher incidence of stroke[6,7] and mortality after stroke.[8] However, there is limited research examining neighborhood effects on stroke-related participation restrictions (i.e., disability) and nonmortality outcomes.[9-11] The few existing studies have been limited by possible selection bias from differential attrition, have not accounted for prestroke health and functioning states, and have examined only 1 poststroke outcome. Furthermore, it is largely unknown how stroke severity might influence the relationship between nSES and poststroke outcomes. Ignoring the dynamic relationship between neighborhoods and individual functioning could mask true associations and lead to biased conclusions.

Initial stroke severity has been shown to be highly predictive of functional recovery after stroke independent of individual demographic factors.[12] Therefore, we expect that among people for whom initial impairments after stroke are minimal, neighborhood associated barriers to recovery such as lower social cohesion and poorer built environments will affect recovery less. We expect that as severity of stroke increases and life space decreases,[13] the trajectory of recovery may be more influenced by the neighborhood environment. In other words, as individuals' functioning declines and the space in which they inhabit constricts, barriers and facilitators within their proximate environments will have greater influence on functional recovery.

This study examines the overall association between nSES and multiple clinically relevant patient-reported stroke outcomes in a population-based cohort study with comprehensive adjustment for individual-level confounders and the differential effects of nSES on poststroke patient-reported outcomes depending on initial stroke severity. We hypothesize that higher nSES is associated with better 90-day mental health, functional status, and biopsychosocial health and that these associations are most pronounced in those with moderate to severe strokes compared to individuals with mild strokes.

Methods

Study Population

Participants were identified from the Brain Attack Surveillance in Corpus Christi (BASIC) Project, for which detailed methods have been previously described.[14] Briefly, the BASIC Project is a population-based stroke surveillance study among individuals ≥45 years of age in a biethnic community in Nueces County, Texas. As of April 2010, there were an estimated 340,223 people in the county. Roughly 12% of the population were ≥65 years old; 50.9% were female; and 60.6% were Mexican American.[15] Stroke cases were identified via both active and passive surveillance between 2010 and 2016, with details found elsewhere.[16] This study was limited to participants with incident strokes (hemorrhagic and ischemic) to avoid confounding by prior stroke outcomes and treatments; who identified as non-Hispanic White or Mexican American (other racial-ethnic groups excluded due to small sample size); who were living in a noninstitutionalized setting before stroke; who agreed to participate in the interview portion of the BASIC project; and who survived through 90 days after the stroke.

Baseline interviews with a proxy—a close friend or relative—were completed if participants were unable to communicate or to answer cognitive orientation questions shortly after stroke.[16,17] Prestroke depression status was not collected in these proxy baseline interviews. Therefore, participants with proxy baseline interviews were excluded from the analytic sample.[17]

Main Exposure

To capture socioeconomic status at the neighborhood level, nSES was calculated according to the participant's Census tract of residence at the time of their stroke. Participant addresses were abstracted from medical records and geocoded. The geocoded addresses were then linked to 2010 US Census tracts. A summary index of nSES constructed in previous research[18] was calculated from 6 Census variables representing wealth/income, education, and occupation: (1) log of median household income; (2) log of median value of owner-occupied housing units; (3) proportion of households

Figure 1 World Health Organization's International Classification of Functioning, Disability, and Health Theoretical Framework[4]
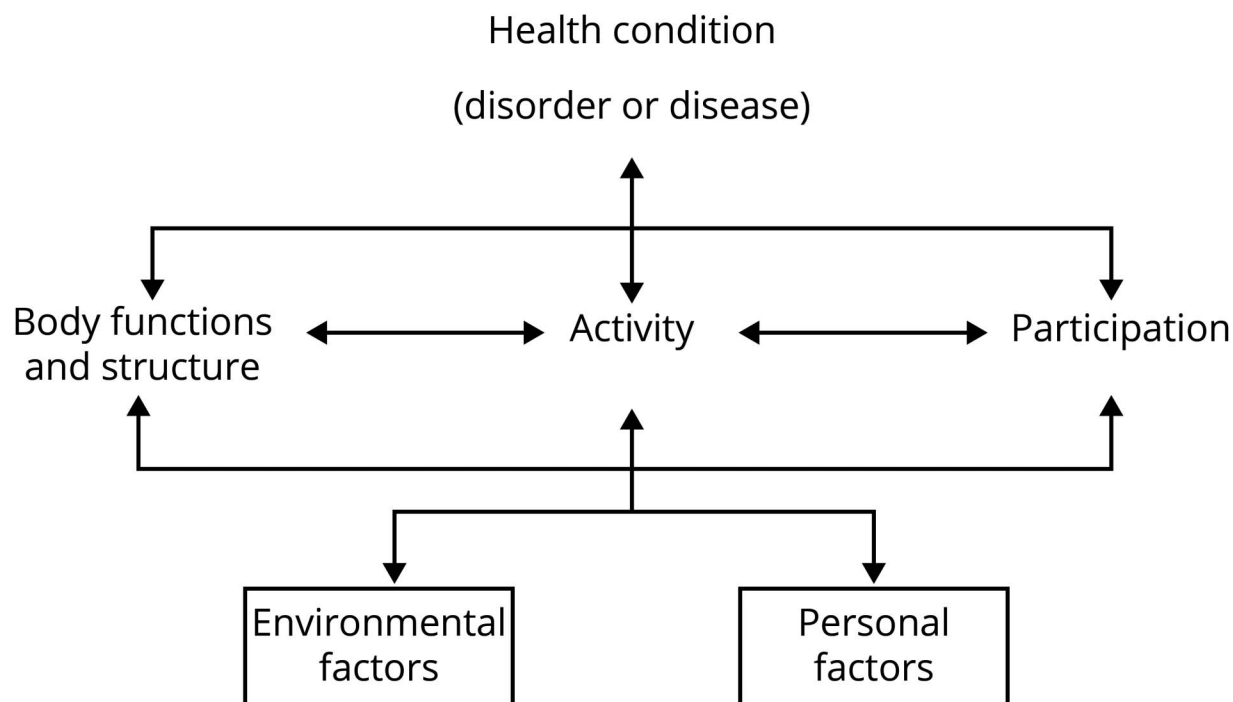
receiving interest, dividend, or net rental income; (4) proportion of adults ≥25 years of age with a high school diploma; (5) proportion of adults ≥25 years of age with a college degree; and (6) proportion of people employed in executive, managerial, or professional occupations.[7,19] Each variable was standardized across every Census tract within the US to allow comparability across studies. The nSES index was created by summing variable z scores, where increasing values of the nSES index represents favorable neighborhood environments with greater wealth/income, education, and occupation. The measure is an established neighborhood marker of the amount of flexible resources available within a neighborhood, affecting outcomes through multiple mechanisms. Thus, a higher nSES measure represents protective contextual effects of the Census tract socioeconomic environment.[19]

