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Maya Karri Date

Stroke Systems of Care Policies: Evaluating the Predictors of State-Level Adoption of Stroke Systems of Care Policies in the United States

By

Maya Karri
Master of Public Health

Epidemiology

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Álvaro Alonso, MD, PhD
Committee Chair

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By

Maya Karri

B.S., University of Georgia, 2021

Thesis Committee Chair: Álvaro Alonso, MD, PhD

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Abstract

Stroke Systems of Care Policies: Evaluating the Predictors of State-Level Adoption of Stroke Systems of Care Policies in the United States

By Maya Karri

Background: Stroke remains a leading cause of death in the United States. Stroke Systems of Care (SSOC) policies were proposed by the American Heart Association, and subsequently adopted by several states, in an effort to coordinate stroke-related healthcare services to allow for more effective stroke care. The purpose of this study is to better understand factors associated with the enactment of SSOC policies, particularly whether SSOC policies are more likely to be enacted in states with higher racial and ethnic disparities in stroke mortality rates and/or higher stroke mortality rate overall.

Methods: This study applied event history analysis to identify and evaluate predictors in state-level policy adoption of SSOC policies from 2005-2018. These predictors included racial and ethnic disparities in stroke mortality rates, stroke mortality rates overall, age, sex, and neighboring states that previously adopted an SSOC policy in the prior year.

Results: This study demonstrated that racial and ethnic disparities in stroke mortality rates, stroke mortality rates overall, age, and sex were not significant predictors in SSOC policy adoption by state. However, having a neighboring state which previously adopted an SSOC policy was a significant predictor of state-level policy adoption, provided that the state had not adopted an SSOC policy in the prior year.

Conclusion: Despite evidence in the literature demonstrating that significant racial and ethnic disparities exist in stroke care, this study provided evidence indicating that racial and ethnic disparities in stroke mortality rates are not a significant predictor in state-level policy adoption. However, it remains critical that this research continues as SSOC policy data expands and is updated into the 2020s.

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Introduction

In 2022, stroke was listed as the fifth leading cause of death in the United States and presents as a significant healthcare burden in the United States.[1] Stroke prevalence and mortality have become increasingly more common in recent U.S. history, with a stroke occurring every 40 seconds and a stroke-related death occurring every 3 minutes and 11 seconds.[2] In addition to this, healthcare costs for stroke have risen significantly, due to the large number of persons afflicted with stroke each year. Between the years of 2019 and 2020, stroke-related costs in the United States amounted to nearly $56.2 billion to account for the cost of health care services and treatment, stroke medications, and missed days of work.[2] Given the immense burden stroke prevalence and mortality pose, medical advancements have been made to implement life-saving treatments for patients who have suffered from stroke. However, while life-saving treatments exist for stroke, it is necessary for patients to receive these treatments early in stroke development to ensure timely receipt of care and increase chance of optimal outcomes.[3]

Stroke Systems of Care (SSOC) aim to coordinate stroke-related healthcare services and activities to allow for effective and efficient care. These approaches are comprehensive, addressing all aspects of the stroke care continuum, including stroke prevention and education, treatment, and rehabilitation. Using these approaches, many states implement laws that coordinate needed health services into SSOCs, allowing for timely and well-rounded stroke care.[3] SSOC policies may be implemented at both the state and regional level, and ultimately serve as methods for coordinating stroke-related care in a comprehensive manner throughout the stroke care continuum.[3] The first SSOC policy was adopted in 2003, and, as of 2018, 38 US states and Washington DC have implemented SSOC policies to support coordinated stroke care.[3] While the implemented policies differ across states, SSOC policies fall into different categories: pre-hospital interventions, in-hospital interventions, and legal authorities and organizational frameworks.[4,5] Dependent on which policy each state chooses to enact, pre-hospital interventions may include laws related to EMS triage and transport, air medical transport, and inter-facility transfers. In-hospital interventions may include establishing state standards for primary and comprehensive stroke centers, development of a state-level stroke database for continuous quality

improvement, and implementing telemedicine protocols. Finally, legal authorities and organizational frameworks may include interventions such as developing a tiered stroke center approach or creating a stroke systems of care task force.[4,5]

In previous studies conducted by the Centers for Disease Control and Prevention's (CDC's) Division for Heart Disease and Stroke Prevention, states, on average, with at least one SSOC policy had improved stroke outcomes, including better access to stroke centers, lower inpatient hospital costs, more timely brain imaging results, and lower age-adjusted stroke mortality, compared to no implementation of a SSOC policy.[3] The American Heart Association/ American Stroke Association (AHA/ASA) also published a statement in 2019 to support the existence of SSOC policies and to provide further guidance for policymakers and public healthcare agencies to continually update their policies based on changes that have occurred within the context of both healthcare field advancements and healthcare policy organization in the United States.[6] In addition to this, this statement discusses the burden of stroke, with an emphasis on the racial and ethnic disparities in stroke prevalence and mortality, highlighting racial and ethnic disease disparities and decreased awareness and access to stroke care.[6]

