Average Temperature, Diurnal Temperature Variation, and Stroke Hospitalizations

Judith H. Lichtman, PhD,* Erica C. Leifheit-Limson, PhD,* Sara B. Jones, PhD,† Yun Wang, PhD,‡ and Larry B. Goldstein, MD§

Background: Studies assessing the relationship between meteorological factors and stroke incidence are inconsistent. We assessed the associations of average temperature and diurnal temperature fluctuations with ischemic stroke hospitalizations in a nationally representative sample of patients in the United States. *Methods:* Hospitalizations were identified for adults aged 18 years or older in the 2009-2011 Nationwide Inpatient Sample and linked with county-level monthly average temperatures from the United States National Climatic Data Center. Logistic regression models assessed the relationships of 5°F increases in average temperature and diurnal temperature variation (difference between high- and low-daily temperatures) with the odds of ischemic stroke hospitalization (*International Classification of Diseases, Ninth Revision, Clinical Modification* codes 433, 434, and 436), adjusting for patient characteristics and dew point. Models were stratified by age (18-64, ≥65 years), season, and region, with analysis at the hospitalization level. *Results:* Increased average temperature was associated with decreased odds of stroke hospitalization among both age groups and across seasons in the Northeast, and among the elderly in the West. Increased diurnal temperature variation was associated with increased odds of stroke hospitalization for nearly all regions in the spring to fall seasons; associations were most pronounced in the Northeast and strongest in the spring. *Conclusions:* Lower average temperature and larger diurnal temperature variations were associated with stroke hospitalizations. Associations were strongest in the Northeast and largely similar across seasons and age. Further research is needed to explore the mechanisms underlying these associations. Understanding these patterns may lead to targeted prevention strategies for vulnerable populations during periods of extreme weather conditions. **Key Words:** Temperature—weather—ischemic stroke—risk factor—hospitalization.

Introduction

Stroke represents a significant public health burden in the United States, with approximately 795,000 events occurring each year.[1] Stroke is the country's fifth leading cause of death and a leading cause of long-term disability. Seasonal variation in stroke incidence has been reported in many populations and may be mediated through changes in temperature and barometric pressure.[2] The majority of prior studies report higher stroke rates in colder months compared with other times of the year[3-9]; however, some studies report no seasonal patterns[10] or higher rates in spring, summer, or autumn.[11-14]

There are only limited U.S. data assessing the association between temperature and stroke risk, irrespective

From the *Department of Chronic Disease Epidemiology, Yale School of Public Health, New Haven, Connecticut; †Department of Epidemiology, University of North Carolina, Chapel Hill, North Carolina; ‡Department of Biostatistics, Harvard T.H. Chan School of Public Health, Boston, Massachusetts; and §Department of Neurology, University of Kentucky College of Medicine and Kentucky Neuroscience Institute, Lexington, Kentucky.

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Address correspondence to Judith H. Lichtman, PhD, Yale School of Public Health, PO Box 208034, New Haven, CT 06520-8034. E-mail: judith.lichtman@yale.edu.

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of seasonal effects and with adjustment for patient-level comorbidities. In a longitudinal study of mortality after ischemic stroke in the United States, we found a seasonal trend for higher mortality rates in colder months with a second peak in July.[15] The current study expands this research by exploring the impact of meteorological factors, including average temperature and diurnal temperature variation, on stroke hospitalizations across geographic regions of the United States.

Methods

Hospital admissions for ischemic stroke (*International Classification of Diseases, Ninth Revision, Clinical Modification* codes 433.xx, 434.xx, and 436.xx)[16] were identified among all hospitalizations for calendar years 2009-2011 in the Nationwide Inpatient Sample (NIS), a multistate database developed as part of the United States Agency for Healthcare Research and Quality's Healthcare Cost and Utilization Project.[17] The NIS is the largest publicly available, all-payer, inpatient database in the United States, comprising a 20% stratified sample of community hospitals and including approximately 8 million all-cause hospitalizations annually. Detailed methods of the NIS are described elsewhere.[17] We limited our analyses to patients aged 18 years or older. In addition, we excluded hospitalizations missing the month of admission and hospital county information because they could not be linked with local climate data.

Patient-level characteristics included age, sex, race (white, black, and other), and comorbid conditions and medical history identified from secondary discharge administrative codes. Hospital geographic region was classified as West, Midwest, South, or Northeast. We aggregated daily temperature data from the United States National Climatic Data Center to calculate a monthly average at the county level in degrees Fahrenheit (°F). We then linked these averages to the hospitalization data by month of admission and county. We repeated this process for diurnal temperature variation (calculated as the difference between high and low temperatures in a given day) and dew point temperature.

Statistical Analysis

We fit a logistic regression model to estimate the association between stroke-specific hospitalization and a 5°F increase in temperature, adjusting for patient age, sex, race, dew point temperature, and the following comorbid conditions and medical history variables: heart failure, prior myocardial infarction, stroke history, hypertension, peripheral vascular disorders, valvular disease, diabetes mellitus, renal failure, chronic pulmonary disease, pulmonary circulation disorders, depression, coagulopathy, liver disease, obesity, weight loss, hyperthyroidism, hypothyroidism, metastatic cancer, lymphoma, paralysis, alcohol abuse, drug abuse, psychoses, and other neurological disorders. A similar model was fit to estimate the association between stroke-specific hospitalization and diurnal temperature variation on a 5°F scale. Models were further stratified by age (18-64 and ≥65 years), season, and geographic region to assess potential season- and region-specific effects of temperature on stroke hospitalizations. Age strata were examined to determine whether temperature differentially affected stroke risk in younger and older individuals as the pathophysiology and risk factors of stroke can differ by age. All analyses were conducted using 64-bit SAS, Version 9.3 (SAS Institute, Cary, NC).

Results

The final cohort included 9,909,608 hospitalizations; 171,695 (1.7%) were ischemic stroke hospitalizations (Table 1). The mean age of the younger population (aged 18-64 years) was 54.4 years and for the older population (≥65 years) was 78.7 years; women represented approximately half of the hospitalizations. Stroke patients had a high prevalence of comorbid conditions, including heart failure, hypertension, and diabetes. Black race and diabetes were more common in younger than older stroke patients. The mean length of hospital stay was 4.2 days for both age groups; 2% of younger stroke patients and 4% of older patients died during hospitalization.

The distribution of average temperature variables according to season and region is shown in Figure 1. Diurnal temperature variation was smallest in the winter months for all regions. The West had the largest mean diurnal temperature variation and the largest within-season variation. In general, the Northeast had the smallest within-season variation for both average temperature and diurnal temperature variation.

Increased average temperature was associated with decreased odds of stroke hospitalization; however, the effect varied by season, region, and patient age (summarized in Fig 2, with corresponding odds ratios [ORs] presented in Table 2). The relationship was most pronounced in the Northeast, with each 5°F increase in average temperature associated with a 7%-18% decrease in the odds of stroke hospitalization for those aged 18-64 years (ORs ranging from .93, 95% confidence interval [CI] .86-1.00 in the summer to .82, 95% CI .76-.88 in the spring) and a 14%-17% decrease in the odds of stroke hospitalization for those aged 65 years or older (ORs ranging from .86, 95% CI .82-.91 in the spring to .83, 95% CI .79-.87 in the winter). Average temperature was also associated with decreased odds of stroke hospitalization among the elderly in the West, but it was not otherwise observed in younger adults or other regions (with the exception of the Midwest elderly during the fall).

Diurnal temperature variation was more consistently related to stroke hospitalization than average temperature