90-Day Outcome Measures

Functional status was determined by averaging the score of a 22-item questionnaire designed to assess 7 activities of daily living (ADL) and 15 instrumental ADL (IADL). Respondents self-reported their level of difficulty with each ADL/IADL task using an ordered scale: 1 (no difficulty), 2 (some difficulty), 3 (a lot of difficulty), and 4 (can only do with help). Responses were then summed across all 22 items and divided by the number of items, resulting in a score range of 1 to 4.[16] The variable was treated as continuous, with lower scores representing better functioning.

Self-reported biopsychosocial health was assessed with the 12-item Stroke-Specific Quality of Life (SS-QOL) scale.[20] The 12-item questionnaire is a patient-centered, stroke-specific measure, which has been previously validated in the study population.[20] Scores across the domains were averaged to yield a composite average, with higher scores representing better biopsychosocial health (range 1–5).

Respondents self-reported depressive symptoms using the Patient Health Questionnaire Eight (PHQ-8).[17] This is equivalent to the PHQ-9 except with the response for item 9 on suicide or self-harm removed. Details on the scale can be found elsewhere.[21] The score was treated as a continuous measure, with lower scores representing fewer depressive symptoms (range 0–24).

Covariates

Variables were obtained from baseline interviews completed at the time of stroke or abstracted from medical records. Variables from the baseline interview included race-ethnicity (non-Hispanic White or Mexican American), marital status (married/living together or single/widow/divorced), social support (7-item scale),[22] educational attainment to capture individual socioeconomic status[23] (less than completion of high school, completion of high school to some post–high school education, or completion of at least 4 years of college), prestroke functional status, prestroke cognitive status, and prestroke depressions status (no history of depression, history of depression or antidepressant use at time of stroke). Social support was captured via self-report. Participants were asked 7 questions focused on loneliness, finding help when sick, ability to seek advice, trust, support at home, and family

Figure 2 Study Flowchart Using the BASIC Study, United States, 2010 to 2016
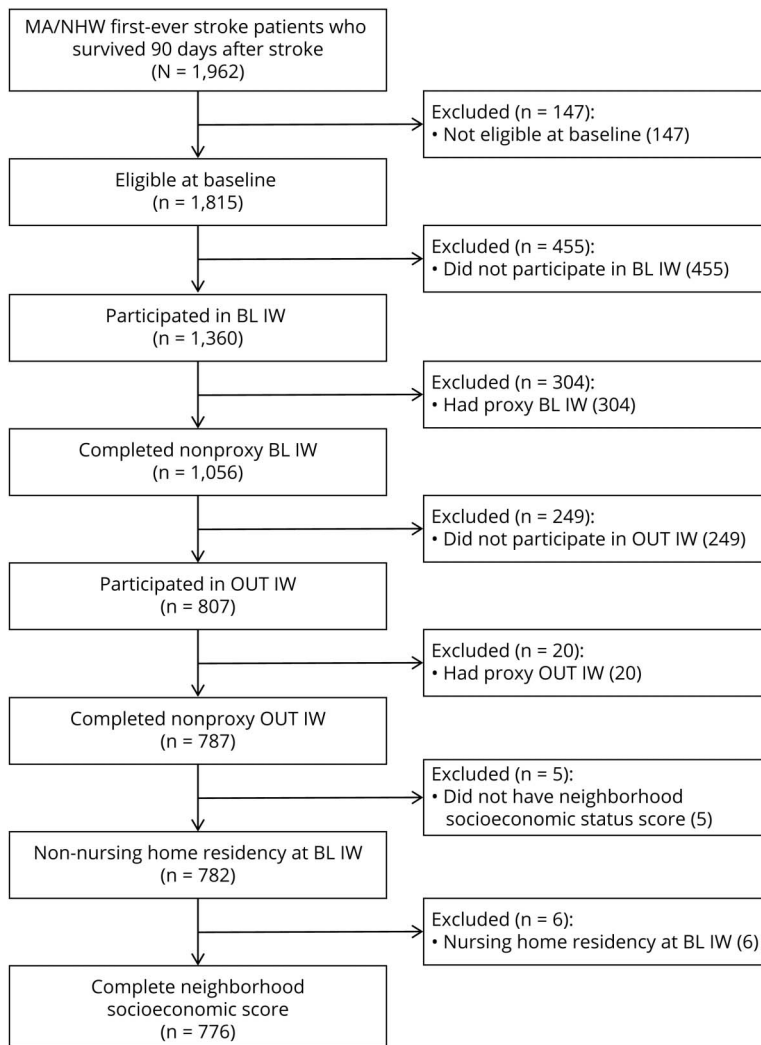
BASIC = Brain Attack Surveillance in Corpus Christi; BL IW = baseline interview; MA = Mexican Americans; NHW = non-Hispanic White individuals; and OUT IW = outcome interview.

support. Each item was scored from 1 (never/rarely) to 3 (always). The item scores were then summed, and 7 was subtracted from the summed score, yielding a final score of 0 to 14, with higher scores indicating more social support. Prestroke function was measured with the modified Rankin Scale. The resultant score was categorized as 0 to 1, 2 to 3, and ≥4 (only 38 individuals had scores of 4 or 5, and thus these categories were combined), with higher scores representing worse function. The Informant Questionnaire on Cognitive Decline in the Elderly was used to assess prestroke cognitive status, with scores averaged across the 16-item questionnaire, resulting in a range of scores from 1 to 5 (higher scores indicate worse cognition).

