RESEARCH ARTICLE

Effects of Social Determinants of Health on Acute Stroke Care Among Patients With Acute Ischemic Stroke

A Retrospective Cohort Study

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Abstract

Background and Objectives

Social determinants of health (SDOH) are important contributors to poor stroke-related outcomes. While some have suggested that this association is driven by the increased incidence of stroke observed with poor SDOH, others have raised concerns regarding disparities in acute stroke care. This study aimed to determine the association between SDOH and the administration of thrombolytic therapy and mechanical thrombectomy among patients with acute ischemic stroke.

Methods

A retrospective cohort analysis was conducted using Texas Emergency Department Public Use Data (2016–2019), including adult patients diagnosed with acute ischemic stroke. The risk ratios (RRs) of administering thrombolysis and thrombectomy based on variables representing SDOH and a collective measure (Social Vulnerability Index [SVI]) were computed using mixed-effects Poisson regression models accounting for the nested nature of patients in hospitals and neighborhoods. The Charlson comorbidity score was considered as a covariate.

Results

Of the 139,852 patients with ischemic stroke (female, 51.7%; White, 67.2%; Black, 16.6%; Hispanic, 25.1%), 16,831 (12.3%) received thrombolytic therapy and 5,951 (4.3%) received mechanical thrombectomy. Age older than 65 years (RR 0.578 [0.537–0.621]) vs 18–45 years, Black (RR 0.801 [0.761–0.844]) vs White, Hispanic (RR 0.936 [0.895–0.98]) vs non-Hispanic, Medicare/Medicaid/Veterans Affairs (VA) (RR 0.917 [0.882–0.954]) or uninsured (RR 0.883 [0.833–0.935]) vs private insurance, and rural (RR 0.782 [0.723–0.845]) vs urban dwelling were less likely to be associated with thrombolysis. Patients in the highest quintile based on the SVI were less likely to receive thrombolysis than those in the lowest quintile (RR 0.926 [0.867–0.989]). Patients were less likely to receive thrombectomy if they were 65 years and older (RR 0.787 [0.691–0.895]), belonged to the Black race (RR 0.745 [0.679–0.818]) or Hispanic ethnicity (RR 0.919 [0.851–0.992]), had Medicare/Medicaid/VA insurance (RR 0.909 [0.851–0.971]), or were from a rural area (RR 0.909 [0.851–0.971]). Similarly, SVI decreased the likelihood of undergoing mechanical thrombectomy (RR 0.842 [0.747–0.95]).

Discussion

Despite many improvements in stroke management, SDOH continue to be a significant driver of treatment access for acute ischemic stroke. While our findings are limited to Texas, our results should raise awareness and promote more studies regarding the effects of these SDOH at the national and international levels.

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Glossary

CCS = Charlson comorbidity score; **CDC** = Centers for Disease Control and Prevention; ***ICD-10*** = *International Classification of Diseases, Tenth Revision*; **RR** = risk ratio; **SDOH** = social determinants of health; **SVI** = Social Vulnerability Index; **VA** = Veterans Affairs.

Introduction

Globally, stroke remains the second-leading cause of death and the third-leading cause of death and disability combined. In the Global Burden of Disease Study, ischemic strokes constituted a majority of 62.4% of all incident strokes, with a total of 7.63 million cases worldwide.[1] Furthermore, the incidence and disability associated with stroke are projected to increase in countries with low socioeconomic status within the next decade because sociodemographic factors have a substantial role in stroke prevention and management.[2] Effective acute stroke management is paramount to minimize neurologic damage and optimize patient outcomes. Recent advancements in acute stroke care, such as the widespread implementation of thrombolytic therapy and endovascular interventions, have significantly improved the prognosis of patients presenting with ischemic stroke, especially in the United States. However, roughly 795,000 individuals experience a stroke, of which 77% are new onset and 87% are of ischemic etiology, making stroke the fifth leading cause of death in the United States.[3]

The social determinants of health (SDOH), which encompass a complex array of conditions in which individuals are born, grow, live, work, and age, exert a profound influence on the health outcomes and well-being of individuals and communities. These determinants, including socioeconomic status, educational attainment, housing conditions, health care access, and social support networks, contribute significantly to the persistent health inequities observed across diverse populations. Stroke exhibits profound racial and ethnic inequities in its incidence, prevalence, treatment, and outcomes.[4] While some studies have suggested that this association is driven by the increased incidence of stroke observed with poor SDOH, others have highlighted the disparities in stroke care, which can arise because of social determinants affecting access to services,[5] acute care,[6-9] the transition of care,[10] rehabilitation, long-term functional recovery,[11] and secondary prevention.[6-8,12] Many studies have shown that SDOH could play a crucial role in shaping the acute management of stroke. Therefore, proper screening tools to detect SODH in neurologic populations need to be identified and validated.[13]

The Social Vulnerability Index (SVI) developed by the Centers for Disease Control and Prevention (CDC) is becoming increasingly popular as a tool to measure SDOH within the field of population health.[14] This index calculates a social vulnerability score for counties and census tracts, taking into account various determinants such as socioeconomic status, household composition, disability, minority status, language barriers, housing conditions, and transportation accessibility. SVI has been used as an indicator of SDOH in the context of various public health outcomes, including cardiovascular health and cancer care.[15,16] Recognizing differences in access to thrombolytic therapy or mechanical thrombectomy is crucial for identifying potential interventions to ensure that all patients have fair and equal access to acute stroke care. Many studies have been published indicating severe degrees of socioeconomic disparities related to acute stroke care at the national and international levels.[6,7,9,17-19] It could be expected that patients who visit the same hospital and reside in the same neighborhood may have a similar likelihood of receiving care, which is called the clustering effect or the nested nature of data. While the importance of considering the nested nature of data has been well known and widely accepted, many studies have often overlooked this aspect and have not considered the nested nature of the analyses.[20] This study seeks to investigate the relationship between SDOH, including SVI, and the receipt of thrombolytic therapy or mechanical thrombectomy, specifically in the state of Texas, accounting for the nested nature of the data, while attempting to assess the utility of SVI as a measure. We hypothesized that disparities captured regarding acute stroke care therapy would be similarly captured using SVI.

