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Insurance-Based Disparities in Stroke Center Access in California: A Network Science Approach

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Abstract

Background: Our objectives were to determine whether there is an association between ischemic stroke (IS) patient insurance and likelihood of transfer overall and to a stroke center, and whether hospital cluster modified the association between insurance and likelihood of stroke center transfer.

Methods: This retrospective network analysis of California data included every nonfederal hospital IS admission from 2010–2017. Transfers from an ED to another hospital were categorized based on whether the patient was discharged from a stroke center (primary or comprehensive). We used logistic regression models to examine the relationship between insurance (private, Medicare, Medicaid, uninsured) and odds of 1) any transfer among patients initially presenting to non-stroke center hospital EDs and 2) transfer to a stroke center among transferred patients. We used a network clustering method to identify clusters of hospitals closely connected through transfers. Within each cluster, we quantified the difference between insurance groups with the highest and lowest proportion of transfers discharged from a stroke center.

Results: Of 332,995 total IS encounters, 51% were female, 70% 65 years and over, and 3.5% were transferred from the initial ED. Of 52,316 presenting to a non-stroke center, 3,466 (7.1%) were transferred. Relative to privately insured patients, there was lower odds of transfer and of transfer to a stroke center among all groups (Medicare OR 0.24 [95%CI 0.22–0.26]

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and 0.59 [95%CI 0.50–0.71], Medicaid OR 0.26, [95%CI 0.23–0.29] and OR 0.49, [95%CI 0.38–0.62], uninsured OR 0.75 [95%CI 0.63–0.89] and 0.72 [95%CI 0.6–0.8] respectively). Among the 14 identified hospital clusters, insurance-based disparities in transfer varied and the lowest performing cluster (also the largest; n=2,364 transfers) fully explained the insurance-based disparity in odds of stroke center transfer.

Conclusions: Uninsured patients had less stroke center access through transfer than patients with insurance. This difference was largely explained by patterns in one particular hospital cluster.

Keywords

ischemic stroke; patient transfer; stroke centers; insurance disparities

INTRODUCTION

There are significant disparities in access to acute ischemic stroke care between patient groups. For example, in the US, differential treatment rates have been described among racial and ethnic groups and by patient insurance status.[1–4]

Access to time-sensitive reperfusion interventions depends on the initial hospital where patients present, which is connected with where patients live. Because there are disparities in the distribution of hospitals with stroke-related resources and stroke center certification, there are disparities in access.[5–7] As a result, interfacility transfer of stroke patients is relatively common, typically for accessing higher levels of care or resources that would be otherwise unavailable.[8] In this way, interhospital transfers present an opportunity to equitably match patients with the appropriate level of resources for their care, regardless of where they live or to which hospital they first presented. Yet in one analysis, 16% of ischemic stroke patients in the US lacked access to endovascular thrombectomy (EVT) because they presented to 'gap hospitals' that did not transfer any ischemic stroke patients to thrombectomy-capable hospitals.[9] Furthermore, there is substantial variability in stroke patient transfer patterns, suggesting a lack of standardization in transfer practices.[10–12]

A well-organized system of interhospital transfer is critical to ensure equitable access to disability-reducing reperfusion with EVT for all patients regardless of initial hospital of presentation. These ongoing transfers of patients between hospitals over time can be understood as forming a hospital transfer network. Hospitals that are closely connected through transfers form hospital clusters within the network, and together the clusters compose the full transfer network. Network science provides valuable tools to study these stroke transfer networks.[13]

Prior work in other populations and conditions has demonstrated varying transfer patterns between patients with different insurance, with the likelihood of transfer and ultimate transfer destination both varying by patient insurance status.[14–18] While this has not been previously examined in stroke, understanding disparities in transfer patterns of stroke patients is critical. Transfers are increasingly frequent with evolving evidence supporting expanded indications for interventional stroke care. These transfers are critical for ensuring access to reperfusion interventions for all patients regardless of their initial hospital of presentation. Yet is not clear whether regionalization varies by patients' financial characteristics, namely insurance status. Ensuring equitable access requires a well-organized system and an equitable transfer network.

We investigated how patient insurance status is associated with stroke transfers and the underlying network that facilitates them in California. California is a large state with diversity in patient population and geographic characteristics, thus we anticipate these findings may have value in understanding patterns more broadly. Because transfer patterns may vary between regions and between different clusters of hospitals that interact through transfer, we chose to examine this question using hospital clusters as a framework for examining whether transfer patterns and access vary between communities. Specifically, our objectives were to determine whether there is an association between patient insurance status and likelihood of transfer of stroke patients from an emergency department (ED) to another hospital, likelihood of transfer to a stroke center hospital among transferred patients, and whether hospital cluster modified the association between insurance status and likelihood of transfer to a stroke center.

METHODS

Data Source, Setting and Sample

We used non-public data from the state of California which includes all ED and hospital discharges from all non-federal, acute care hospitals licensed in California.[19] Encounters for ischemic stroke from 2010–2017 were identified based on primary discharge diagnoses.[20] The study was approved by the local institutional review board. Because of the sensitive nature of the data collected for this study, requests to access the dataset from qualified researchers trained in human subject confidentiality protocols may be sent to California Department of Health Care Access and Information at DataandReports@OSHPD.ca.gov.

Outcomes of Interest

We identified encounters transferred from an ED to a different hospital based on (1) a discharge disposition from the initial ED indicating any transfer (regardless of whether to a stroke center or non-stroke center); and (2) existence of consecutive records from 2 distinct sites on the same or consecutive dates.[10,20] Because our primary interest was related to acute stroke care, we did not consider transfers from the inpatient setting and focused on transfers from EDs.