Variables from the medical record included age, sex, insurance status (yes or no), comorbidity score, and NIH Stroke Scale (NIHSS) score. Comorbidity score was created by summing the following individual risk factors and comorbid conditions: cancer, chronic obstructive pulmonary disease, dementia, heart failure, Parkinson disease, end-stage renal disease, amyotrophic lateral sclerosis, epilepsy, myocardial infarction or coronary artery disease, hyperlipidemia, diabetes, atrial fibrillation, current smoker, and current excessive alcohol use. NIHSS score was abstracted from the medical record or calculated with a validated method.[24] Given the nonlinear association of the score with most outcomes, NIHSS score was categorized into 2 groups—mild strokes (NIHSS score ≤5) vs moderate to severe strokes (NIHSS score >5)—predictive of acute rehabilitation destination, a marker for rehabilitation potential.[25,26]

Analytical Strategy

For the 77 Census tracts with stroke cases in this study, medians and interquartile ranges were calculated for each of the neighborhood-level variables. Median and interquartile range of the nSES score among stroke cases were calculated by ethnicity, sex, and age group. The median and interquartile range of nSES, ADL/IADL score, PHQ-8 score, and SS-QOL score were graphed within each Census tract using packages implemented in R version 3.6.2 (R Project for Statistical

Table 1 Summary Table of Health, Demographic, and Functional Characteristics of Stroke Survivors for the Total Sample and Stratified by Quartiles of nSES Among Stroke Survivors (N = 776) From the BASIC Project

| | Total Sample | | nSES Score | | | | |
	No.	%/Median (IQR)	<−7.48 M/%	−7.48 to −4.56 M/%	−4.56 to −0.46 M/%	>−0.46 M/%	p Value
ADL/IADL score	764	1.80 (1.23, 2.49)	2.11	2.20	1.83	1.70	<0.0001
SS-QOL score	725	3.67 (2.83, 4.50)	3.41	3.43	3.74	3.87	<0.0001
PHQ-8 score	663	13 (9, 19)	16.24	15.75	14.22	13.89	0.0014
Age, y							0.0688
<57	185	23.84%	6.70%	5.67%	6.06%	5.41%	
57–63.9	180	23.20%	8.38%	4.51%	5.67%	4.64%	
64–72.9	208	26.80%	6.31%	7.22%	6.19%	7.09%	
≥73	203	26.16%	6.06%	5.93%	5.93%	8.25%	
Sex							0.4548
Male	411	52.96%	14.43%	12.24%	11.73%	14.56%	
Female	365	47.04%	13.02%	11.08%	12.11%	10.83%	
Race/ethnicity							<0.0001
Non-Hispanic White	293	37.76%	3.48%	5.16%	12.76%	16.37%	
Mexican American	483	62.24%	23.97%	18.17%	11.08%	9.02%	
Education							<0.0001
Less than high school	219	28.26%	13.16%	9.29%	3.74%	2.07%	
High school	223	28.77%	6.45%	6.71%	8.65%	6.97%	
College or more	333	42.97%	7.74%	7.35%	11.48%	16.39%	
Insurance status							0.7648
Not insured	118	15.55%	4.74%	3.56%	3.82%	3.43%	
Insured	641	84.45%	22.66%	19.63%	20.16%	22.00%	
Modified Rankin Scale score							0.009
No disability	417	54.87%	13.29%	11.32%	13.29%	16.97%	
Slight to moderate disability	310	40.79%	12.24%	10.66%	9.87%	8.03%	
Severe disability	33	4.34%	1.45%	1.45%	0.66%	0.79%	
IQCODE							0.3296
Normal	381	58.62%	16.92%	14.15%	13.85%	13.69%	
Cognitive impairment, no dementia	199	30.62%	6.92%	6.77%	7.54%	9.39%	
Dementia	70	10.77%	3.39%	2.77%	2.62%	2.00%	
Comorbidity score	776	2 (1, 4)	2.67	2.59	2.50	2.22	0.0126
Prestroke depression status							0.3576
No	510	66.75%	17.54%	14.92%	16.23%	18.06%	
Yes	254	33.25%	9.95%	8.25%	7.85%	7.20%	
Social support	739	10 (7, 12)	8.93	9.48	9.60	9.40	0.1570
Marital status							0.1201

Continued

Table 1 Summary Table of Health, Demographic, and Functional Characteristics of Stroke Survivors for the Total Sample and Stratified by Quartiles of nSES Among Stroke Survivors (N = 776) From the BASIC Project *(continued)*

	Total Sample		nSES Score				
			<−7.48	−7.48 to −4.56	−4.56 to −0.46	>−0.46	
	No.	%/Median (IQR)	M/%	M/%	M/%	M/%	p Value
Single/never married	73	9.42%	2.58%	2.32%	2.58%	1.94%	
Married/living with someone	385	49.68%	11.36%	11.74%	11.74%	14.84%	
Widowed	153	19.74%	6.58%	4.26%	4.26%	4.65%	
Divorced/separated	164	21.16%	6.84%	5.03%	5.29%	4.00%	
NIHSS score							0.1103
Mild	603	78.01%	21.22%	17.34%	18.24%	21.22%	
Moderate/severe	170	21.99%	6.34%	5.95%	5.69%	4.01%	

Abbreviations: ADL = activities of daily living; BASIC = Brain Attack Surveillance in Corpus Christi; IADL = instrumental ADL; IQCODE = Informant Questionnaire on Cognitive Decline in the Elderly; IQR = interquartile range; M = mean; NIHSS = NIH Stroke Scale; nSES = neighborhood socioeconomic status; PHQ-8 = Patient Health Questionnaire Eight; SS-QOL = Stroke-Specific Quality of Life.