Methods

Study Population

This study represents a retrospective review of the Texas Hospital Emergency Department Public Use Data Files from 2016 to 2019.[21] Patients who had a diagnosis of acute ischemic stroke were identified based on the *International Classification of Diseases, Tenth Revision* (*ICD-10*) Clinical Modification codes (I63.0, I63.1, I63.2, I63.3, I63.4, I63.5, I63.6, I63.8, I63.9, and all subgroups). Patients younger than 18 years of age were excluded. Receipt of thrombolytic therapy and mechanical thrombectomy was identified for each patient based on the *ICD-10* Procedure Coding System (eTable 1).

Standard Protocol Approvals, Registrations, and Patient Consents

Because the database used in this study is publicly available and contains deidentified data, IRB approval was deemed exempt and the requirement for informed patient consent was waived.

Covariables

Patient demographics (i.e., age, sex, race, and ethnicity), Charlson comorbidity score (CCS), comorbidities (diabetes, hypertension, hyperlipidemia, and obesity), smoking status, insurance status, urban/rural status, and SVI were assessed. Race, ethnicity, and sex were self-reported data recorded at the date of admission or the start of care. Rural-Urban Continuum Codes of 2023 were used to stratify counties as urban (i.e., codes 1–3) and rural (i.e., codes 4–9).[22] CCS was calculated for each patient to use as a covariate in the analyses using the weights outlined previously based on comorbidities identified using *ICD-10* Clinical Modification codes (eTable 2).[23]

The overall SVI is the average of subscale scores for each of the following subthemes: socioeconomic status, household characteristics, racial and ethnic minority status, housing type, and transportation. The most recent SVI report from 2020 for the census tract level, which is available from the CDC and Agency for Toxic Substances and Disease Registry,[24] was accessed for this analysis. SVI was then matched to the study population at the zip code level. Because zip codes and census tracts do not align, we pulled data based on Zip Code Tabulation Areas created by the US Census Bureau that show the representation of census tract levels within each zip code. We then calculated a mean weighted SVI for each zip code by combining the SVI from each representing the census tract when we built our models.[25,26] SVI is a continuous scale ranging from 0 to 1, with higher values indicating greater vulnerability.

Statistical Analysis

All statistical analyses were conducted using R statistical software (R version 4.3.1).

The differences in baseline patient characteristics were examined using independent-sample *t* tests with the Welch-Satterthwaite correction based on whether the patient received thrombolytic therapy or mechanical thrombectomy. The normality of the distributions for continuous variables was determined using quantile-quantile plots. If the assumption of normality was not met, Wilcoxon rank-sum tests were used for comparison. Chi-square tests were used, followed by pairwise chi-square tests of proportions when multiple groups were present for categorical variables. Patient vulnerability profiles were ranked according to the overall SVI. Patients were stratified based on SVI quintiles into 5 groups, with the lowest quintile (quintile 1) designated as the lowest vulnerable group and the highest (quintile 5) as the highly vulnerable group. Owing to the nested nature of providers within zip codes or counties, the necessity of using a mixed model for the analysis was examined by computing the intraclass correlation coefficient and model performance was assessed using the Akaike information criterion. Risk ratios (RRs) of receiving thrombolytic therapy and mechanical thrombectomy were calculated for high vulnerability groups, with the lowest vulnerability group as the reference, using mixed-effects Poisson regression models computed using the lme4 package (version 1.1-34) in R, which allowed computation of RRs of receiving thrombolysis or thrombectomy. Random intercepts were computed for provider facilities (i.e., hospitals) nested within zip codes for all the models except for those using the urban-rural status as a variable because the urban-rural status was based on the county level. When urban-rural status was considered as a variable in the model, providers nested within counties were used as random effects. Subgroup sensitivity analyses were performed for patients who received thrombolytic therapy by eliminating mechanical thrombectomy in the control group and vice versa.

Spearman rank correlation and variance inflation factors were used to assess collinearity and multicollinearity. Adjusted RRs were calculated for traditional racial, socioeconomic, and geographic factors using multivariate Poisson regression models adjusted for age, sex, race, ethnicity, insurance status, CCS, and urban/rural status. Adjusted RRs were calculated for SVI quintiles after adjusting for age, sex, race, ethnicity, insurance status, and CCS. Another set of adjusted models was constructed using individual comorbidities (i.e., diabetes, hypertension, hyperlipidemia, and obesity) instead of CCS as a sensitivity analysis. In all the analyses, missing variables in the database were considered missing at random. The familywise error rate was set at 0.05, using the Holm-Bonferroni approach.

Hierarchical mediation analyses were performed to detect whether the hospital-level thrombolysis rate (i.e., number of patients receiving thrombolysis/total number of patients with acute ischemic stroke) and thrombectomy rate (i.e., number to thrombectomy/total number of patients with acute ischemic stroke) mediated the association between patient-level factors and acute ischemic stroke care (effect c, i.e., receipt of thrombolytic therapy or mechanical thrombectomy). These analyses tested the effect of patient-level factors on the mediator (effect a) and the effect of the mediator on receipt of thrombolytic therapy or mechanical thrombectomy (effect b). Then, the direct effect (effect c′, i.e., presumably unconfounded effect of patient-level factors on thrombolytic therapy or mechanical thrombectomy receipt) and the indirect effect (effect ab, i.e., the effect of the abovementioned association mediated through the hospital thrombolysis rate or thrombectomy rate), were calculated. Hierarchical mediation models were created considering the nested nature of the patients in the zip/county levels. The direct and indirect effects of thrombolytic therapy or mechanical thrombectomy were examined using the Sobel method.[27]

Results

Patient Characteristics and Receipt of Thrombolytic Therapy and Mechanical Thrombectomy