Our second outcome of interest was whether transferred patients were transferred to a stroke center hospital, defined dichotomously as either a primary or comprehensive stroke center. Acute stroke ready hospitals were not considered stroke center hospitals. We identified hospitals with stroke center certification based on a comprehensive stroke center inventory that included national certifying bodies and local emergency medical services certification in 2017.[21]

Other Variables of Interest

Our primary independent variable of interest was patient insurance status. This was based on expected payer, categorized as private, Medicare, Medicaid, and self-pay/uninsured. Other patient visit-level variables of interest included age, sex, Charlson Comorbidity index and year of presentation.

In additional to stroke center status, other hospital-level variables of interest included rural versus urban location, academic status, and annual stroke volume (mean annual stroke volume during the study period).

Analysis

After identifying patient visits with and without transfers, we compared characteristics of the groups and their initial ED/hospital of presentation using standardized mean differences for bivariate comparisons. For our first objective, among patients initially presenting to a hospital without primary, thrombectomy-capable, or comprehensive stroke center status, we used a generalized linear mixed model with a random effect for hospital of presentation to examine the relationship between patient insurance status and likelihood of transfer to a hospital of any type (stroke center or not) after adjusting for sex, Charlson comorbidity index, and characteristics of the initial ED/hospital of presentation (rural location, academic status, and mean annual stroke volume). Variables included in the model were chosen *a priori* based on prior literature and clinical experience, with the exception of year of presentation, which we added to the models after observing a positive linear relationship between year and proportion of encounters transferred. We chose not to include age given concern for potential collinearity with Medicare insurance, though we did examine a version of the model that included patient age and an age*insurance interaction to examine this. For our second objective, among all transferred patients we examined likelihood of transfer to a primary, thrombectomy-capable, or comprehensive stroke center hospital using a generalized linear mixed model with a random effect for hospital of presentation. The model accounted for the same set of patient and hospital variables and additionally included stroke center status of initial ED/hospital of presentation. Fitting this model required removal of 4 hospitals with zero events (contributing 18 observations). As a robustness check, we examined the results of a generalized linear model without random effects and found that the point estimates between the models were very similar and confirmed that removing those hospitals from the model did not cause substantial bias. Finally, though we did not include race/ethnicity in our primary analysis as our aim was to measure insurance-based disparity only adjusted for clinical need (informed by the National Academy of Medicine definition of unequal treatment),[22] we did examine versions of our regression models including an interaction for race/ethnicity and insurance status. In these models we dichotomized race/ethnicity to Non-Hispanic White versus all other groups for ease of interpretation of the interaction.

To characterize the degree of stroke care regionalization in the state, and to understand whether it varied by patient insurance, we calculated a regionalization index using a previously defined strategy for each year of data.[23] The definition relies on determining the probability of care completion for each hospital (P), given by the ratio of the number of admissions (A) to the sum of admissions and transfers (T) from a given ED:

$$P(hospital,year) = \frac{A(hospital,year)}{A(hospital,year) + T(hospital,year)}$$

The regionalization index (RI) is then defined using the average probability of transfer over all the hospitals in the state:

$$RI(year) = 1 - \frac{\sum_{hospitals} P(hospital,year)}{Number\ of\ hospitals(year)}$$

Next, we calculated regionalization indices stratified based on insurance status to characterize the degree of regionalization within each insurance category. This RI captures the average probability of transfer from the initial presenting ED. Values approaching 1 indicate high regionalization and higher needs for transfer.

Network Analyses

We constructed the stroke transfer network in California using a previously described method.[24] Briefly, we identified hospitals connected through patient transfer as those within 96 miles of driving distance and with at least 2 patient transfers in either direction during the study period. Connected pairs were used to generate the stroke transfer network for the study period overall. We also generated networks stratified by patient insurance, in which networks were limited to include only transferred encounters with a given insurance status. Networks were characterized using local and global network characteristics, including total number of transfers, mean distance travelled in transfer, and network density and clustering. Density is defined as the proportion of potential connections among hospitals that are actually connected. Clustering is a local network property that describes how closely connected nodes are to their neighbors, where 0 indicates no connections between a node’s neighbors and 1 indicates that all of a node’s neighbors are also connected to one another. Networks were generated using the igraph package in R.[25]

We identified clusters of hospitals that are closely connected through patient transfers using a community detection method that makes use of properties of random walks on networks (walktrap.community function in the igraph library).[26] A walk on a network is defined as a sequence of nodes such that consecutive nodes in the sequence are connected by edges. This community detection method is based on the intuitive idea that short random walks on a network tend to become trapped in the community where the walk started. Combining this idea with rigorous mathematical techniques makes it possible to use the approach to identify clusters of nodes in a network. After identifying each cluster, we used basic descriptive statistics to characterize clusters based on total number of hospitals included, proportion of those hospitals that are rural and that are stroke centers. Within each cluster we determined the proportion of patient transfers that were ultimately discharged from a stroke center hospital overall and stratified by patient insurance status. We calculated the insurance disparity as the difference in transfer rates between insurance groups with the highest and lowest proportion of transfers discharged from a stroke center. As a sensitivity analysis, we performed community detection using an alternative method (cluster_louvain function in igraph library).[25]

After recognizing the outsized influence of one cluster, we were interested in further examining the impact of that cluster on our results. We repeated our regression models after removing the hospital nodes from that cluster, examining (1) the relationship between patient insurance and odds of transfer among all patients presenting initially to an ED in a non-stroke center hospital and a (2) odds of transfer to a stroke center hospital among all transferred encounters.