Racial and ethnic disparities in stroke prevalence and mortality is a critical point of discussion when examining stroke in the United States, with Black individuals being at a higher risk of incident stroke even when adjusted for traditional stroke risk factors, as well as having the highest rates of mortality from stroke.[2,7] In the 2019 statement published by the AHA/ASA that centered on recommendations for established SSOC policies, it is noted that racial/ethnic minorities are less likely to use EMS and receive post-acute rehabilitation after stroke.[6] Given this evidence on the existing disparity in stroke mortality and care, this study seeks to understand if disparities in stroke mortality rates by race/ethnicity influence the state-level adoption of SSOC in the United States, as it may be hypothesized that states with lower overall stroke mortality rates and lower stroke mortality rates by race/ethnicity may be associated with the implementation of SSOC policies which aim to facilitate and enhance provision of stroke care and have been demonstrated to be associated with improved stroke outcomes.[3] Currently, there is little known about specific state characteristics that influence SSOC policy adoption and

implementation. Thus, this study seeks to better understand factors associated with the enactment of SSOC policies, particularly whether SSOC policies are more likely to be enacted in states with higher racial and ethnic disparities in stroke mortality rates and/or higher stroke mortality rate overall.

Methods

Study Design

To determine if SSOC policies are more likely to be enacted in states with higher racial or ethnic disparities in stroke mortality, this author conducted an event history analysis. Event history analysis is a form of survival analysis, which uses longitudinal data to study the duration of time in years until an event of interest occurs, as well as to predict the occurrence of the event of interest.[8] It is applied to study the time at which an individual or population is at risk of experiencing the event of interest, until the event itself occurs.[8] Although typically used in sociological studies, event history analysis has previously been applied in economic and political contexts, including in the examination of employment histories and state-level policy adoption, for example. [8,9] Based on previous studies that used event history analysis to examine state-level policy adoption, the authors of this study applied event history analysis in a novel approach to investigate predictors of SSOC policy adoption using a hazard rate, which is a statistical measure that quantifies the risk of an event occurring at a given time assuming that the event has not yet occurred.[10] This study defined its outcome measure as the hazard rate based on the conditional probability of a state implementing an SSOC policy provided that the state did not implement an SSOC policy in the preceding years, which was also identified as the event of interest in this study. The primary independent variable was defined as the stroke mortality rates, including overall stroke mortality rates and stroke mortality rates by race/ethnicity, in the year preceding SSOC policy adoption. This study aimed to identify if states with higher stroke mortality rates overall and/or higher racial and ethnic disparities in stroke mortality rates were predictors of state-level enactment of SSOC policies.

Data Sources and Dataset Creation

First, using the National Environmental Public Health Tracking Network, a data explorer tool created by the CDC which compiles health data from national, state, and city sources using tracking programs, data on all United States' state-enacted SSOC policies, as operationalized and defined by recommendations from the AHA[4,6], from 2005-2018 were extracted (Appendix A). This data was then translated into a longitudinal SSOC dataset using R software, in which the data was organized by state (including all 50 states and Washington D.C.), year (from 2005-2018), and policy (all SSOC policies). The data extracted from the National Environmental Public Health Tracking Network was cleaned, so that irrelevant variables for this study, such as "Month", "Policy Effect Type", and "Policy Type", were removed. These variables were removed for simplicity, so that the authors examined only "State", "Year", and all SSOC policy variables. In event history analyses, for data collected retrospectively, durations are often measured in discrete time units, such as months or years.[1] As a result of this, the SSOC dataset is framed in a discrete-event time model. This discrete-event time model is structured so that each state is set to "0" for each year it was at risk of SSOC policy implementation and "1" for the year the state implemented an SSOC policy between the years of 2005 and 2018. Next, the SSOC dataset was merged with the CDC Wonder dataset from 2005-2018, which provides age-standardized state-level stroke mortality rates compiled from estimates made available from the National Vital Statistics System (NVSS). Stroke mortality rates were defined using ICD-10 codes I60-I69, only including individuals with stroke as the underlying cause of death. This merged dataset was then again merged with the Kaiser Family Foundation Analysis of American Community Survey (KFF-ACS) dataset from 2005-2018, which provided state-level sociodemographic characteristics. The KFF-ACS data provided state-level sociodemographic data, which were included as 'motivational covariates', or predictor variables, which consist of sex (% Female population and % Male population), age (grouped by % of population aged 19-25 years, 26-35 years, 55-64 years, and 65+ years), race/ethnicity (grouped by % of population White/non-Hispanic, Black/non-Hispanic, Hispanic, and Other), measures for stroke mortality rates (by race/ethnicity and overall) in the preceding year, and a measure of the proportion of bordering states which implemented an SSOC policy

in the preceding year, as evidence in the literature demonstrates this is a significant motivator in state policy diffusion[9,11].