Of 139,852 patients with ischemic stroke, 12.3% received thrombolytic therapy and 4.3% received mechanical

Table 1 Demographics of the Whole Cohort

	Overall (n = 139,852)	Received thrombolytic therapy (n = 16,831)	Did not receive thrombolytic therapy (n = 119,774)	*p* Value	Received mechanical thrombectomy (n = 5,951)	Did not receive mechanical thrombectomy (n = 133,901)	*p* Value
Age, y				<0.001			<0.001
18–45	7,269 (5.2)	1,273 (18.1)	5,771 (81.9)		430 (5.9)	6,839 (94.1)	
45–64	46,759 (33.4)	6,081 (13.3)	39,525 (86.7)		1,940 (4.1)	44,819 (95.9)	
>65	85,820 (61.4)	9,476 (11.3)	74,475 (88.7)		3,580 (4.2)	82,240 (95.8)	
Sex				0.222			0.130
Female	66,340 (51.7)	7,934 (12.2)	56,942 (87.8)		2,736 (4.1)	63,604 (95.9)	
Male	61,996 (48.3)	7,533 (12.5)	52,934 (87.5)		2,663 (4.3)	59,333 (95.7)	
Race				<0.001			<0.001
Black patients	23,152 (16.6)	2,559 (11.2)	20,211 (88.8)		784 (3.4)	22,368 (96.6)	
Other races[a]	22,756 (16.3)	2,902 (13.1)	19,221 (86.9)		1,228 (5.4)	21,528 (94.6)	
White patients	93,928 (67.2)	11,369 (12.4)	80,327 (87.6)		3,939 (4.2)	89,989 (95.8)	
Ethnicity				0.414			0.065
Hispanic patients	35,056 (25.1)	4,275 (12.5)	30,055 (87.5)		1,553 (4.4)	33,503 (95.6)	
Non-Hispanic patients	104,559 (74.9)	12,534 (12.3)	89,507 (87.7)		4,390 (4.2)	100,169 (95.8)	
Insurance status				<0.001			<0.001
Private insurance	46,830 (35.1)	6,058 (13.3)	39,633 (86.7)		2,089 (4.5)	44,741 (95.5)	
Medicare/Medicaid/ Veterans Affairs	68,795 (51.6)	7,619 (11.3)	59,671 (88.7)		2,738 (4)	66,057 (96)	
No insurance	17,773 (13.3)	2,147 (12.4)	15,199 (87.6)		808 (4.5)	16,965 (95.5)	
Charlson comorbidity score				<0.001			<0.001
0	29,376 (21.0)	2,321 (8)	26,668 (92)		389 (1.3)	28,987 (98.7)	
>1	110,476 (79.0)	14,510 (13.5)	93,106 (86.5)		5,562 (5)	104,914 (95)	
Hypertension				<0.001			<0.001
No	16,634 (11.9)	2,358 (14.6)	13,775 (85.4)		873 (5.2)	15,761 (94.8)	
Yes	123,218 (88.1)	14,473 (12)	105,999 (88)		5,078 (4.1)	118,140 (95.9)	
Hyperlipidemia				0.942			<0.001
No	52,058 (37.2)	6,246 (12.3)	44,559 (87.7)		2,477 (4.8)	49,581 (95.2)	
Yes	87,794 (62.8)	10,585 (12.3)	75,215 (87.7)		3,474 (4)	84,320 (96)	
Diabetes				<0.001			<0.001
No	112,225 (80.2)	13,698 (12.5)	95,818 (87.5)		4,975 (4.4)	107,250 (95.6)	
Yes	27,627 (19.8)	3,133 (11.6)	23,956 (88.4)		976 (3.5)	26,651 (96.5)	
Smoking				0.647			<0.001
No	87,793 (62.8)	10,549 (12.3)	75,292 (87.7)		3,950 (4.5)	83,843 (95.5)	
Yes	52,059 (37.2)	6,282 (12.4)	44,482 (87.6)		2,001 (3.8)	50,058 (96.2)	
BMI ≥30 kg/m²				<0.001			0.004
No	118,901 (85.0)	13,869 (11.9)	102,272 (88.1)		4,981 (4.2)	113,920 (95.8)	

Continued

Table 1 Demographics of the Whole Cohort *(continued)*

	Overall (n = 139,852)	Received thrombolytic therapy (n = 16,831)	Did not receive thrombolytic therapy (n = 119,774)	*p* Value	Received mechanical thrombectomy (n = 5,951)	Did not receive mechanical thrombectomy (n = 133,901)	*p* Value
Yes	20,951 (15.0)	2,962 (14.5)	17,502 (85.5)		970 (4.6)	19,981 (95.4)	
Urban-rural status				<0.001			0.033
Rural	16,420 (12.2)	1,368 (8.8)	14,206 (91.2)		640 (3.9)	15,780 (96.1)	
Urban	117,756 (87.8)	14,743 (12.8)	100,883 (87.2)		5,014 (4.3)	112,742 (95.7)	

[a] Other races include races coded as American Indian/Eskimo/Aleut, Asian or Pacific Islander, and other in the database.

thrombectomy (Table 1). The overall cohort comprised predominantly women (51.7%), White patients (67.2%), non-Hispanic patients (74.9%), and patients older than 65 years (61.4%). Most of the patients had Medicare/Medicaid/Veterans Affairs (VA) insurance (51.6%), followed by private insurance (35.1%) and no insurance (13.3%). Most patients were from urban counties (87.8%) with a mean SVI of 0.552 ± 0.222.