RESULTS

Characteristics of Transferred Encounters

We identified 332,995 encounters for ischemic stroke in California from 2010–2017. Of these, 11,681 (3.5%) were transferred from an ED to a hospital, most to a stroke center (n=10,161); Supplemental Table S1 presents characteristics of encounters stratified by transfer status There were 52,316 encounters that initially presented to an ED at a non-stroke center hospital and of these, 3,466 (7.1%) were transferred (Figure 1). Relative to those who were not transferred, encounters transferred from the ED were younger, more often had private insurance or no insurance, and more often initially presented to a rural ED/hospital with lower annual stroke volume. ED transfers were less often from academic hospitals (Table 1). The proportion of patients transferred from the initial ED varied by patient insurance status (private insurance: 13.7%, Medicare: 4.9%, Medicaid: 4.6%, uninsured: 12.4%, SMD 0.52). After accounting for characteristics of the patient and the initial ED of presentation, patient insurance status was significantly associated with likelihood of transfer, with lower odds of transfer among all insurance groups relative to those with private insurance (Table 2). The relationship between insurance status and odds of transfer did not vary by race/ethnicity (Supplemental Material: Table S2).

Of the 11,681 transferred encounters during the study period, 10,161 (85.0%) were transferred to a stroke center (Table 1). Transfer to a stroke center varied between insurance groups. Among privately insured transferred encounters, 89% were transferred to a stroke center, versus 87% of transferred Medicare patients, 82% of transferred Medicaid patients, and 72% of transferred patients without insurance. After accounting for other patient characteristics, Medicare, Medicaid and uninsured patients were less likely to be transferred to a stroke center than patients with private insurance (Table 2). To examine whether this was driven by patient age or whether the relationship varied by patient age, we examined a version of the model that included patient age and an age*insurance interaction and the results were similar. Finally, we examined whether the relationship between insurance and odds of transfer to a stroke center varied by race/ethnicity, and found that non-White patients without insurance had lower odds of transfer to a stroke center, but the relationship between insurance and transfer to a stroke center otherwise did not vary for other insurance categories (Supplemental Material: Table S1).

Regionalization over Time

Stroke care in California became increasingly regionalized from 2010–2017. The degree of regionalization varied by expected payer, with the highest level of regionalization for privately insured patients (Figure 2).

Stroke Transfer Network, Overall and by Insurance Status

Of the 11,681 transferred encounters during the study period, 10,049 were included in the stroke transfer network map (excluded transfers did not meet criteria either because they were an isolated singleton transfer between two hospitals, the transfer exceeded 96 miles, or both).

Network density was low, as expected, indicating that these were relatively sparse networks in which most hospitals are transferring to the same referral centers. Clustering varied by insurance status (Figure 3), although the lower clustering coefficients in Medicaid (0.14) and self-pay/uninsured (0.07) patient transfer networks may reflect the smaller number of transfers in those networks.

Hospital Clusters

We identified 14 clusters of hospitals closely connected to one another through patient transfer (Table 3). Clusters ranged in size (2–78 hospitals) and rurality (0–100%). Most (n=9) but not all clusters included an academic hospital.

The vast majority of clusters had very high percentage of patient transfers sent to stroke center hospitals, but this did vary by cluster. One cluster (Cluster 3, Table 3) had 0 stroke center hospitals, however all 13 others had at least 1. Apart from Cluster 3, the percentage of patient transfers within a cluster that were sent to a stroke center ranged from 69% to 100% and was over 80% in 12 of the 14 clusters.

To determine whether there were different rates of transfer to stroke center between insurance groups *within clusters*, we examined the percentage of transfers to a stroke center stratified by insurance status within each cluster (Figure 4). Most clusters had similar rates of transfer to stroke center hospitals regardless of insurance status, however 3 clusters had an insurance disparity of 20% or more between groups. This included Cluster 14, the largest cluster in the state both in terms of number of hospitals (n=78) and of patient transfers, (n=2,364; 24% of all transfers in the state). In this cluster, 81% of privately insured transferred patients were sent to stroke center hospitals versus only 32% of uninsured patients. Interestingly, the direction of the disparity varied. In the other two clusters with higher insurance disparities, (cluster 7, with 425 transfers, and cluster 9 with 583 transfers) 100% of self-pay patients were transferred to stroke centers versus 80% and 73% of privately insured patients, respectively (Figure 5). Findings were similar in our analysis using an alternative clustering strategy (Supplemental Material: Figure S1).

To further examine the impact of Cluster 14 on our results, we repeated our regression models examining the relationship between patient insurance and transfer after removing hospitals from Cluster 14 from the analysis. The insurance-based disparity in transfer to stroke center was no longer present (Table 2).

Discussion

In this analysis of stroke patient transfers in California from 2010–2017, we identified insurance-based disparities in access to stroke center care among transferred patients. We found that among patients initially presenting to an ED at non-stroke center hospitals, privately insured patients with acute ischemic stroke were more likely to be transferred (to any type of hospital) than patients with Medicare, Medicaid, or no insurance. We also found that among transferred patients, stroke center access varied by insurance status. The relationship between patient insurance and stroke center access through transfer varied between clusters of hospitals, with the largest hospital cluster in the state demonstrating the widest insurance-based disparity.

Literature in other conditions has been mixed with respect to the relationship between patient insurance status and transfer. For example, in a study of encounters for five common diagnoses in the National Inpatient Sample (biliary tract disease, chest pain, pneumonia, septicemia, and skin or subcutaneous infection), uninsured patients were significantly less likely to be transferred.[15] In contrast, among encounters for frequently-transferred conditions in the National ED Sample, uninsured patients were *more* likely to be transferred.[18] Uninsured patients were also more likely to be transferred in a study of patients in the National ED Sample with acute ST-elevation myocardial infarction.[27]

In our study, privately insured patients were the most likely to be transferred to any type of hospital and were also more likely to be transferred to stroke center hospitals. In contrast, uninsured patients were less likely to be transferred and, when transferred, least often transferred to stroke centers. Particularly given the association between stroke center care and improved patient outcomes,[28–31] this finding underscores important structural factors in the health care system that contribute to disparities in patient access to high-quality care and subsequent disparities in outcomes.