Statistical Analysis

Following the creation of the dataset, a logistic regression model was developed where the outcome is the probability that a state will implement an SSOC policy given that the state did not implement an SSOC policy in the preceding years and the predicting variables are a duration dependence variable (either a year-fixed effects variable or a linear year variable) and both time-varying and time-invariant covariate variables. The functional form of the event history analysis model is defined as:

$$\log\left(\frac{p_{ti}}{1-p_{ti}}\right) = \alpha D_{ti} + \beta x_{ti}$$

Where:

- p_{ti} is the probability of an event during time t, provided that the policy was not implemented at time $t-1$.
- D_{ti} is a vector of the cumulative duration by time t with coefficient α
- x_{ti} is our array of covariates (both time-varying or constant over time) with coefficients β

Coefficient β shall be interpreted as the effect of a 1-unit change in a covariate x on the log-odds of an event in interval *t*, and the exponent of the coefficient will provide an odds ratio. The coefficient of interest is the effect of stroke mortality rates and Black/White stroke mortality rate ratios on the likelihood of SSOC policy implementation.

Results

Following data extraction from the National Environmental Public Health Tracking Network[4], creation and analysis of the dataset indicated that the most frequently policies enacted by states included laws which implemented Nationally Certified Comprehensive Stroke Centers, Nationally Certified Primary

Stroke Centers, State Agency Authorized to Designate Stroke Centers, Stroke Center Tiered Approach, and EMS Triage and Ground Transport to Most Appropriate Stroke Facility (Appendix A). Each of these SSOC policies had at least 20 states which implemented a law encompassing the respective SSOC framework (Appendix A).

State-specific maps were also generated utilizing the Centers for Disease Control and Prevention's Atlas of Heart Disease and Stroke.[12] Maps were generated to provide a visual aid of stroke mortality rates by race/ethnicity, age, sex, and year (Appendix B). These maps include stroke mortality rates for the years 2005-2007 and 2016-2018 to demonstrate the change of stroke mortality rates from the earlier years of this study's time period to the later years of this study's time period. *

After conducting the analysis, all predictor variables, or motivational covariates, were evaluated to deduce their role in motivating state-level SSOC policy diffusion. These predictors included overall stroke mortality rates, stroke mortality rates by race and ethnicity (White, non-Hispanic and Black, non-Hispanic), ratio of Black, non-Hispanic/White, non-Hispanic stroke mortality rates (comparing Black, non-Hispanic stroke mortality rates to White, non-Hispanic stroke mortality rates), sex, age, race/ethnicity, and neighboring states that implemented an SSOC policy in the previous year. **

Overall, White/non-Hispanic stroke mortality rate, Black/non-Hispanic stroke mortality rate, overall stroke mortality rates, ratio of Black, non-Hispanic/White, non-Hispanic stroke mortality rates, population sex, population age, or population race/ethnicity distribution were not associated with an increase or decrease in the odds of a state implementing SSOC policies, provided that they did not implement any such policy in the preceding years.

In measuring bordering states which implemented an SSOC policy and implementation of SSOC policy by state from 2005-2018, it was found that there is evidence to support that for each one-unit increase in

the number of neighboring states which implemented SSOC policies, when controlling for all other state demographics and stroke mortality rates, the odds of a state implementing an SSOC policy was 0.44 times 95% CI: 0.25-0.73) the odds of a state not implementing an SSOC policy, provided that the state had not implemented an SSOC policy in the preceding years.[**]

[*]Data on the CDC Atlas of Heart Disease and Stroke only included stroke mortality data starting in the year of 2005.

[**]Relevant tables and graphs that numerically and visually depict these results were unable to be downloaded due to limitations imposed by the federal government on federal agencies; and they are unfortunately unable to be shared at this time.

Discussion

An event history analysis was conducted to examine whether states with higher overall stroke mortality rates or racial/ethnic differences in stroke mortality rate based on race/ethnicity were more likely to enact SSOC policies between 2005 and 2018. The results showed no significant evidence that SSOC policies were more likely to be enacted in states with greater racial and ethnic disparities in stroke mortality rates or higher overall stroke mortality rate. Additionally, other covariates, including age and sex, were not significant predictors of SSOC policy diffusion at the state level. However, the analysis found that states were significantly more likely to enact an SSOC policy if a neighboring state had previously implemented one, provided that they had not already done so in the preceding years.