RRs of Receiving Thrombolytic Therapy

According to mixed-effects Poisson regression models, patients who were older than 45 years, of Black race or Hispanic ethnicity, insured by Medicare/Medicaid/VA, uninsured, or from rural areas were less likely to receive thrombolytic therapy (Figure 1A; Table 2). It is important to note that when compared with patients who were younger than 45 years, patients who were older than 65 years were 42% less likely to receive thrombolytic therapy (RR 0.578 [0.537–0.621]). Similarly, Black patients and Hispanic patients were 20% (RR 0.801 [0.761–0.844]) and 6% (RR 0.936 [0.895–0.98]) less likely to receive thrombolytic therapy, respectively. Moreover, the patients living in a rural setting compared to an urban setting had a lower likelihood of receiving thrombolysis (RR 0.782 [0.723–0.845]). Similarly, patients covered by government-funded insurance such as Medicare/Medicaid/VA or without insurance compared with private insurance had lower likelihoods of receiving thrombolysis (RR 0.917 [0.882–0.954] and RR 0.883 [0.833–0.935], respectively) .

Patients in the highest quintile based on SVI (i.e., quintile 5), who were most vulnerable, were 7% less likely to receive thrombolytic therapy (RR 0.926 [0.867–0.989]) compared with the lowest quintile group (i.e., quintile 1), who were least vulnerable (Figure 1C; Table 3). When subgroup sensitivity analysis was performed after removing the patients who received mechanical thrombectomy from the whole cohort, the result remained significant (RR 0.914 [0.852–0.981]). Similar results were obtained when adjusted models were constructed using individual comorbidities along with other individual variables as a sensitivity analysis (eTables 3 and 4 and eFigure 1).

RRs of Receiving Mechanical Thrombectomy

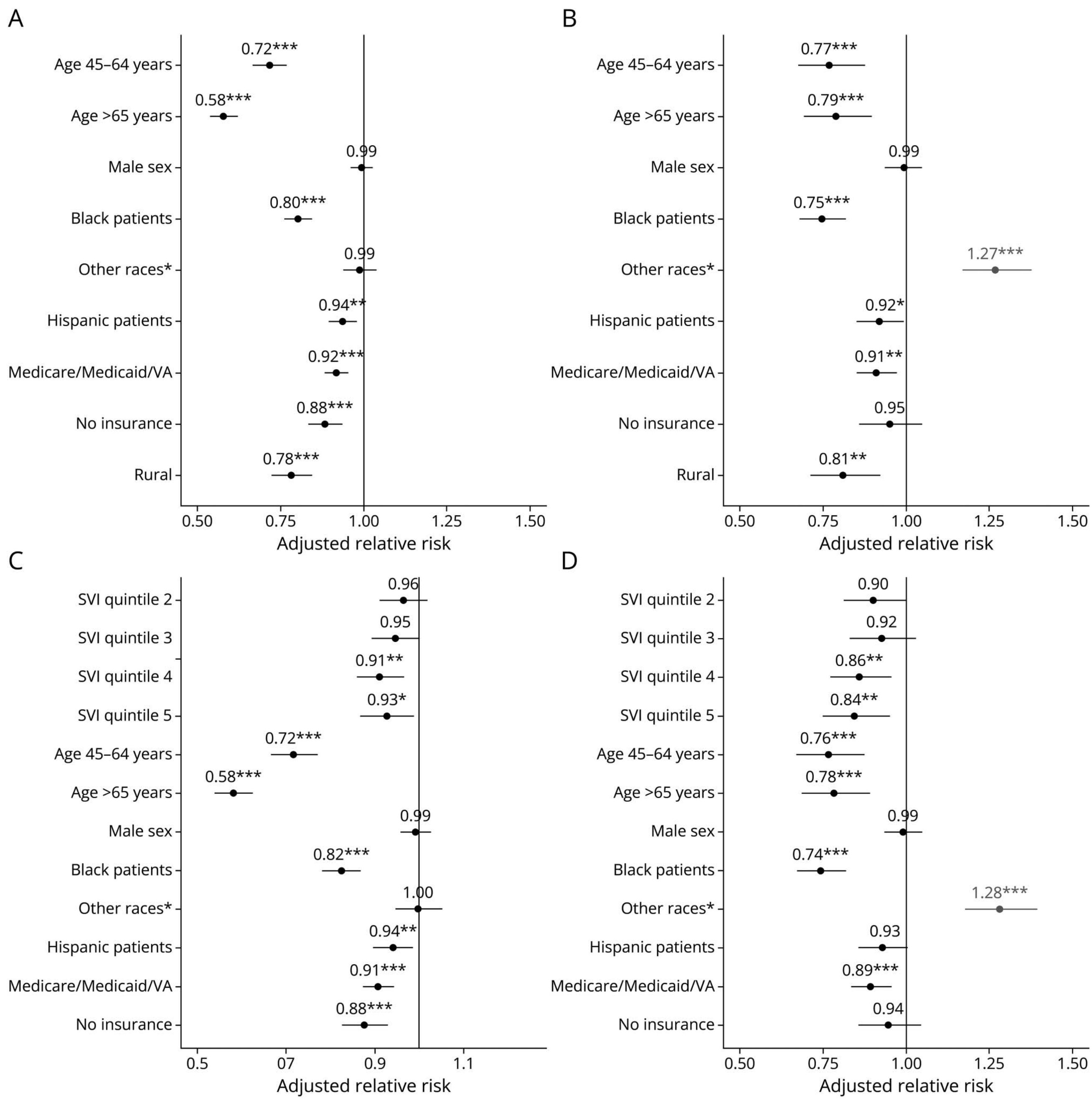
Patients who were older than 45 years, were of Black race or Hispanic ethnicity, had either Medicare/Medicaid/VA, and were living in rural areas were less likely to receive mechanical thrombectomy (Figure 1B; Table 4). Specifically, a patient with an ischemic stroke who was older than 65 years was 21% less likely to receive mechanical thrombectomy on average (RR 0.787 [0.691–0.895]). The likelihood of receiving mechanical thrombectomy was 25% less for Black patients (RR 0.745 [0.679–0.818]) and 8% less for Hispanic patients (RR 0.919 [0.851–0.992]). Moreover, a lower likelihood of receiving mechanical thrombectomy was reported if the patients were covered by government-funded insurance (RR 0.909 [0.851–0.971]) compared with private insurance. The likelihood of receiving mechanical thrombectomy was significantly different between patients from rural and urban areas (RR 0.809 [0.711–0.922]).