The network-based approach proved valuable for better understanding the origin of differences in access between insurance groups. Rather than the insurance-based difference being evenly distributed across the state, we found that the insurance-based difference in access was largely explained by the transfer patterns within particular clusters of hospitals. Whereas most clusters of hospitals connected to each other through patient transfer achieved similar rates of access to stroke center care for transferred patients regardless of insurance status, we found that three of the clusters had larger differences in access to stroke center care depending on patients' insurance status.

Interestingly, the direction of the disparity varied between these three clusters. One cluster (Cluster 14) – also the largest, including nearly a quarter of all stroke transfers in the state – more frequently transferred privately insured patients to a stroke center than it did for uninsured transferred patients. Where 81% of privately insured patients in the cluster who were transferred were sent to stroke center hospitals, only 32% of uninsured transferred patients were sent to a stroke center. Yet in the other two clusters (Clusters 7 and 9) that demonstrated insurance-based differences, uninsured patients were *more frequently* transferred to stroke center hospitals.

It is likely that several mechanisms contribute to varying transfer behaviors and patterns of access. Our findings of varying transfer patterns between communities of hospitals suggest differences in transfer culture vary between the communities. Factors at the individual hospital and health system level may also contribute. This may include different reasons or motivation to transfer uninsured patients on the part of the transfer-sending hospital, or it may reflect varying receptiveness to transfers by the receiving hospitals. With many US hospitals experiencing strained capacity, ability to receive transfers may be limited and processes to address capacity and optimize bed use may inadvertently (or intentionally) have differential impacts on patients depending on their insurance status. Understanding many of these factors is beyond what can be achieved with administrative data alone. Further mixed-methods or qualitative work will be valuable to better characterize barriers to equitable transfer processes.

Interhospital transfer patterns are an intervenable component in the structure of the healthcare system. Many structural components of the system that contribute to disparities in access and outcomes, such as location and distribution of hospitals and stroke centers,[5] may take years to address. In contrast, interhospital patient transfers may be readily redirected. Further research and investment in a well-organized system of interhospital transfer may lead to more equitable access to high-quality stroke care and improved patient outcomes.

This study has important limitations. First, in this administrative dataset we were unable to include some clinical information that may have informed need for transfer, and there may have been important differences between groups that we were unable to identify (e.g., stroke severity or patient preference). Patient insurance status may, in fact, be a proxy for other characteristics that impact eligibility for interventions such as age, health literacy or time to presentation during eligibility windows for acute interventions. Second, our data do not include the years of the COVID-19 pandemic and it is possible that varying capacity issues and strains on the healthcare system led to different trends in care and transfer patterns that are not captured in these results. Third, because of collinearity concerns we did not include age in our primary analysis. Fourth, we did not incorporate hospital openings or closures into our analysis, which may have impacted transfer patterns during the study period. Finally, given the use of administrative data, we are not able to identify the underlying mechanisms that are contributing to the disparities that we report here. For example, it is possible that patient preference may vary by ability to pay.

Conclusion

Interhospital transfers may be a valuable way to overcome disparities in access to stroke center care that arise based on the distribution of hospitals and stroke centers relative to different populations. However, we identified important differences in patterns of transfer for patients with acute ischemic stroke in California, with uninsured patients having less access to stroke center care through transfer than patients with insurance. This difference was largely explained by transfer patterns in one particular cluster of closely connected hospitals. Further work to understand barriers and facilitators of equitable transfer patterns is warranted.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

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Non-Standard Abbreviations and Acronyms

CSC	comprehensive stroke center
ED	emergency department
EVT	endovascular thrombectomy
NH	Non-Hispanic
PSC	primary stroke center
RI	regionalization index
SMD	standardized mean difference
tPA	intravenous thrombolytic

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WHAT IS KNOWN

- There are important disparities in access to stroke center care among ischemic stroke patients based on the distribution of stroke centers relative to different populations.
- Stroke patients are frequently transferred between hospitals and transfers may be an important place to better understand and address known access disparities.

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WHAT THE STUDY ADDS

- This study found that uninsured patients in California have less access to stroke center care through transfer and used network science methods to identify sources of the disparity.
- One particular cluster of hospitals was found to be the primary source of this disparity.

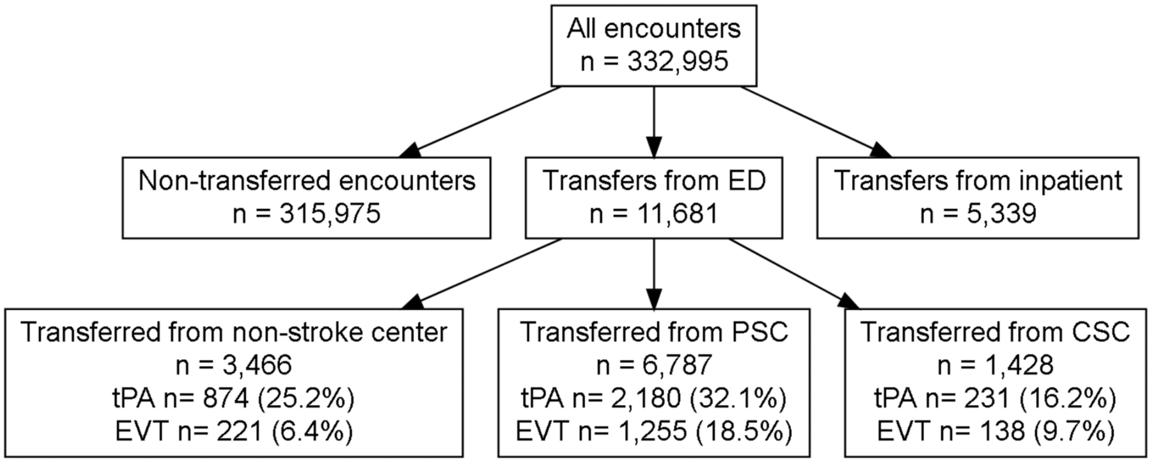


Figure 1. Distribution of Ischemic Stroke Encounters by Transfer Status and Stroke Center Status of Destination Hospital