These findings demonstrate that state-level adoption of SSOC policies is not associated with racial and ethnic disparities in stroke mortality rates, despite the existing evidence surrounding racial and ethnic disparities in stroke mortality rates and care.[2,6,7] Additionally, state demographics, including sex, age, and overall stroke mortality rates, do not appear to influence states in their decision to adopt SSOC policies. This evidence may suggest that states incorporate state-level policy adoption due to other variables, such as identifying a need for improved organization for streamlining stroke care processes,

accommodating growing healthcare systems by state, or following coordinated and successful approaches to reducing a leading cause of death in the United States. The latter may be further proven by the evidence found in this study that suggests states were more likely to implement an SSOC policy given that a neighboring state had implemented an SSOC policy in a prior year. As discussed in the literature, policy adoption by neighboring states is found to be a strong predictor in policy diffusion.[9] It is a possibility that states may view their neighboring states success with SSOC policy implementation and be increasingly motivated to adopt their own SSOC policy.

Limitations of this study include its small sample size due to evaluating only the years 2005-2018 and missingness data across states. Given that the first SSOC policy was only implemented in 2005 and data on SSOC policies only currently exist on the National Environmental Public Health Tracking Network through 2018, the sample size of this data was relatively limited. It is recommended to continue this study design and re-run these analyses following additional collection and report of data that extends into the 2020s. Additionally, relevant tables and graphs were unable to be downloaded and are unable to be shared in this paper.

Conclusion

This study examined the state-level policy adoption of Stroke Systems of Care across the United States to better understand and identify predictors in policy diffusion. While this analysis demonstrated that racial and ethnic disparities in stroke mortality, overall stroke mortality rates, age, and sex by state were not significant predictors in the adoption of SSOC policies, the results showed that implementation of SSOC policies by neighboring states was a significant predictor in policy adoption. Stroke Systems of Care policies, while a relatively new framework introduced by the American Heart Association in 2003, have been demonstrated to be comprehensive, coordinated, and effective approaches to stroke care. While this study did not identify many statistically significant predictors, it is necessary to continue to understand the potential determinants of state-policy diffusion and the role racial and ethnic disparities in stroke

mortality and overall stroke mortality rates play in policy adoption, as this data continues to expand. Stroke remains a leading cause of death in the United States, and coordinated SSOC may be crucial in the management of stroke care, improving quality of life for persons affected by stroke, and reducing stroke mortality rates across the United States. As such, it is imperative to continue this research, as well as to examine updated data in an effort to better understand the characteristics of states that may influence state-level policy adoption, and in turn, expand and encourage state-level SSOC policy adoption across all 50 states.

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Appendix A.

List of Enacted SSOC Policies Extracted from the National Environmental Public Health Tracking Network

In-Hospital Policy Interventions	States Enacted (2000-2018)
Nationally Certified Acute Stroke-Ready Hospitals	Alabama, Arizona, Connecticut, Florida, Georgia, Idaho, Illinois, Kentucky, Nebraska, New Mexico, North Carolina, North Dakota, Oklahoma, Pennsylvania, South Carolina, Utah, West Virginia, Wyoming
Nationally Certified Comprehensive Stroke Centers***	Alabama, Arizona, Connecticut, Delaware, Florida, Georgia, Idaho, Illinois, Kentucky, Maryland, Minnesota, Nebraska, Nevada, New Mexico, North Carolina, North Dakota, Oklahoma, Pennsylvania, Rhode Island, South Carolina, Texas, Utah, West Virginia, Wyoming
Nationally Certified Primary Stroke Centers***	Alabama, Arizona, Connecticut, Delaware, Florida, Georgia, Idaho, Illinois, Kentucky, Maryland, Minnesota, Missouri, Nebraska, New Mexico, North Carolina, North Dakota, Oklahoma, Rhode Island, South Carolina, Texas, Utah, Virginia, Washington, West Virginia, Wyoming
State Standards for Acute Stroke-Ready Hospitals	Alabama, Florida, Idaho, Illinois, Louisiana, Minnesota, Missouri, Oklahoma
State Standards for Comprehensive Stroke Centers	Alabama, Florida, Idaho, Missouri, New Jersey
State Standards for Primary Stroke Centers	Florida, Idaho, Missouri, New Jersey, Oklahoma
State-Level Continuous Quality Improvement Registry	--
Telemedicine to Initiate Treatment On-Site	Alabama, Arizona, Georgia, Idaho, Louisiana, Massachusetts, Missouri, Nebraska, Oklahoma, South Carolina