Considering SVI, a significant difference was observed between the highest quintile (i.e., quintile 5) and the lowest quintile group (i.e., quintile 1) (RR 0.842 [0.747–0.95], Figure 1D; Table 5). When a subgroup sensitivity analysis was performed after removing the patients who received thrombolytic therapy from the whole cohort, the group with the highest vulnerability was 25% less likely to receive thrombectomy (RR 0.751 [0.641–0.88]) compared with the group with the least vulnerability. The results of the sensitivity analyses adjusting for individual comorbidities, along with other individual variables, are shown in the Supplement (eTables 3 and 4 and eFigure 1). Controlling for individual comorbidities showed that patients who either were 45–65 years old, belonged to the Black race, or were from rural areas were less likely to receive thrombolytic therapy. Age older than 65 years, insurance status, and ethnicity did not change the RR of receiving mechanical thrombectomy when controlled for individual comorbidities such as diabetes, hypertension, hyperlipidemia, and obesity.

Mediation Analyses

The hierarchical mediation analyses (eTable 5) that examined the mediation of the associations between SDOH and receiving

Figure 1 Adjusted Risk Ratios for Receiving Acute Stroke Treatments (Thrombolytic Therapy or Mechanical Thrombectomy)



(A) Model with conventional variables for thrombolytic therapy. (B) Model with conventional variables for mechanical thrombectomy. (C) Model with SVI with different quintiles for thrombolytic therapy. (D) Model with SVI with different quintiles for mechanical thrombectomy. Quintile 1 is the least vulnerable group, which is the reference category, and quintile 5 is the most vulnerable group. Models A and B were adjusted for age, sex, race, ethnicity, insurance status, CCS, and urban/rural status. Models C and D were adjusted for age, sex, race, ethnicity, insurance status, and CCS. Because CCS was used as a covariate for all the models, it is not displayed. CCS = Charlson comorbidity score; SVI = Social Vulnerability Index; VA = Veterans Affairs.

thrombolysis by the hospital-level thrombolysis rate revealed significant indirect negative effects for the observed associations of age, rural vs urban status, non-Black vs White race, and having government-sponsored insurance or no insurance vs private insurance with thrombolysis, suggesting that having access to a hospital with a high rate of thrombolysis seems to contribute to the decreased likelihood of receiving thrombolytic therapy in the presence of these SDOH risk factors. For instance, the indirect effect of urban-rural status on receipt of thrombolytic therapy through the hospital thrombolysis rate was significant ($\beta = -0.144$ [-0.216 to -0.073], $p < 0.001$). This indirect effect accounted for approximately 57% of the total effect, suggesting that of approximately 22% of lower thrombolysis rates observed among rural-dwelling patients, 12.5% (i.e., 57% of the 22%) was contributed by accessing a center with a higher rate of thrombolysis. Of interest, the

Table 2 RRs of Receiving Thrombolytic Therapy According to the Traditional Racial, Socioeconomic, and Geographic Factors

	Unadjusted model	*p* Value	Adjusted model[a]	*p* Value
18–45 y	Ref	Ref	Ref	Ref
45–64 y	0.762 (0.718–0.809)	<0.001	0.715 (0.666–0.768)	<0.001
>65 y	0.64 (0.604–0.679)	<0.001	0.578 (0.537–0.621)	<0.001
Female sex	Ref	Ref	Ref	
Male sex	1.013 (0.982–1.046)	0.409	0.993 (0.96–1.027)	0.674
White patients	Ref	Ref		Ref
Black patients	0.877 (0.838–0.918)	<0.001	0.801 (0.761–0.844)	<0.001
Other races[b]	0.991 (0.947–1.038)	0.705	0.987 (0.938–1.039)	0.622
Non-Hispanic patients	Ref	Ref	Ref	Ref
Hispanic patients	0.975 (0.937–1.015)	0.217	0.936 (0.895–0.98)	0.004
Private insurance	Ref	Ref		Ref
Medicare/Medicaid	0.868 (0.838–0.899)	<0.001	0.917 (0.882–0.954)	<0.001
No insurance	0.958 (0.911–1.008)	0.097	0.883 (0.833–0.935)	<0.001
CCS 0	Ref	Ref	Ref	Ref
CCS ≥1	1.578 (1.51–1.649)	<0.001	1.637 (1.559–1.719)	<0.001
Urban	Ref	Ref	Ref	Ref
Rural	0.776 (0.72–0.836)	<0.001	0.782 (0.723–0.845)	<0.001

Abbreviation: CCS = Charlson comorbidity score.
[a] Adjusted model included all variables listed in this table. Random effects for univariate models were considered for providers nested at zip code levels, except for urban-rural status. Random effects were considered for providers nested at the county level in the adjusted model.
[b] Other races include races coded as American Indian/Eskimo/Aleut, Asian or Pacific Islander, and other in the database.

hospital-level thrombolysis rate did not significantly mediate the association between the Black race and the likelihood of receiving thrombolysis compared with the White race. The hierarchical mediation analysis performed for the associations between SDOH and mechanical thrombectomy revealed significant mediation by the hospital-level thrombectomy rates of the observed associations of age or having government-sponsored insurance vs private insurance with the likelihood of receiving thrombectomy. These findings suggested that for older patients and patients with government-sponsored insurance, accessing a center with a higher thrombectomy rate will only decrease the likelihood of receiving thrombectomy. Hospital-level thrombectomy rates did not mediate the effects of urban-rural status or Black race on thrombolysis.