ED: emergency department; PSC: Primary Stroke Center; CSC: Comprehensive Stroke Center; tPA: intravenous thrombolytic; EVT: endovascular thrombectomy

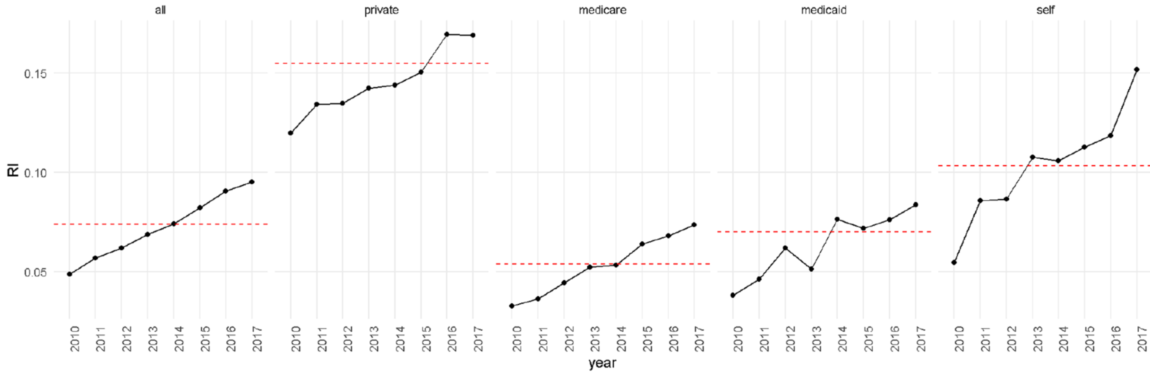


Figure 2. Regionalization of Ischemic Stroke Care in California, 2010–2017

The regionalization index (RI; range 0–1) is defined in the Methods as a representation of the degree to which stroke care is regionalized or dependent on transfers for patients to access definitive care. Values approaching 1 indicate high regionalization and higher needs for transfer. The red dashed line indicates the mean RI for each given panel.

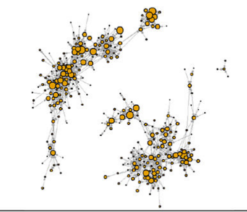
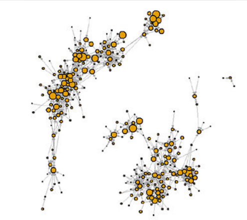
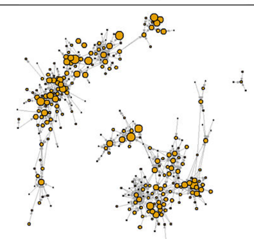
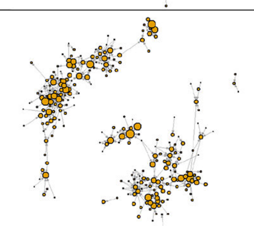
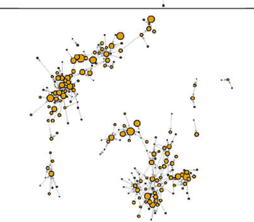
Network	Network Visualization	Network Characteristics
Overall		Number of Transfers: 10,049 Number of Hospital Nodes: 307 Mean Driving Distance: 26.0 mi Edge Density: 0.01 Clustering Coefficient: 0.26 Proportion of transferred patients discharged from a stroke center: 87%
Private		Number of Transfers: 5,297 Number of Hospital Nodes: 290 Mean Driving Distance: 22.2 mi Edge Density: 0.01 Clustering Coefficient: 0.26 Proportion of transferred patients discharged from a stroke center: 89%
Medicare		Number of Transfers: 3,328 Number of Hospital Nodes: 290 Mean Driving Distance: 31.7 mi Edge Density: 0.01 Clustering Coefficient: 0.17 Proportion of transferred patients discharged from a stroke center: 87%
Medicaid		Number of Transfers: 904 Number of Hospital Nodes: 250 Mean Driving Distance: 27.0 mi Edge Density: 0.01 Clustering Coefficient: 0.14 Proportion of transferred patients discharged from a stroke center: 82%
Self-Pay/uninsured		Number of Transfers: 520 Number of Hospital Nodes: 211 Mean Driving Distance: 26.0 mi Edge Density: 0.01 Clustering Coefficient: 0.07 Proportion of transferred patients discharged from a stroke center: 72%

Figure 3. California Stroke Transfer Network 2010–2017, Overall and by Insurance Status

These figures represent the ischemic stroke transfer network in California. Each node represents a hospital; the size of the node is proportional to the hospital's annual stroke volume (emergency department + inpatient discharges). Each line between hospitals indicates that those two hospitals are connected through patient transfer. Mean driving distance is the mean driving distance for all transfers represented in the network figure. Edge density (range 0–1) is the proportion of potential connections between hospitals that are actually connected through patient transfer. Clustering coefficient (range 0–1) is a property describing the degree to which hospitals tend to cluster together.