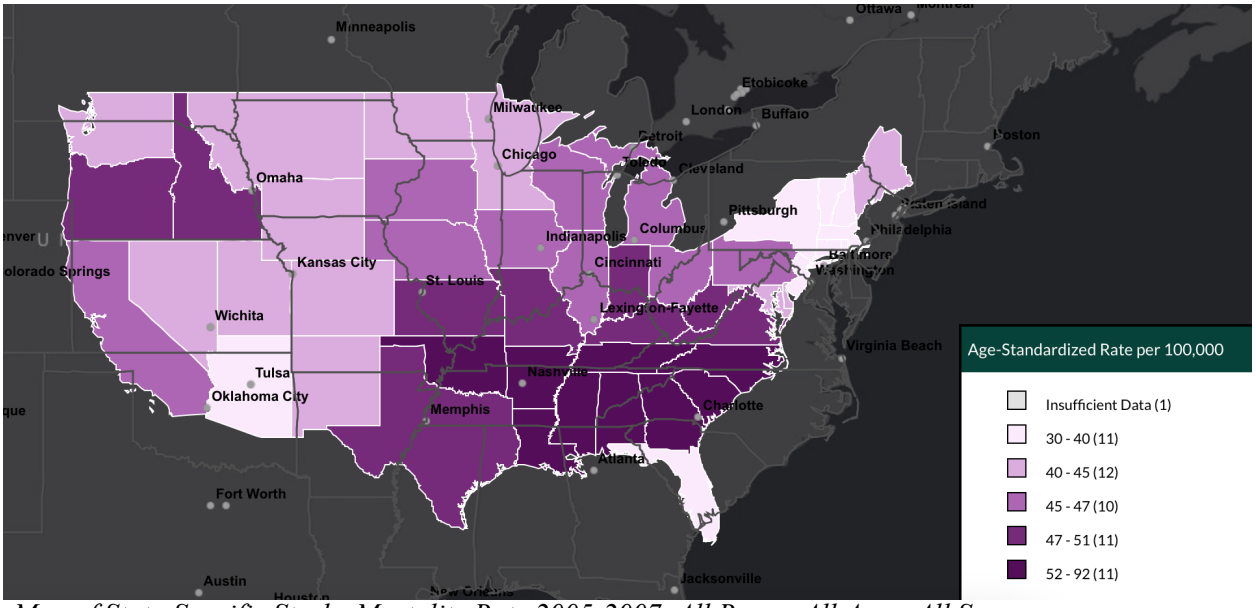
Legal Authorities and Organizational Frameworks	States Enacted (2000-2018)
State Agency Authorized to Designate Stroke Centers***	Alabama, Colorado, Connecticut, Delaware, Florida, Georgia, Idaho, Illinois, Indiana, Kentucky, Louisiana, Maryland, Massachusetts, Minnesota, Missouri, Nebraska, New Jersey, New Mexico, Nevada, North Carolina, North Dakota, Oklahoma, Pennsylvania, Rhode Island, South Carolina, Texas, West Virginia, Wyoming
State Agency Rule Making Authority	Arizona, Maryland, Missouri, West Virginia, Wyoming
Stroke Center Tiered Approach***	Alabama, Arizona, Colorado, Connecticut, Delaware, Florida, Georgia, Idaho, Illinois, Indiana, Iowa, Kentucky, Louisiana,

	Massachusetts, Maryland, Minnesota, Mississippi, Missouri, Nebraska, New Jersey, New Mexico, Nevada, North Carolina, North Dakota, Oklahoma, Oregon, Pennsylvania, Rhode Island, South Carolina, Texas, Utah, Virginia, Washington, West Virginia, Wyoming
Stroke Systems of Care Task Force	Alabama, Arkansas, Colorado, Delaware, Idaho, Mississippi, Louisiana, North Carolina, North Dakota, South Carolina, Tennessee, Texas