Computing, Vienna, Austria) and run in RStudio version 1.2.5033. Differences were assessed with the χ^2 and analysis of variance tests. The associations between nSES and 90-day ADL/IADL, PHQ-8, and SS-QOL scores were assessed with generalized estimating equations with the identity link function and exchangeable working correlation structure to account for the clustering of observations within neighborhoods and potential nonnormality of the PHQ-8 measures.[27] The linearity of the nSES variable was confirmed for all 90-day outcome measures through the use of marginal residuals.

To account for missing data due to nonparticipation of baseline interview, baseline interview completed by a proxy, and incompletion of 90-day outcome interview, we used an inverse probability weighting approach in combination with chained multiple imputation.[17] Inverse probability weighting was used to upweight participants in the final analytical sample who were similar to those excluded due to no participation of baseline interview, baseline interview being completed by a proxy, or incomplete 90-day outcome interview by nonproxy. Chained multiple imputation was used to impute the remaining missing data: 18 participants (2.23%) had missing values for insurance status; 1 patient had a missing value for marital status (0.12%); 1 patient had a missing value for education level (0.12%); 84 participants had missing values for prestroke depression (10.66%); 16 had missing values for modified Rankin Scale score (2.03%); 131 had missing values for prestroke cognitive status (16.62%); 3 had missing values for NIHSS score (0.38%); 4 had missing values for body mass index (0.51%); and 40 had missing values for social support (5.07%). Among the 304 individuals who were excluded from the analytical sample for having baseline proxy interviews, only 64 individuals had complete follow-up data, making a sensitivity analysis with their inclusion not beneficial in demonstrating any potential selection bias.

The association of nSES with each of the outcomes was sequentially assessed. In models 1 and 2, the unadjusted and demographic factor–adjusted (age, sex, and ethnicity) nSES effects were examined. The third model (model 3) additionally adjusted for individual socioeconomic status by including education and insurance status. The fourth model (model 4) additionally adjusted for individual-level prestroke medical-functional status by including prestroke cognition, prestroke depression status, prestroke functional status, and comorbidity score. The fifth (model 5) additionally adjusted for prestroke social support and marital status. The sixth model (model 6) additionally adjusted for NIHSS score given the potential for stroke severity to be on the pathway between nSES and stroke outcomes. In the seventh and last model (model 7), an nSES × NIHSS interaction was included to explore whether the associations of nSES with the outcomes varied by stroke severity. A priori, a value of $p = 0.15$ was set to determine the presence of effect modification, consistent with recommendations in the literature.[28]

Due to potential heterogeneity of effect among those with moderate to severe strokes, a sensitivity analysis was conducted excluding those with severe strokes (NIHSS score ≥ 14). Statistical analyses were completed with SAS (SAS Institute, Inc, Cary, NC).
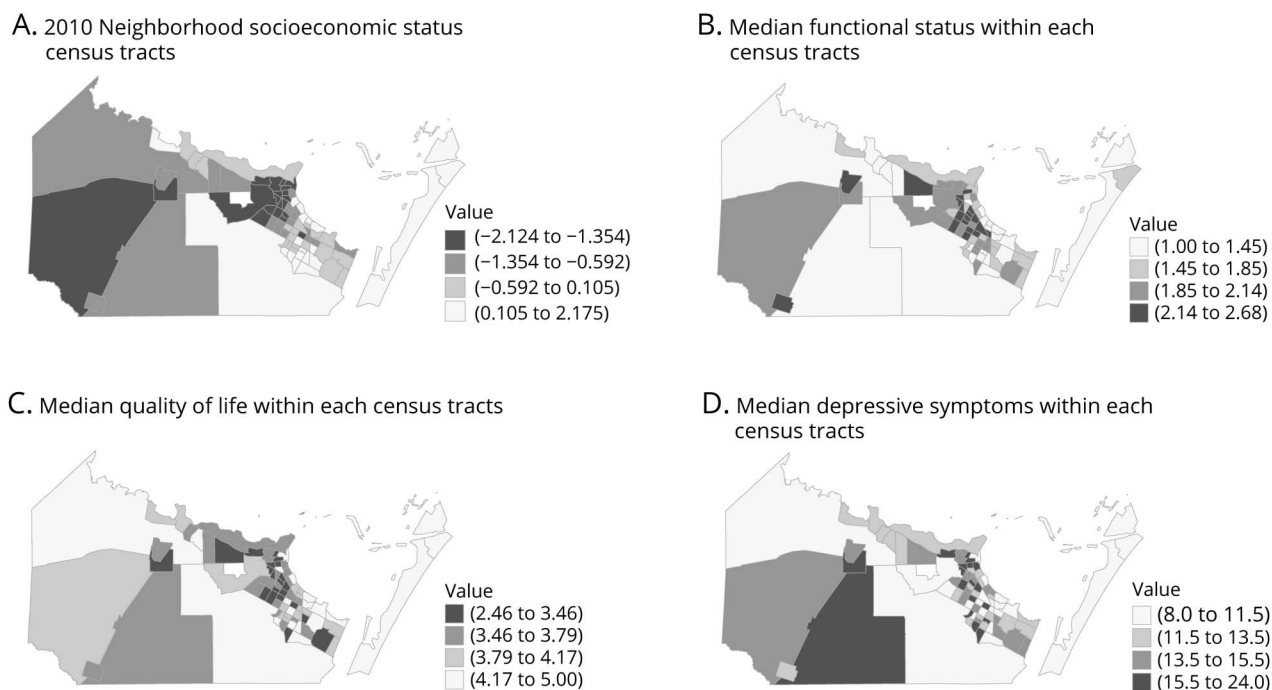
Standard Protocol Approvals, Registrations, and Patient Consents
The BASIC study was approved by the Institutional Review boards at the University of Michigan and the 2 local hospital systems. Written informed consent was obtained from all patients.