Discussion

Over more than a decade, several population-based studies around the world have stated that SODH determine overall stroke care management.[18,28] However, despite recent advancements and the broader availability of high-quality stroke care, low socioeconomic status continues to adversely predict acute stroke outcomes.[5-8,29-31] According to our study performed using the Texas emergency database, age, race, ethnicity, insurance status, and geographic location continue to determine the quality of acute stroke care. We have also established that SVI is a valid single measure to show these differences. Of interest, our study showed a dissociation between the disparities seen with thrombolytic therapy compared with mechanical thrombectomy in an acute stroke setting, indicating that biases may mainly exist in the presence of only mild-to-moderate disease states vs severe large vessel occlusions. A possible explanation is that vulnerable patients struggle to access thrombolysis within its narrow treatment window (i.e., 4.5 hours), whereas they can reach the 24-hour window for thrombectomy, allowing them to be eligible for surgical intervention.

Our study showed that older patients tended to receive less thrombolytic therapy and mechanical thrombectomy, which corroborates the findings of earlier studies. Many previous studies have shown worse overall outcomes and mortality after thrombolytic therapy in older (>80 years) patients.[32-34] Furthermore, many trials have not included the older population; therefore, there is a concern regarding the usage of thrombolytic therapy in older populations.[32] One notable

Table 3 RRs of Receiving Thrombolytic Therapy According to the Social Vulnerability Index

	RR for low vulnerability	Adjusted model[a]	Subgroup analysis on patients who received thrombolytic therapy only[b]
Quintile 1	Ref	Ref	Ref
Quintile 2	0.967 (0.916–1.021)	0.964 (0.911–1.019)	0.963 (0.907–1.023)
Quintile 3	0.937 (0.886–0.99)	0.945 (0.893–1.001)	0.921 (0.866–0.98)
Quintile 4	0.899 (0.85–0.951)	0.91 (0.859–0.965)	0.892 (0.838–0.951)
Quintile 5	0.907 (0.852–0.966)	0.926 (0.867–0.989)	0.914 (0.852–0.981)
18–45 y		Ref	Ref
45–64 y		0.717 (0.667–0.771)	0.711 (0.658–0.769)
>65 y		0.58 (0.539–0.624)	0.554 (0.512–0.6)
Female sex		Ref	Ref
Male sex		0.991 (0.958–1.025)	0.984 (0.948–1.02)
White patients		Ref	Ref
Black patients		0.824 (0.781–0.869)	0.834 (0.788–0.883)
Other races[c]		0.997 (0.946–1.051)	0.975 (0.921–1.032)
Non-Hispanic patients		Ref	Ref
Hispanic patients		0.94 (0.898–0.985)	0.939 (0.894–0.988)
Private insurance		Ref	Ref
Medicare/Medicaid		0.908 (0.873–0.944)	0.91 (0.872–0.949)
No insurance		0.876 (0.826–0.93)	0.857 (0.804–0.914)
CCS 0		Ref	Ref
CCS ≥1		1.636 (1.557–1.719)	1.572 (1.493–1.656)

Abbreviations: CCS = Charlson comorbidity score; RR = risk ratio.
[a] Adjusted for all the variables listed in the table; random effects were considered for providers nested at zip code levels.
[b] Patients who received mechanical thrombectomy were removed.
[c] Other races include races coded as American Indian/Eskimo/Aleut, Asian or Pacific Islander, and other in the database.

exception is the third international stroke trial, which showed an even greater benefit of thrombolytic therapy in older patients.[35] Nevertheless, a meta-analysis conducted on the usage of alteplase showed that age has little bearing on the overall outcome.[36] In our study, we have shown that as age progresses, the RR of receiving acute stroke therapy is low. Therefore, necessary steps should be taken to eliminate bias related to age. Similarly, mechanical thrombectomy was found to be beneficial even in older patients,[33,34] and as a result, the implementation of mechanical thrombectomy has increased over the years.[37] Nevertheless, other sociodemographic factors related to old age could act as mediators or moderators in decreasing the RRs of receiving thrombolytic and mechanical thrombectomy—for instance, underlying comorbidities, delays in presentation, and insurance states.[38] By developing an adjusted model, we tried to control the influence of some of the variables. For instance, we have seen some confounding effects of comorbidities on receiving mechanical thrombectomy in our sensitivity analysis. However, we did not further explore the influence of comorbidities on acute stroke care because there were limitations related to missing and underreporting of comorbidities in this administrative database. Furthermore, there may still be many confounding variables that cannot be taken into account because of the limitations of the data set.

In contrast to earlier studies,[6,8] we have not seen any sex-related bias in this cohort after considering the nested nature of the data into account. This result could be due to increased awareness and progressive narrowing of the gap between the utilization of thrombolysis and thrombectomy in men and women. A previous study clearly pointed out this notion, stating that gender differences were minimal in the National Inpatient Sample regarding receiving thrombolysis and endovascular thrombectomy.[9]

A study conducted using the Get With The Guidelines registry found that roughly 25% of patients who presented within 4.5

Table 4 RRs of Receiving Mechanical Thrombectomy According to the Traditional Racial, Socioeconomic, and Geographic Factors

	Unadjusted model	*p* Value	Adjusted model[a]	*p* Value
18–45 y	Ref	Ref		Ref
45–64 y	0.767 (0.691–0.853)	<0.001	0.768 (0.675–0.874)	<0.001
>65 y	0.803 (0.726–0.889)	<0.001	0.787 (0.691–0.895)	<0.001
Female sex	Ref	Ref	Ref	
Male sex	0.991 (0.939–1.046)	0.752	0.989 (0.934–1.047)	0.700
White patients	Ref	Ref		Ref
Black patients	0.778 (0.716–0.845)	<0.001	0.745 (0.679–0.818)	<0.001
Other races[b]	1.217 (1.131–1.309)	<0.001	1.269 (1.168–1.377)	<0.001
Non-Hispanic patients	Ref	Ref	Ref	Ref
Hispanic patients	0.982 (0.918–1.051)	0.596	0.919 (0.851–0.992)	0.030
Private insurance	Ref	Ref		Ref
Medicare/Medicaid	0.916 (0.863–0.972)	<0.001	0.909 (0.851–0.971)	0.005
No insurance	0.922 (0.847–1.004)	0.061	0.949 (0.859–1.048)	0.298
0 CCS	Ref	Ref	Ref	Ref
≥1 CCS	3.114 (2.809–3.453)	<0.001	3.247 (2.89–3.65)	<0.001
Urban	Ref	Ref	Ref	Ref
Rural	0.802 (0.707–0.909)	<0.001	0.809 (0.711–0.922)	0.001