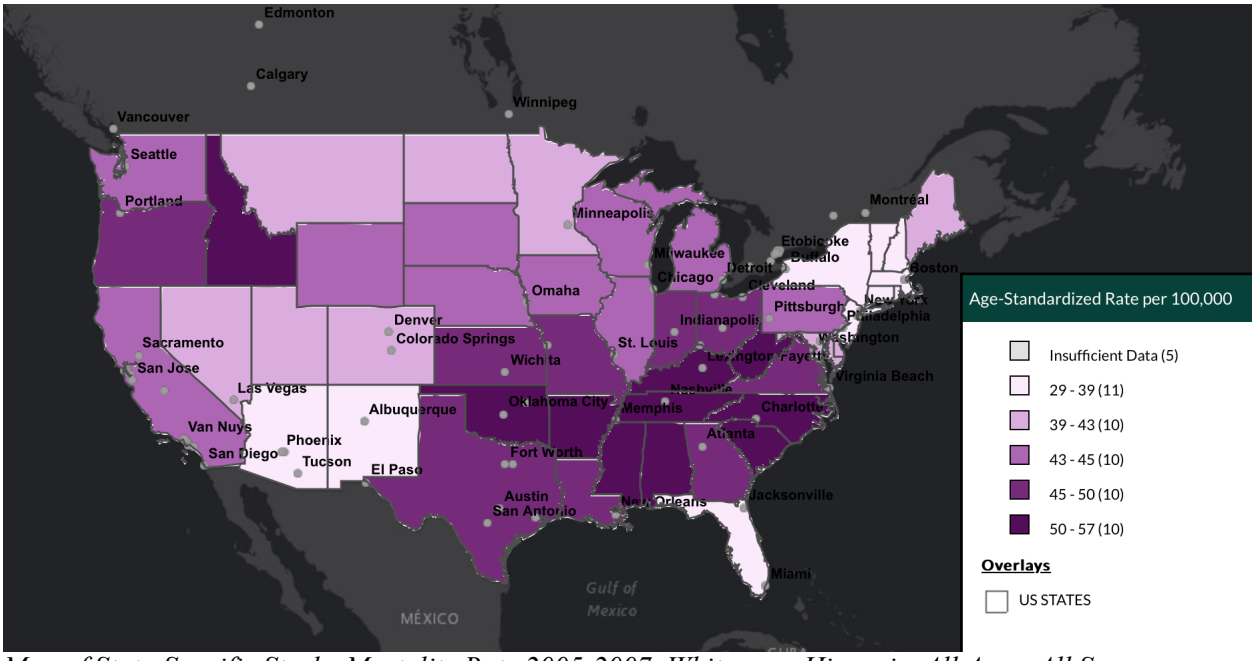
Pre-Hospital Policy Interventions	**States Enacted (2000-2018)**
Air Medical Transport to Most Appropriate Stroke Facility	Idaho, Missouri, Wyoming
EMS Provider Stroke Continuing Education	Arizona, Arkansas, Florida, Illinois, Massachusetts, Missouri, New Mexico, North Dakota, Pennsylvania, Washington
EMS Stroke Pre-Notification of Receiving Facility	Alabama, Louisiana, Massachusetts, Missouri, Nebraska, Wyoming
EMS Triage and Ground Transport to Most Appropriate Stroke Facility***	Alabama, Arizona, Connecticut, Florida, Georgia, Illinois, Indiana, Louisiana, Minnesota, Missouri, New Mexico, North Carolina, North Dakota, Pennsylvania, Rhode Island, Texas, Virginia, West Virginia, Wyoming
EMS Stroke Continuous Quality Improvement	Alabama, Arizona
Inter-Facility Transfer to Most Appropriate Stroke Facility	Florida, Georgia, Illinois, Indiana, Louisiana, Maryland, Minnesota, Missouri, Nebraska, New Jersey, North Carolina, North Dakota, Oklahoma, Rhode Island, Texas, Utah, Virginia, Wyoming
Standardized EMS Stroke Assessment Tool	Arizona, Connecticut, Illinois, Indiana, Missouri, Nebraska, North Dakota, Pennsylvania, Rhode Island, South Carolina, Virginia, Wyoming

***Denotates most frequently state-enacted policies by the year 2018.

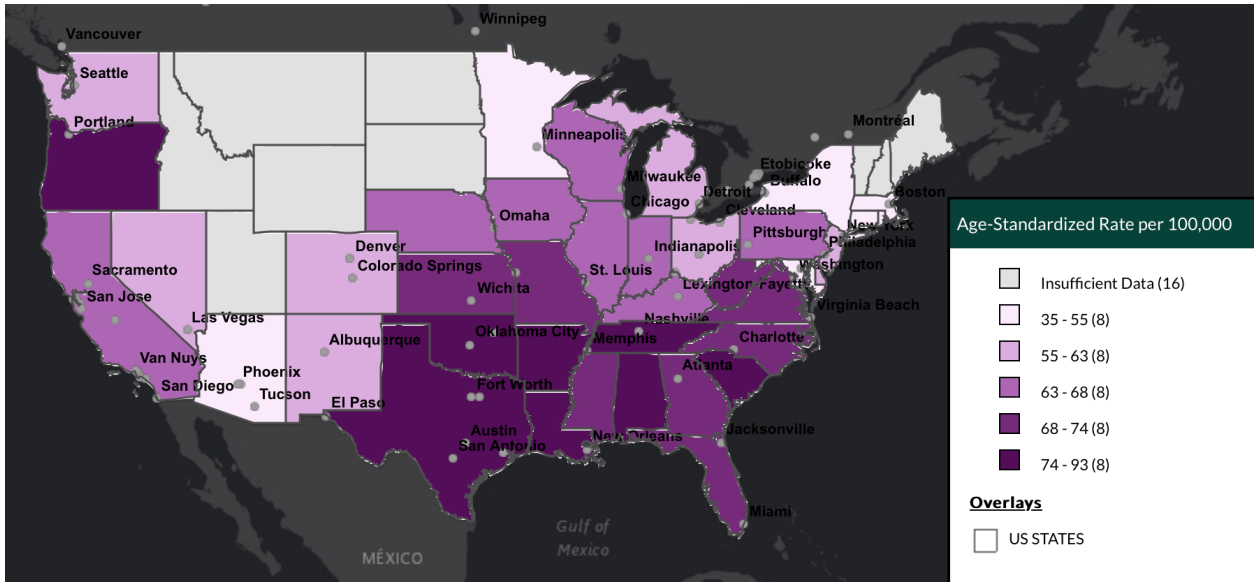
Appendix B.