Data Availability
The data will not be made publicly available because of the restricted nature of the data.

Figure 3 Maps of nSES and 90-Day Poststroke Outcomes Within 77 Census Tracts

A. 2010 Neighborhood socioeconomic status census tracts

Value
(−2.124 to −1.354)
(−1.354 to −0.592)
(−0.592 to 0.105)
(0.105 to 2.175)

B. Median functional status within each census tracts

Value
(1.00 to 1.45)
(1.45 to 1.85)
(1.85 to 2.14)
(2.14 to 2.68)

C. Median quality of life within each census tracts

Value
(2.46 to 3.46)
(3.46 to 3.79)
(3.79 to 4.17)
(4.17 to 5.00)

D. Median depressive symptoms within each census tracts

Value
(8.0 to 11.5)
(11.5 to 13.5)
(13.5 to 15.5)
(15.5 to 24.0)

Maps of the 77 Census tracts were stroke cases reside in the Brain Attack Surveillance in Corpus Christi (BASIC) Project. (A) Relative neighborhood socioeconomic status (nSES) by quartile for each Census tract within the county of origin. (B–D) Median functional status, biopsychosocial health, and depressive symptoms by quartile. In all maps, lighter shading implies a better value: higher nSES, better poststroke functional status, better poststroke biopsychosocial health, and fewer depressive symptoms.

Results

Figure 2 displays the development process of our analytic sample. Among the final analytic of 776 individuals, only 48 individuals were monolingual Spanish speakers. As shown in figure 2, a total of 1,962 participants within the BASIC cohort survived 90 days after stroke and identified as non-Hispanic White or Mexican American. Figure 2 depicts reasons for exclusion and derivation of our final analytical sample composed of 776 individuals living in 77 Census tracts. Among the 776 individuals, the median nSES was −4.56 with an interquartile range from −7.48 to −0.46. Descriptive statistics of the study sample are presented in table 1. Approximately half of participants were male, were married, had attended college or more, and reported no prestroke disability. A greater proportion of the study sample identified as Mexican American, had medical insurance, did not have prestroke depression, and had a mild stroke according to the NIHSS score. Those living in neighborhoods with worse nSES indexes were more likely to be Mexican American, to have less education, and to have a higher comorbidity score. To facilitate comparison of Census tracts, figure 3 shows the relative nSES by quartile for each Census tract within Nueces County, along with median outcome values by quartile. In all of the maps, lighter shading implies a better value: higher nSES, better poststroke functional status, better poststroke biopsychosocial health, and fewer depressive symptoms.

Table 2 presents the sequentially adjusted associations of nSES with ADL/IADL score (range 1–4), SS-QOL score (range 1–5), and PHQ-8 score (range 0–24). Associations are presented as an interquartile range difference in nSES to facilitate a comparison of high- and low-nSES neighborhoods. In the unadjusted model, a higher nSES (comparing 75th and 25th percentiles) was associated with a 0.32 better ADL/IADL score (95% confidence interval [CI] −0.41 to −0.24), 0.33 better (95% CI 0.23–0.42) SS-QOL score, and 1.77 lower (95% CI −2.49 to −1.05) PHQ-8 score. These associations persisted after adjustment for all individual-level covariates (models 2–5), with the association between nSES and PHQ-8 score greatly attenuated after adjustment for demographic and individual-level socioeconomic factors. In model 6, the effect estimates for an NIHSS score >5 compared to NIHSS score ≤5 was 0.31 (95% CI 0.17–0.44, $p < 0.01$), −0.36 (95% CI −0.51 to −0.21, $p < 0.01$), and 0.94 (95% CI −0.23 to 2.12, $p = 0.12$) for the association with ADL/IADL, SS-QOL, and PHQ-8 score, respectively.

Figure 4 displays the combined effects of nSES and NIHSS score on ADL/IADL, SS-QoL, and PHQ-8 scores. Stroke severity significantly modified the association between nSES and PHQ-8 score (model 7, table 2) and SS-QOL score (model 7, table 2). Among those with moderate to severe strokes, nSES was significantly associated with fewer depressive symptoms (−1.77, 95% CI −3.06 to −0.48) and

Table 2 Association Between IQR Increase in nSES and 90-Day Poststroke Functional Status, Biopsychosocial Health, and Depression Severity, Accounting for Missing Data and Differential Attrition in the BASIC Study (N = 776)

Model	Functional status[a]		Biopsychosocial health[b]		Depressive symptoms[c]	
	IQR increase in nSES (95% CI)	p Value	IQR increase in nSES (95% CI)	p Value	IQR increase in nSES (95% CI)	p Value
1	−0.32 (−0.41 to −0.24)	<0.01	0.33 (0.23 to 0.42)	<0.01	−1.77 (−2.49 to −1.05)	<0.01
2	−0.28 (−0.37 to −0.18)	<0.01	0.26 (0.16 to 0.36)	<0.01	−0.99 (−1.72 to −0.25)	0.01
3	−0.24 (−0.34 to −0.14)	<0.01	0.21 (0.10 to 0.32)	<0.01	−0.61 (−1.38 to 0.17)	0.13
4	−0.18 (−0.28 to −0.08)	<0.01	0.14 (0.06 to 0.26)	0.01	−0.17 (−0.87 to 0.53)	0.64
5	−0.18 (−0.28 to −0.08)	<0.01	0.14 (0.03 to 0.24)	0.01	−0.14 (−0.85 to 0.58)	0.71
6	−0.17 (−0.27 to −0.06)	<0.01	0.13 (0.02 to 0.23)	0.02	−0.10 (−0.81 to 0.61)	0.78
7						
NIHSS score ≤5	−0.13 (−0.24 to −0.02)	0.02	0.08 (−0.03 to 0.20)	0.17	0.43 (−0.40 to 1.25)	0.31
NIHSS score >5	−0.27 (−0.49 to −0.05)	0.02	0.26 (0.06 to 0.47)	0.01	−1.77 (−3.06 to −0.48)	<0.01