Abbreviation: CCS = Charlson comorbidity score.
[a] Adjusted model included all the variables listed in this table. Random effects for univariate models were considered for providers nested at zip code levels except for urban-rural status. Random effects were considered for providers nested at county levels for the adjusted model.
[b] Other races include races coded as American Indian/Eskimo/Aleut, Asian or Pacific Islander, and other in the database.

hours of symptom onset did not receive thrombolytic therapy. Most of the patients who did not receive thrombolytic therapy were either older than 85 years, women, or Black patients.[8] In that study, several hospital-related factors, such as time of the day and geographic location, were also identified. Similarly, another study also showed an implicit bias among physicians, which decreased the likelihood of recommending thrombolysis to Black patients.[39] Furthermore, Black patients with stroke received fewer evidence-based care processes than Hispanic or White patients.[11] We have shown that, on average, the likelihood of receiving thrombolysis or thrombectomy for both Black and Hispanic patients seems to be lower than for White and non-Hispanic patients, respectively. Several factors have been previously described to contribute to these disparities, including delayed symptom recognition leading to delayed presentation,[29,30] restricted access to health care,[40] less utilization of emergency care,[40] delayed transfer,[10] longer wait time,[5,10] systemic biases in acute stroke care,[8,41] socioeconomic influences,[42] deep-seated mistrust of the medical system,[43] varied perceptions of stroke severity,[42] uncontrolled comorbidities,[44] and poor overall stroke literacy.[42,43] Many of the factors mentioned above cannot be explored entirely in this data set.

Several attempts have been made to increase access to acute stroke care. Telestroke was implemented to minimize these inequities and disparities. However, there are inconsistent findings regarding its ability to address socioeconomic disparities. For instance, in a South Carolina–based telestroke system, Black patients were notably less likely to receive timely thrombolytics compared with White patients, although no differences were observed in the rates of mechanical thrombectomy.[45] Conversely, a telestroke network in Texas, which had a much larger sample size compared with the previous, showed no racial differences in acute stroke care.[46] Furthermore, data from the Lone Star Stroke Consortium Telestroke Registry indicated that approximately 8% of patients eligible for thrombolytic treatment refused it, with refusal rates being higher among women, non-Hispanic Black patients, and those with stroke history.[47] The predominant reasons for refusal included rapidly improving symptoms, mild or nondisabling symptoms, and concerns about potential side effects. These elements underscore the need to enhance health care accessibility, improve stroke preparedness, and foster trust within these communities.

Table 5 RRs of Receiving Mechanical Thrombectomy According to the Social Vulnerability Index

	RR for low vulnerability	Adjusted model[a]	Subgroup analysis on patients who received mechanical thrombectomy only[b]
Quintile 1	Ref	Ref	Ref
Quintile 2	0.905 (0.816–1.005)	0.901 (0.81–1.001)	0.861 (0.751–0.987)
Quintile 3	0.928 (0.836–1.031)	0.925 (0.831–1.028)	0.868 (0.756–0.996)
Quintile 4	0.836 (0.753–0.928)	0.858 (0.771–0.955)	0.764 (0.664–0.879)
Quintile 5	0.803 (0.714–0.902)	0.842 (0.747–0.95)	0.751 (0.641–0.88)
18–45 y		Ref	Ref
45–64 y		0.765 (0.67–0.873)	0.783 (0.659–0.929)
>65 y		0.782 (0.686–0.893)	0.748 (0.63–0.887)
Female sex		Ref	Ref
Male sex		0.989 (0.933–1.049)	0.957 (0.888–1.031)
White patients		Ref	Ref
Black patients		0.742 (0.673–0.819)	0.739 (0.652–0.838)
Other races[c]		1.281 (1.177–1.394)	1.305 (1.172–1.453)
Non-Hispanic patients		Ref	Ref
Hispanic patients		0.928 (0.857–1.005)	0.924 (0.834–1.023)
Private insurance		Ref	Ref
Medicare/Medicaid		0.892 (0.833–0.954)	0.894 (0.82–0.975)
No insurance		0.945 (0.854–1.046)	0.903 (0.793–1.028)
CCS 0		Ref	Ref
CCS ≥1		3.297 (2.925–3.717)	3.667 (3.136–4.287)

Abbreviations: CCS = Charlson comorbidity score; RR = risk ratio.
[a] Adjusted for all variables listed in the table; random effects were considered for providers nested at zip code levels.
[b] Patients who received thrombolytic therapy were removed.
[c] Other races include races coded as American Indian/Eskimo/Aleut, Asian or Pacific Islander, and other in the database.

Insurance status plays a crucial role in stroke care outcomes. Studies have shown that uninsured patients tend to have higher levels of neurologic impairment, longer hospital stays, and increased mortality risks compared with privately insured patients.[18,48] Research indicates that the presence of health insurance has a significant impact on the accessibility and standard of health care services, highlighting insurance as one of the modifiable SDOH.[5,18] Similar to previous studies,[7,31] we have shown evidence that private insurance patients get a higher chance of acute stroke care. Similarly, urban and rural statuses have a significant impact on stroke care.[49] We observed a profound effect of urban and rural statuses on receiving thrombolysis while inconsistent effect on mechanical thrombectomy. Our results substantiated previous studies on thrombolysis and mechanical thrombectomy.[7,49] Only 37% of stroke centers in the nation perform mechanical thrombectomy, and only 20% of Americans can be transported within 15 minutes to a hospital that provides mechanical thrombectomy. Similarly, only 5.5 million individuals (22.1%) in Texas have direct access to endovascular therapy–capable centers within 15 minutes.[50] Therefore, it is worth exploring the factors that contributed to the differences in urban-rural status in Texas. These contributors may be useful in decreasing the effects of geographic barriers on the acute management of other diseases and acute stroke.