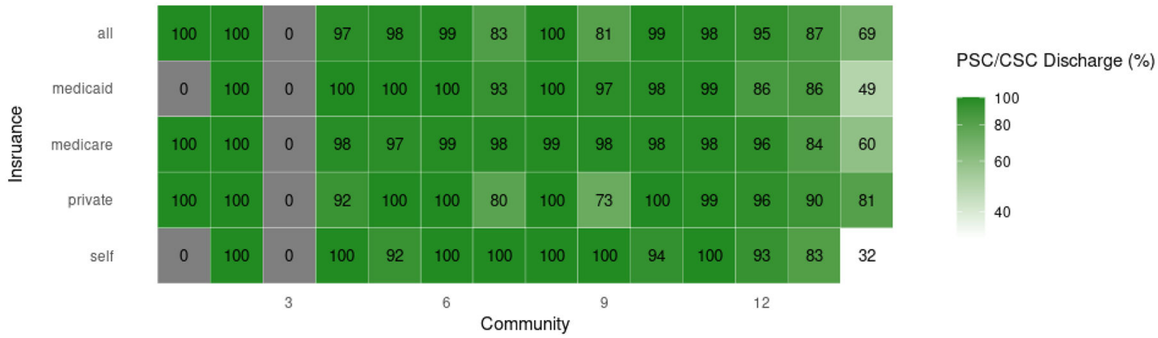


Figure 4. Community-Level Visualization of Stroke Center Access and Transfer Patterns by Insurance Status

Each of the 14 hospital clusters is represented by a column in the figure. The green rows present the percentage of patients discharged from a stroke center within each community, stratified by insurance category. The blue rows present the number of patient encounters transferred from the initial emergency department (ED) of presentation within each community, stratified by insurance status. Community numbers correspond to those in Table 3. PSC: primary stroke center; CSC: comprehensive stroke center.

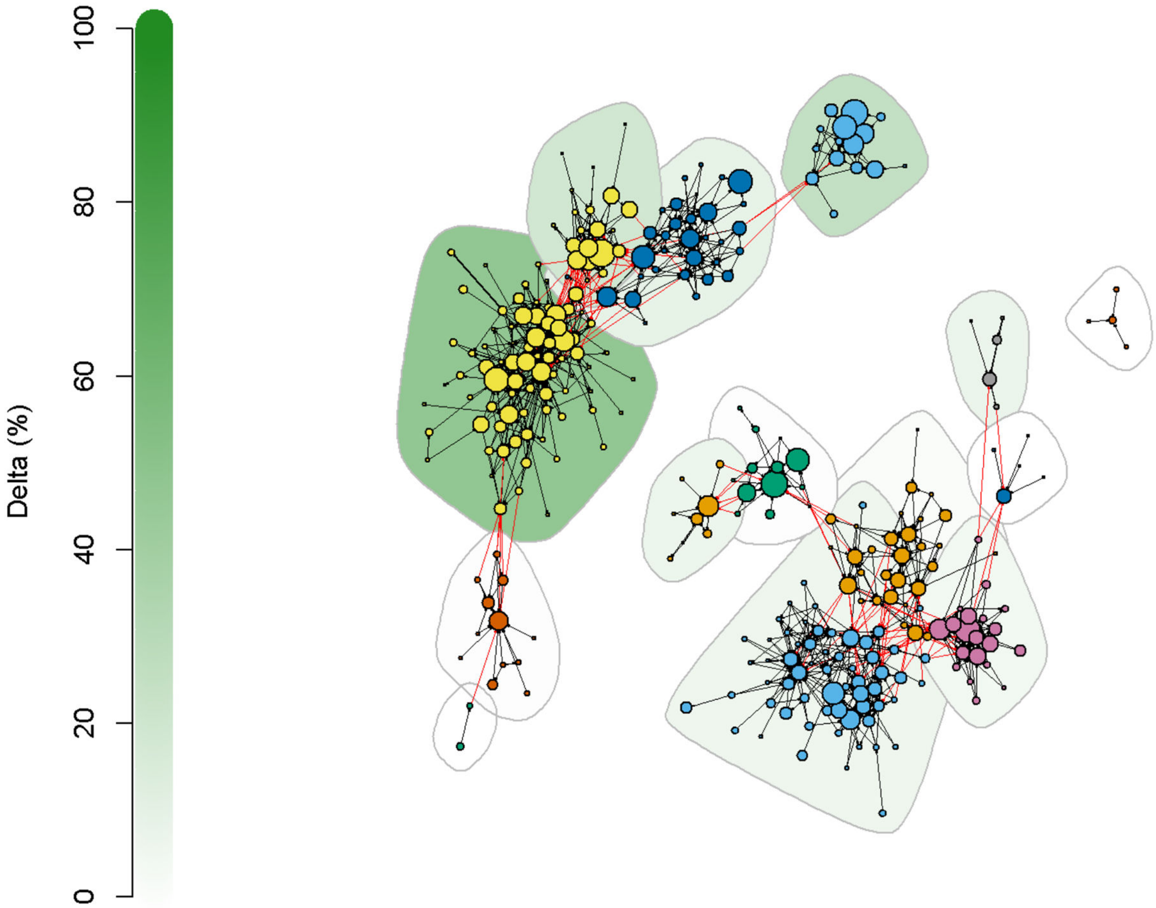


Figure 5. Communities of Hospitals Connected through Transfer in California, Characterized by Degree of Insurance-Based Disparity in Stroke Center Access among Transferred Patients

This figure represents the ischemic stroke transfer network for the full study period in California. Each node represents a hospital; the size of the node is proportional to the hospital's annual stroke volume (emergency department + inpatient discharges). Each line between hospitals indicates that those two hospitals are connected through patient transfer. Communities of hospitals closely connected through patient transfer are depicted as clusters with the same color node and a shape outlining the cluster. The green shading surrounding each cluster indicates the degree of disparity in access to stroke center care (i.e., the insurance disparity). The darkest green community is the lowest performing, with a delta of 49% between privately insured and self-pay transfers.

Table 1.