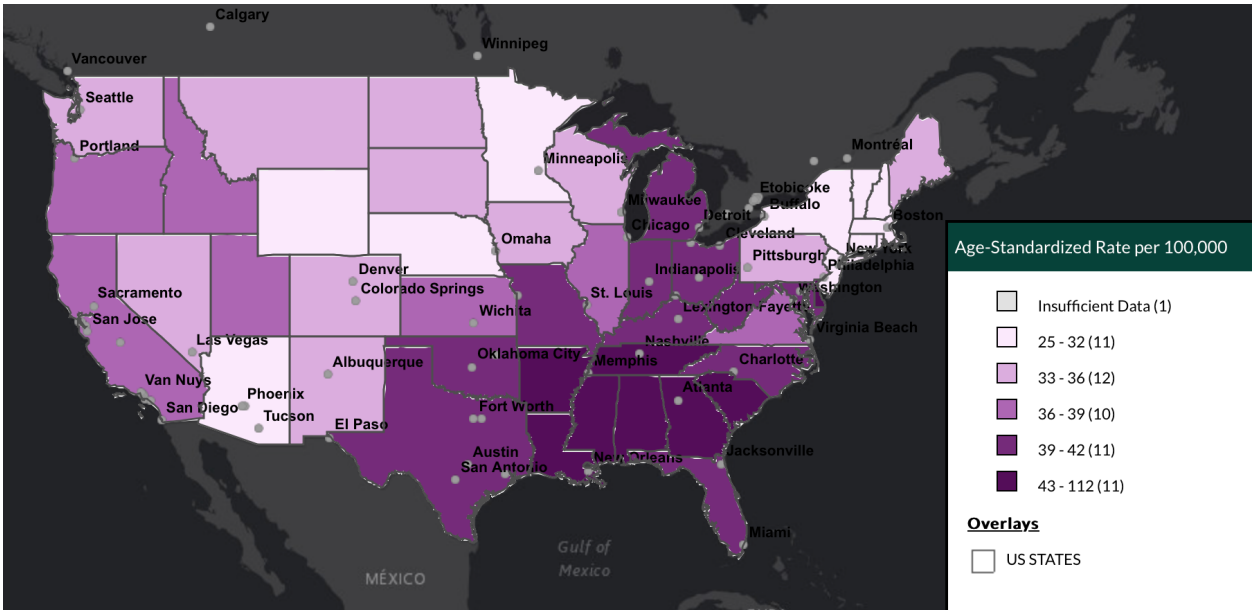
Map of State-Specific Stroke Mortality Rate 2005-2007, All Races, All Ages, All Sexes