Our mediation analyses revealed that while stroke centers with higher rates of thrombolysis and thrombectomy may be relatively immune to biases associated with certain SDOH (e.g., race), the decreased likelihood of receiving thrombolysis or thrombectomy in certain vulnerable populations (e.g., older patients) seems to be at least partially mediated by the rates of thrombolysis or thrombectomy provided by a hospital. Of interest, the decreased likelihood of patients with stroke receiving thrombolysis from a rural setting was mediated by the thrombolysis rates of the center. By contrast, the thrombectomy rates of the center did not mediate the decreased likelihood of thrombectomy in the same population. As discussed previously, difficulties in accessing a high-quality stroke center within the critical window of 4.5 hours may explain this finding.

While previous studies have primarily focused on individual factors that determine SDOH, this study captures the impact of several SDOH in conjunction with using the SVI as a collective measure. The SVI was developed as a composite measure encompassing multiple variables that correspond to key SDOH. The SVI is built on 16 social factors, which are drawn from the American Community Survey and are organized into 4 subcategories/subthemes: socioeconomic status, household characteristics, housing type, and transportation.[24] SVI predicts adverse health care events among socially disadvantaged patients, independent of chronic disease burden, emphasizing the importance of addressing social factors in health care settings.[14] Hence, SVI can be beneficial in recognizing additional SDOH that act as barriers to care that are not typically recorded or reported in electronic health records or administrative databases. While this study represents the preliminary utilization of the SVI for evaluating the administration of acute stroke treatment, several previous studies have established a similar relationship between increasing SVI and a lower likelihood of receiving therapy.[15,16]

Our findings indicated that patients with the highest vulnerability indicated by high SVI were less likely to receive thrombolytic therapy and mechanical thrombectomy when compared with patients with the lowest vulnerability indicated by low SVI, which corresponds to previous studies that have shown significant disparities related to socioeconomic status.[7,44] However, results for mechanical thrombectomy became profound once we eliminated those who received thrombolytic therapy from the whole group, indicating potential biases related to the severity of the disease. Furthermore, our findings indicated the utility of SVI in identifying vulnerable patients who may be at a higher risk of not receiving appropriate acute stroke care. Our results also showed that the overall SVI performs comparably with a more complex model that accounts for individual patient risk factors when assessing health disparities. Therefore, the SVI could serve as a significant proxy for encompassing SDOH; as such, SVI itself can capture the vulnerability of a patient, allowing it to be included in a model without adjusting for baseline variables. The SVI could then be used to guide policy proposals and resource allocation aimed at providing equitable care for the most vulnerable communities. Thus, our findings contribute to the existing literature by recommending SVI as a valuable tool for assessing SDOH in neurologic diseases.

Furthermore, our findings highlight the need for stroke care teams to consider external SDOH when assessing patients with stroke and formulating treatment plans. Many EHRs include data on patient-level SDOH, which are components of SVI. It is feasible to integrate a system within the EHR to flag at-risk stroke patients based on their SVI calculated from their zip code of residence. This information could enable health care providers to address barriers to receiving care. Furthermore, SVI can be incorporated into quality improvement initiatives and risk adjustment models in stroke care. Moreover, strategies can be implemented to target specific elements of the SVI, such as socioeconomic status, minority status, and barriers related to housing and transportation. For instance, policymakers can adopt measures to foster improvements in stroke care by implementing interventions to improve accessibility, social support, and rehabilitation. These can ultimately decrease health care costs and improve outcomes. By acknowledging the intricate interplay between social, economic, and environmental factors, policymakers can develop targeted interventions and implement policies that promote health equity, reduce disparities, and foster supportive environments. Such initiatives enable individuals to lead healthy lives irrespective of their background or circumstances, ultimately contributing to the overall well-being of the society.

Our study had several limitations. We conducted this retrospective cohort study using a large publicly available Texas emergency database, which is not immune to shortcomings of utilization of administration databases. For instance, the inclusion of patients was based on *ICD-10* codes for a diagnosis of ischemic stroke; thus, all coding errors within the database cannot be avoided. Similarly, missing, inaccurate, or incomplete data on comorbid conditions can contribute to erroneous conclusions. Therefore, we combined all comorbid conditions into a single variable and included it in our primary models. While the health systems included in the database serve a diverse patient population, Texas has the highest percentage of uninsured patients among its population compared with other US states and the largest rural Hispanic population. Thus, the results may not be broadly generalizable to all other states across the country or the rest of the world. Nevertheless, similar disparities related to racial, ethnic, socioeconomic, and geographic location factors are widely reported in other parts of the world.[18,19,28] Furthermore, the lack of information pertaining to stroke severity (NIH Stroke Scale is not widely coded in the database), the prestroke condition (which is crucial for endovascular treatment), time from onset to presentation, and the living status of patients (such as nursing homes vs private residences) are all factors that contribute to the unmeasured confounders in the data. Similarly, the absence of specific details regarding the eligibility requirements for thrombolysis and utilization of telestroke resources, which are crucial for determining the appropriate denominator for treatment, is a significant weakness in the data. Finally, the SVI was reported at the censor track level. As such, the results may not reflect trends at the individual patient level.

In conclusion, our study provides evidence of socioeconomic disparities in access to thrombolysis or thrombectomy for acute ischemic stroke in the state of Texas. Social vulnerability plays a significant role in receiving acute care for ischemic stroke. Thoughtfully designed studies are necessary to understand specific causes, mediators, and moderators of the problem driving these disparities at the national and possibly global levels and to develop effective interventions to improve access to care for all individuals, regardless of their socioeconomic status. Until we come up with these specific answers, at least health care providers can be more cognizant, especially when making that decision in the ER, to make sure that those who medically deserve acute stroke care receive the acute stroke care.

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