Characteristics of Stroke ED Encounters by Initial Presentation and Transfer Status

	Among patient encounters initially presenting to an ED at a non-stroke center hospital (n= 52316)			**Among transferred patient encounters (n=11681)**		
	Encounters Transferred from Initial ED n = 3,466	**Encounters *not* Transferred from Initial ED n = 48,850**	**Standardized mean difference**	**Encounters Transferred from Initial ED to a Stroke Center n = 10,161**	**Encounters Transferred from Initial ED to a Non-Stroke Center n = 1,520**	**Standardized mean difference**
Age, n (%)						
<45 years	181 (5.2)	1,681 (3.4)	0.19	493 (4.9)	54 (3.6)	0.14
45–64 years	1,061 (30.6)	13,716 (28.1)		2,731 (26.9)	500 (32.9)	
65–79 years	1,273 (36.7)	16,957 (34.7)		3,782 (37.2)	522 (34.3)	
80–89 years	770 (22.2)	11,977 (24.5)		2,478 (24.4)	349 (23.0)	
90 years and above	181 (5.2)	4,519 (9.3)		677 (6.7)	95 (6.2)	
Female, n (%)	1,612 (46.5)	24,758 (50.7)	0.08	4,784 (47.1)	705 (46.4)	0.01
Expected payer, n (%)						
Private	1,273 (36.7)	7,992 (16.4)	0.52	5,243 (51.6)	660 (43.4)	0.27
Medicare	1,627 (46.9)	31,621 (64.7)		3,569 (35.1)	516 (33.9)	
Medicaid	384 (11.1)	7,946 (16.3)		910 (9.0)	195 (12.8)	
Self-pay/uninsured	182 (5.3)	1,291 (2.6)		439 (4.3)	149 (9.8)	
Charlson comorbidity index, mean (SD)	3.1 (1.6)	3.1 (1.6)	0.03	3.3 (1.6)	3.2 (1.6)	0.10
Race/ethnicity, n (%)						
Non-Hispanic Asian	202 (5.8)	6,240 (12.8)	0.35	752 (7.4)	179 (11.8)	0.33
Non-Hispanic Black	171 (4.9)	4,689 (9.6)		839 (8.3)	161 (10.6)	
Hispanic	742 (21.4)	11,379 (23.3)		1,985 (19.5)	428 (28.2)	
Non-Hispanic White	2,151 (62.1)	24,842 (50.9)		5,966 (58.7)	654 (43.0	
Other	200 (5.8)	1,700 (3.5)		619 (6.1)	98 (6.4)	
Characteristics of Initial ED/Hospital of Presentation						
Rural location, n (%)	704 (20.3)	4,331 (8.9)	0.3	802 (7.9)	152 (10.0)	0.07
Academic, n (%)	55 (1.6)	4,083 (8.4)	0.32	638 (6.3)	231 (15.2)	0.29
Mean annual stroke volume, n (%)						

	Among patient encounters initially presenting to an ED at a non-stroke center hospital (n= 52316)			**Among transferred patient encounters (n=11681)**		
	Encounters Transferred from Initial ED n = 3,466	**Encounters *not* Transferred from Initial ED n = 48,850**	**Standardized mean difference**	**Encounters Transferred from Initial ED to a Stroke Center n = 10,161**	**Encounters Transferred from Initial ED to a Non-Stroke Center n = 1,520**	**Standardized mean difference**
≤ 60 cases	2,353 (67.9)	15,814 (32.4)	0.78	2,533 (24.9)	345 (22.7)	0.14
60–120	566 (16.3)	13,251 (27.1)		2,110 (20.8)	286 (18.8)	
120–240	382 (11.0)	12,900 (26.4)		3,038 (29.9)	423 (27.8)	
>240	165 (4.8)	6,885 (14.1)		2,480 (24.4)	466 (30.7)	

ED: emergency department. Given the large sample size, standardized mean differences (SMD) were used to characterize differences between groups. SMD > 0.10 is a standard threshold for significance.

Table 2.

Characteristics Associated with Likelihood of Transfer from the Initial ED of Presentation and for Characteristics Associated with Likelihood of Transfer to a Stroke Center Hospital when Transferred

	Models Including All Hospital Clusters		**Models Excluding Hospital Cluster 14**	
	Likelihood of Transfer among Encounters presenting to a Non-Stroke Center ED (n= 52,316)	**Likelihood of Transfer to a Stroke Center among Transferred Patients (n= 11,681)**	**Likelihood of Transfer among Encounters presenting to a Non-Stroke Center ED (n= 38,341)**	**Likelihood of Transfer to a Stroke Center among Transferred Patients (n= 8,743)**
	Odds Ratio (95% Confidence Interval)	**Odds Ratio (95% Confidence Interval)**	**Odds Ratio (95% Confidence Interval)**	**Odds Ratio (95% Confidence Interval)**
Year of presentation (per additional year)	1.17 (1.15–1.19)	1.18 (1.14–1.22)	1.19 (1.17 – 1.21)	1.38 (1.32 – 1.45)
Female	0.91 (0.84–0.98)	1.05 (0.92–1.21)	0.89 (0.82 – 0.97)	0.97 (0.8 – 1.17)
Expected payer				
Private	Reference	Reference	Reference	Reference
Medicare	0.2 (0.18–0.22)	0.59 (0.50–0.71)	0.23 (0.21 – 0.26)	1.21 (0.95 – 1.54)
Medicaid	0.24 (0.21–0.28)	0.49 (0.38–0.62)	0.27 (0.24 – 0.32)	0.9 (0.63 – 1.28)
Self-pay/Uninsured	0.72 (0.6–0.87)	0.67 (0.48–0.93)	0.76 (0.62 – 0.94)	1.04 (0.65 – 1.67)
Charlson comorbidity index (per point increase)	1.1 (1.07–1.13)	1.05 (1.01–1.1)	1.08 (1.05 – 1.11)	0.97 (0.92 – 1.03)
Characteristics of Initial ED/Hospital of Presentation				
Rural location	1.94 (1.06–3.54)	1.45 (0.46–4.56)	1.42 (0.8 – 2.52)	0.53 (0.18 – 1.63)
Academic hospital	0.41 (0.13–1.31)	0.86 (0.34–2.16)	0.51 (0.1 – 2.55)	1.25 (0.35 – 4.38)
Mean annual stroke volume				
≤ 60 cases	Reference	Reference	Reference	Reference
60–120	0.27 (0.15–0.51)	0.97 (0.39–2.45)	0.29 (0.15 – 0.57)	2.46 (0.87 – 6.95)
120–240	0.23 (0.1–0.52)	1.74 (0.65–4.63)	0.23 (0.1 – 0.52)	3.75 (1.25 – 11.29)
>240	0.09 (0.02–0.37)	0.77 (0.25–2.36)	0.03 (0.01 – 0.17)	1.94 (0.55 – 6.78)
Stroke center status				
Non-stroke center	-	Reference		Reference
Primary stroke center	-	0.77 (0.34–1.75)		0.42 (0.16 – 1.06)
Comprehensive center	-	0.5 (0.15–1.72)		0.18 (0.04 – 0.74)

Table 3.