Abbreviations: BASIC = Brain Attack Surveillance in Corpus Christi; CI = confidence interval; IQR = interquartile range; NIHSS = NIH Stroke Scale; nSES = neighborhood socioeconomic status.
Model 1: unadjusted. Model 2: adjusted for age, sex, and race/ethnicity. Model 3: model 2 + education and insurance status. Model 4: model 3 + prestroke functional status, prestroke cognitive status, comorbidity score, and prestroke depression status. Model 5: model 4 + marital status and social support index. Model 6: model 5 + NIHSS score. Model 7: model 6 + nSES × NIHSS score interaction term.
[a] Functional status defined by activities of daily living and instrumental activities of daily living score (range 1–4, lower scores represent better function).
[b] Biopsychosocial health defined by Stroke-Specific Quality of Life score (range 1–5, higher scores represent better biopsychosocial health).
[c] Depressive symptoms defined by the Patient Health Quality Eight score (range 0–24, lower scores represent less depression symptom burden).

improved biopsychosocial health (0.26, 95% CI 0.06–0.47). There was no significant association between nSES and depressive symptoms or biopsychosocial health among those with mild strokes. Stroke severity also appears to modify the relationship between nSES and ADL/IADL score, with the strength of association between nSES and functional status being greater among those with moderate to severe strokes (−0.27, 95% CI −0.49 to −0.05) compared to those with mild strokes (−0.13, 95% CI −0.24 to −0.02), although the interaction did not reach statistical significance (p = 0.2429).

With respect to all outcomes, adjusting for stroke severity (model 6) did not significantly change the associations of nSES with the 3 outcomes. In our sensitivity analyses excluding those with severe strokes (NIHSS score ≥14), the effect estimates were largely unchanged in the final model, and statistical significance did not differ (results not shown). In our complete case analysis (table 3), there were significant interactions between nSES and NIHSS score with respect to poststroke functional status and biopsychosocial health but not with respect to depressive symptoms. The associations between nSES and ADL/IADL and SS-QOL scores were more pronounced among those with moderate to severe stroke in the complete case analyses, although the direction of effects was the same.

Discussion

This study examined the association of nSES with 90-day poststroke functional status, depressive symptoms, and biopsychosocial health in a population-based cohort study, as

well as the role of stroke severity in modifying these associations. Residence in areas with higher nSES was associated with significantly better poststroke functional status and biopsychosocial health when all stroke survivors were analyzed as 1 group. Higher nSES was associated with significantly fewer poststroke depressive symptoms in those with moderate to severe strokes but not in those with mild strokes. The impact of nSES on biopsychosocial health and functional status was also more prominent among those with moderate to severe strokes. Our results suggest that those living in lower-nSES neighborhoods and with moderate to severe strokes were most susceptible to poor outcomes.

The present study adds to current understanding of how socioenvironmental factors influence stroke outcomes in 4 major ways: (1) estimating the association between nSES and multiple dimensions of poststroke health among survivors in a population-based study after adjusting for multiple individual-level confounders not accounted for in prior studies, (2) taking a causal approach to account for differential attrition to minimize selection bias, (3) testing the interaction between personal and environmental factors as theorized in the ICF,[4] and (4) exploring whether stroke severity mediates associations between nSES and outcomes. This study empirically demonstrates the role of environmental factors (i.e., nSES) and personal factors (i.e., NIHSS score) on functioning as theorized by the ICF (figure 1). We observed that nSES affects a variety of outcomes among all stroke survivors, although most prominently in those with moderate to severe strokes. The identified role of nSES on poststroke 90-day outcomes has potential implications for policy and clinical practice. Both clinicians and policy makers should be

Figure 4 IQR Difference in nSES and 90-Day Poststroke Outcomes by Stroke Severity
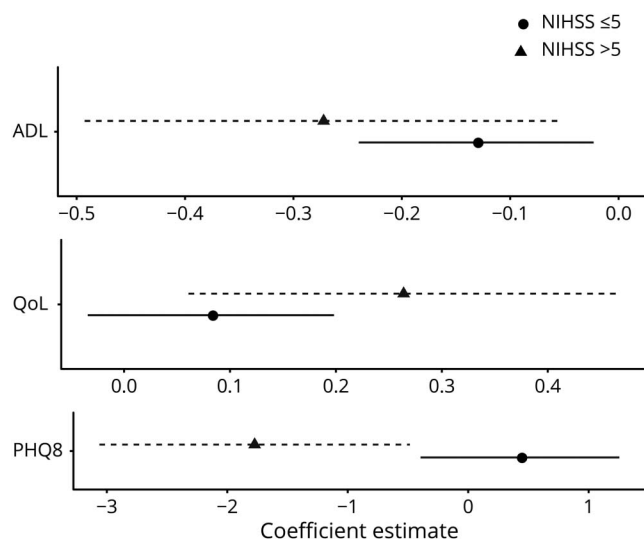
Association between interquartile range (IQR) difference in neighborhood socioeconomic status (nSES) and 90-day poststroke functional status, biopsychosocial health, and depressive symptoms by stroke severity. Effect estimates are adjusted for age, sex, race/ethnicity, education, insurance status, prestroke functional status, prestroke cognitive status, comorbidity score, prestroke depression status, marital status, and social support index. Estimates account for missing data and differential attrition in the Brain Attack Surveillance in Corpus Christi (BASIC) study (N = 766). ADL = activities of daily living; NIHSS = NIH Stroke Scale; PHQ8 = Patient Health Quality Eight; QoL = quality of life.