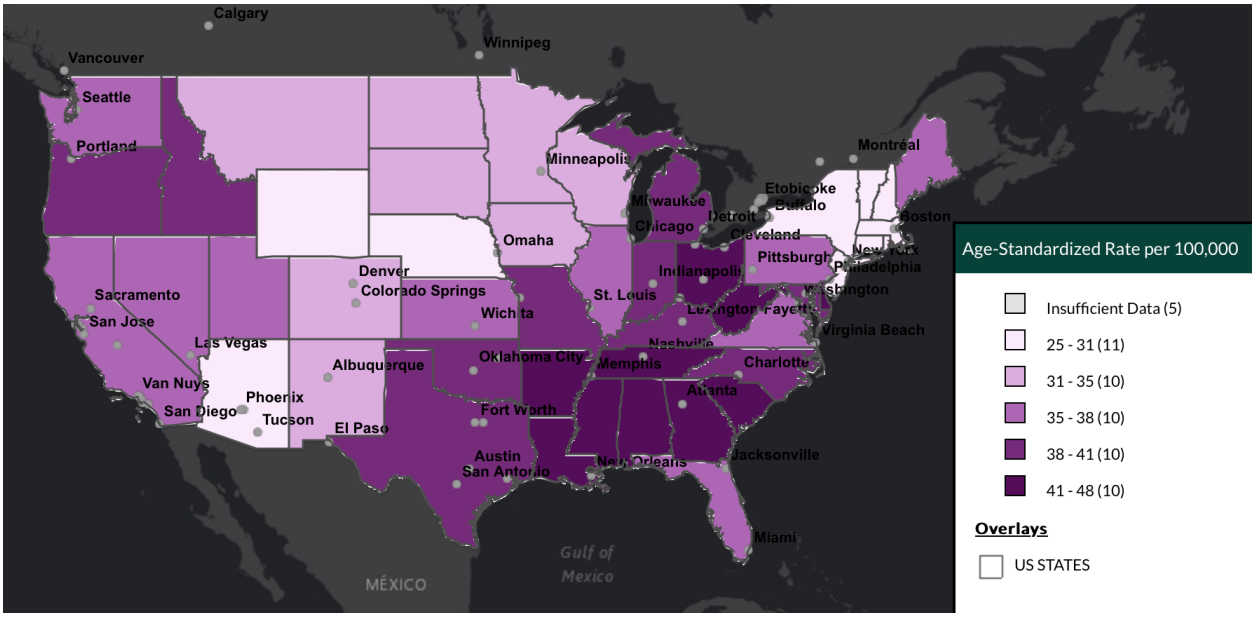
Map of State-Specific Stroke Mortality Rate 2005-2007, White, non-Hispanic, All Ages, All Sexes



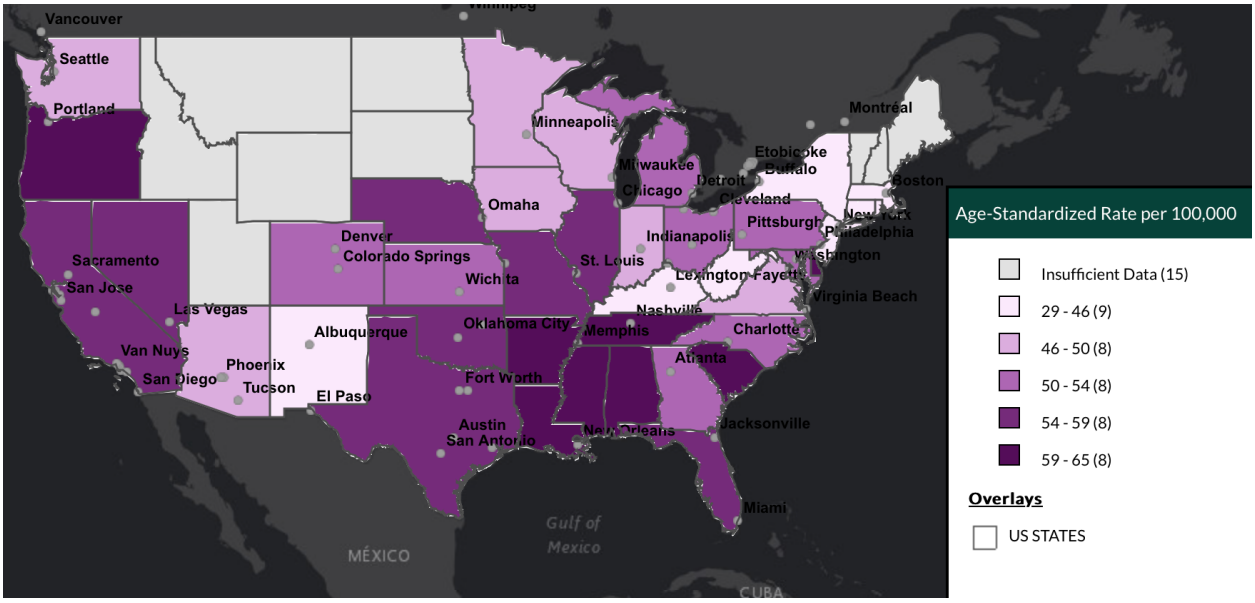
Map of State-Specific Stroke Mortality Rate 2005-2007, Black, non-Hispanic, All Ages, All Sexes



Map of State-Specific Stroke Mortality Rate 2016-2018, All Races, All Ages, All Sexes



Map of State-Specific Stroke Mortality Rate 2016-2018, White, non-Hispanic, All Ages, All Sexes



Map of State-Specific Stroke Mortality Rate 2016-2018, Black, non-Hispanic, All Ages, All Sexes