Characteristics of Hospital Clusters Connected through Stroke Patient Transfer, listed by # hospitals in each cluster

		Characteristics of Hospitals in Each Cluster				Characteristics of Stroke Patient Encounters in Each Cluster					Characteristics of Transferred Stroke Encounters in Each Cluster				
Cluster	Number of Hospitals	Rural, n (%)	Academic, n (%)	PSC, n (%)	CSC, n (%)	Number of Patients	Private Insurance, n (%)	Medicare, n (%)	Medicaid, n (%)	Self-pay, n (%)	Number of Transfers	Transfers sent to a stroke center, n (%)	Insurance category with highest stroke center access	Insurance category with lowest stroke center access	Insurance disparity
1	2	0 (0)	0 (0)	2 (100)	0 (0)	1,465	235 (16)	1,132 (77.3)	85 (5.8)	13 (0.9)	14	14 (100)	All categories	-	n/a
2	5	3 (60)	0 (0)	1 (20)	0 (0)	2,153	274 (12.7)	1,646 (76.5)	209 (9.7)	24 (1.1)	29	29 (100)	All categories	-	n/a
3	4	4 (100)	0 (0)	0 (0)	0 (0)	1,782	184 (10.3)	1,365 (76.6)	180 (10.1)	53 (3)	41	0 (0)	-	All categories	n/a
4	5	3 (60)	0 (0)	2 (40)	0 (0)	3,689	332 (9)	2,857 (77.4)	408 (11.1)	92 (2.5)	76	74 (97)	Medicaid and self-pay (100%)	Private (92%)	8%
5	8	0 (0)	1 (12.5)	3 (37.5)	1 (12.5)	7,248	1,136 (15.7)	4,601 (63.5)	1,265 (17.5)	246 (3.4)	148	145 (98)	Private and Medicaid (100%)	Self-pay (92%)	5%
6	12	0 (0)	0 (0)	5 (41.7)	2 (16.7)	9,821	1,726 (17.6)	7,076 (72)	704 (7.2)	315 (3.2)	366	364 (99)	All others (100%)	Medicare (99%)	1%
7[^]	20	0 (0)	1 (5)	7 (35)	7 (35)	24,795	5,451 (22)	16,980 (68.5)	1,976 (8)	388 (1.6)	425	353 (83)	Self-pay (100%)	Private (80%)	20%
8	13	1 (7.7)	1 (7.7)	5 (38.5)	0 (0)	15,211	2,286 (15)	10,014 (65.8)	2,545 (16.7)	366 (2.4)	441	439 (100)	All others (100%)	Medicare (99%)	1%
9[^]	15	0 (0)	2 (13.3)	10 (66.7)	3 (20)	26,625	4,981 (18.7)	18,210 (68.4)	2,885 (10.8)	549 (2.1)	583	471 (81)	Self-pay (100%)	Private (73%)	27%
10	21	2 (9.5)	1 (4.8)	15 (71.4)	2 (9.5)	30,058	5,464 (18.2)	20,451 (68)	3,438 (11.4)	705 (2.3)	719	712 (99)	Private (100%)	Self-pay (94%)	6%
11	30	2 (6.7)	2 (6.7)	15 (50)	4 (13.3)	34,745	6,770 (19.5)	22,843 (65.7)	4,253 (12.2)	879 (2.5)	788	775 (96)	Self-pay (100%)	Medicare (98%)	2%
12	33	0 (0)	3 (9.1)	16 (48.5)	4 (12.1)	39,563	8,803 (22.3)	24,065 (60.8)	5,422 (13.7)	1,273 (3.2)	1159	1100 (95)	Private and Medicare (96%)	Medicaid (86%)	10%

		Characteristics of Hospitals in Each Cluster				Characteristics of Stroke Patient Encounters in Each Cluster					Characteristics of Transferred Stroke Encounters in Each Cluster				
Cluster	**Number of Hospitals**	**Rural, n (%)**	**Academic, n (%)**	**PSC, n (%)**	**CSC, n (%)**	**Number of Patients**	**Private Insurance, n (%)**	**Medicare, n (%)**	**Medicaid, n (%)**	**Self-pay, n (%)**	**Number of Transfers**	**Transfers sent to a stroke center, n (%)**	**Insurance category with highest stroke center access**	**Insurance category with lowest stroke center access**	**Insurance disparity**
13	61	4 (6.6)	8 (13.1)	40 (65.6)	4 (6.6)	57,788	12,861 (22.3)	37,629 (65.1)	5,901 (10.2)	1,397 (2.4)	1824	1591 (87)	Private (90%)	Self-pay (83%)	7%
14[^]	78	0 (0)	11 (14.1)	36 (46.2)	13 (16.7)	90,912	18,899 (20.8)	56,886 (62.6)	12,626 (13.9)	2,501 (2.8)	2364	1631 (69)	Private (81%)	Self-pay (32%)	49%

[^] The three lightly shaded rows indicate the three communities with an insurance disparity of 20% or greater based on examining percentage of transfers to a stroke center stratified by insurance status within each cluster.