cognizant that those who bear the dual burden of more severe strokes and residence in worse socioenvironmental conditions are at greater risk for poor outcomes. Integrating information on a patient's neighborhood context within the demographic information in the medical chart would assist with hospital discharge and disposition planning. Research into how nSES affects discharge location (e.g., home, skilled nursing facility, acute inpatient rehabilitation) would also be informative in identifying disparities in postacute care by nSES. Future studies should also aim to delineate what specific aspects of low-nSES neighborhoods contribute to worse poststroke outcomes to more effectively intervene.

This study empirically demonstrates an interaction between stroke severity (i.e., body functions and structure) and neighborhood economic characteristics (i.e., environmental factors), as theorized by the ICF (figure 1). We observed effect modification (also known as moderation) by stroke severity on the relationship between nSES and multiple 90-day poststroke outcomes, suggesting that stroke survivors with moderate to severe strokes may be more vulnerable to facilitators and barriers within the surrounding neighborhood environment. Those with mild stroke severity may be less affected by nSES because their "distance" to recovery is smaller, and functional recovery can occur independently of neighborhood surroundings.[29] Individuals with moderate to severe strokes may have more constricted life spaces with less ability to leave their neighborhoods and proximate surroundings, resulting limited access to spaces in

the neighborhood and restriction of participation in community gatherings.[13,30] Consequently, those with more severe strokes are likely more susceptible to poorer social and physical organization of their communities and hence are less engaged in prorecovery social and physical activity.[5] This is supported by research finding that the presence of meaningful destinations within the community facilitated stroke survivors' travel outdoors[31] and that the presence of barriers in the built environment is a detriment to reintegration to the community after stroke.[32]

While nSES seemed to affect outcomes more prominently among those with moderate to severe strokes, the nSES and NIHSS score interaction was most salient with respect to poststroke depressive symptom burden. This is consistent with prior findings on associations between nSES and depression.[33] It may be that stroke survivors with moderate to severe strokes in low-nSES communities are at risk for increased social isolation, a strong risk factor for depression—a difficult poststroke complication affecting about one-third of survivors, often leading to lack of independence.[34] In addition to less social cohesion, other potential contributors to our finding include more noise pollution, fewer public spaces, and poorer features of the built environment.[33]

We found that the associations between nSES and 90-day poststroke outcomes were not largely affect by the inclusion of NIHSS score adjustment to the models, suggesting that stroke severity is not mediating the observed associations. While a formal causal-mediation analysis is needed to confirm these findings, our results suggest that the mechanism through which nSES is associated with poststroke outcomes is not via more severe stroke. In other words, nSES does not seem to lead to worse strokes, which subsequently leads to worse outcomes. This is supported by a growing body of literature suggesting that neighborhood context significantly influences poststroke outcomes beyond individual-level factors.[11] Low-nSES environments have lower levels of perceived safety,[35] fewer physical activity facilities,[36,37] poorer walking environments,[38] and lower social cohesion.[39] These neighborhood factors are likely relevant in the recovery process after a sudden and dramatic change in life state that occurs after a stroke.

In addition to poorer built and social environmental factors, stroke survivors returning to low-nSES neighborhoods may be less likely to have access to posthospitalization care coordination and support services.[40,41] This may explain previous findings of more frequent, complicated posthospitalization health care transitions among marginalized populations and our findings of worse nonmortality outcomes in low-nSES environments. Multiple studies suggest that improved access to support and navigational services in stroke survivors returning home leads to improved community reintegration and improved nonmortality outcomes.[42,43] While trials have been completed to examine the effectiveness of poststroke care coordination at improving secondary poststroke risk factor management in marginalized populations, similar trials are

Table 3 Association Between IQR Increase in nSES and 90-Day Poststroke Functional Status, Biopsychosocial Health, and Depression Severity, Complete Case Analysis in the BASIC Study

Model	Functional status[a] (n = 579)		Biopsychosocial health[b] (n = 548)		Depressive symptoms[c] (n = 504)	
	IQR increase in nSES (95% CI)	p Value	IQR increase in nSES (95% CI)	p Value	IQR increase in nSES (95% CI)	p Value
1	−0.33 (−0.42 to −0.24)	<0.01	0.36 (0.25 to 0.46)	<0.01	−1.63 (−2.41 to −0.85)	<0.01
2	−0.26 (−0.37 to −0.15)	<0.01	0.28 (0.16 to 0.40)	<0.01	−0.80 (−1.75 to 0.15)	0.10
3	−0.23 (−0.28 to −0.03)	<0.01	0.23 (0.10 to 0.36)	<0.1	−0.47 (−1.39 to 0.45)	0.32
4	−0.16 (−0.28 to −0.03)	0.01	0.15 (0.02 to 0.28)	0.03	0.05 (−0.82 to 0.92)	0.91
5	−0.15 (−0.26 to −0.01)	0.02	0.14 (0.01 to 0.27)	0.04	0.08 (−0.80 to 0.96)	0.86
6	−0.14 (−0.26 to −0.01)	0.04	0.12 (−0.01 to 0.26)	0.07	0.12 (−0.74 to 0.98)	0.79
7						
NIHSS score ≤5	−0.08 (−0.21 to 0.04)	0.18	0.07 (−0.07 to 0.20)	0.34	0.46 (−0.49 to 1.41)	0.35
NIHSS >5	−0.38 (−0.68 to −0.09)	0.01	0.37 (0.09 to 0.65)	0.01	−1.43 (−3.27 to 0.42)	0.13

Abbreviations: BASIC = Brain Attack Surveillance in Corpus Christi; CI = confidence interval; IQR = interquartile range; NIHSS = NIH Stroke Scale; nSES = neighborhood socioeconomic status.
Model 1: unadjusted. Model 2: adjusted for age, sex, and race/ethnicity. Model 3: model 2 + education and insurance status. Model 4: model 3 + prestroke functional status, prestroke cognitive status, comorbidity score, prestroke depression status. Model 5: model 4 + marital status and social support index. Model 6: model 5 + NIHSS score. Model 7: model 6 + nSES × NIHSS score interaction term.
[a] Functional status defined by activities of daily living and instrumental activities of daily living score (range 1–4, lower scores represent better function).
[b] Biopsychosocial health defined by Stroke-Specific Quality of Life score (range 1–5, higher scores represent better biopsychosocial health).
[c] Depressive symptoms defined by the Patient Health Quality Eight (range 0–24, lower scores represent less depression symptom burden).

needed to examine their role in patient-reported poststroke rehabilitation and quality of life outcomes, especially for those returning to low-nSES environments.[44]

While this study was not designed to explore the role of nSES in poststroke disparities between Mexican Americans and non-Hispanic White individuals, we did find that Mexican Americans were significantly more likely to reside in low-nSES neighborhoods. Future research studies should examine the extent to which low-nSES environments—a possible component of structural racism—contribute to known poststroke disparities between Mexican American and non-Hispanic White individuals.[16]

This study also has a number of important limitations. Results may not be generalizable to geographic areas with dissimilar climates[45] or populations with a different composition of urbanicity.[46] This study did not account for whether individuals moved between days 0 and 90 after stroke. However, residential mobility after 35 years of age and within Nueces County is low; it is unlikely that our effect estimates are biased due to moving in our sample.[47,48] This study does not account for postacute care among study participants. However, we did account for stroke severity, a critical individual level predictor of poststroke outcomes. We were not able to distinguish between those who were institutionalized and those who were not at 90 days among the whole study sample. Among participants with information about 90-day residency, only 4.1% were institutionalized. We hypothesize that this would bias our results toward the null, especially among those with moderate to severe strokes, because those in nursing homes or skilled

nursing facilities at 90 days are unlikely to be affected by their neighborhood surroundings. We used Census tracts as the geographic boundaries to measure nSES. It is possible that a more proximal definition of neighborhood may better capture the idealized exposure of neighborhood context and nSES within this population of stroke survivors. We used 2010 Census data to develop the nSES index. It may be that there were significant changes in neighborhoods between 2010 and 2016, which our nSES exposure did not capture. However, we hypothesize that this possible measurement error would not differ by either our exposure or outcomes and hence bias our results toward the null. There may be heterogeneity of effect among those with moderate to severe strokes. However, after sensitivity analyses excluding severe stroke cases (NIHSS score ≥ 14) were conducted, the observed relationships between nSES and 90-day poststroke outcomes were unchanged. Although our consideration of effect modification of the nSES and 90-day poststroke outcomes associations by stroke severity was justified by our a priori hypothesis, our results regarding the presence of effect modification should be interpreted with caution and require replication in other studies. The main effects of nSES were significantly associated with both biopsychosocial health and functional status ($p < 0.05$), and effect modification was significant ($p < 0.05$) with respect to poststroke depressive symptoms. As with all observational research, this study is limited by potential unmeasured confounders, specifically with respect to individual-level socioeconomic status. However, education level and insurance status are likely good surrogate markers of individual socioeconomic status.[49] Education is often regarded as the best indicator of socioeconomic status because educational attainment is often fixed early in life and problems of reverse

causation are less serious.[23] In addition, the use of generalized estimating equations accounts for potential clustering effects. Nonetheless, it is possible that we are not fully controlling for individual socioeconomic status.

This study found that nSES was significantly associated with multiple 90-day poststroke outcomes after adjustment for person-level confounders, especially in those with moderate to severe strokes. Future research is needed to identify which factors of nSES are driving the observed associations between neighborhood environments and stroke outcomes and the role of nSES in poststroke disparities. Clinical and policy initiatives aimed at improving stroke survivors' health and quality of life, such as improved poststroke care coordination, should include and address those who have the dual burden of experiencing a more severe stroke and living in a socioeconomically deprived neighborhood.

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Disclosure

Publication History

Appendix Authors

Name	Location	Contribution
Eric L. Stulberg, MD	University of Utah, Salt Lake City; University of Michigan, Ann Arbor	Conceptualized the study, analyzed the data, interpreted the data, performed statistical design and analysis, drafted the manuscript, revised the manuscript, provided final approval

Appendix (continued)

Name	Location	Contribution
Erica Twardzik, MS	University of Michigan, Ann Arbor	Conceptualized the study, analyzed the data, interpreted the data, performed statistical design and analysis, drafted the manuscript, revised the manuscript, provided final approval
Sehee Kim, PhD	University of Michigan, Ann Arbor	Analyzed the data, interpreted the data, performed statistical design and analysis, revised the manuscript, provided final approval
Chia-Wei Hsu, MS	University of Michigan, Ann Arbor	Analyzed the data, performed statistical design and analysis, provided final approval
Yuliang Xu, MS	University of Michigan, Ann Arbor	Analyzed the data, performed statistical design and analysis, provided final approval
Philippa Clarke, PhD	University of Michigan, Ann Arbor	Interpreted the data, revised the manuscript, provided final approval
Lewis B. Morgenstern, MD	University of Michigan, Ann Arbor	Provided the data, revised the manuscript, provided final approval
Lynda D. Lisabeth, PhD	University of Michigan, Ann Arbor	Provided the data, conceptualized the study, interpreted the data, performed statistical design and analysis, revised the manuscript, provided final approval, supervised the study

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