Neighborhood income inequality associated with functional independence after ischemic stroke: a cohort study

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Abstract

Background

Individual measures of socioeconomic status have been associated with post-stroke disability in patients with ischemic stroke. However, it is not known whether the distribution of income in a community may have an impact on stroke recovery. We hypothesized that increased neighborhood income inequality (as measured by the Gini index) may be associated with a slower recovery after stroke.

Methods

This was a retrospective cohort study of adult patients hospitalized at a comprehensive stroke center with acute ischemic stroke between 1/1/2018-12/31/2019. Individual patient data was abstracted from the EHR, and zip code Gini index was obtained from the US Census Bureau. Binary logistic regression was used to assess the relationship between Gini index and modified Rankin score at discharge and follow-up. A second binary regression was also performed using a subset of patients to assess possible predictors of being discharged as recommended.

Results

Three hundred and thirty-eight patients were included in this analysis. Zip code Gini index was not associated with functional independence at discharge but was associated with independence at follow-up such that patients from high inequality neighborhoods were less likely to be independent. Each 1% increase in neighborhood Gini index was associated with an 7% decreased likelihood of independence at follow-up. Patients living in the highest income inequality neighborhoods were 220% less likely to achieve functional independence by follow-up compared to those in the lowest inequality neighborhoods. Being discharged as recommended was associated with a higher likelihood of independence at follow-up. Greater income inequality and Asian race were associated with a lower likelihood of being discharged as recommended.

Conclusion

Among a cohort of patients with ischemic stroke, increased neighborhood income inequality was associated with a lower likelihood of achieving functional independence by the time of outpatient follow-up. This disparity may be driven by discharge destination and race.

Introduction

Socioeconomic status (SES) is likely a source of disparity in the functional outcomes of patients with ischemic stroke. One novel measure of SES with regards to stroke outcomes is neighborhood income

inequality; this can be quantified using the Gini index (or Gini coefficient), which summarizes income inequality on a scale of 0 to 100 (0 representing complete equality and 100 representing complete inequality).[1] Previous studies have found that greater income inequality is associated with higher stroke incidence and mortality.[2–6] However, it is not known if income inequality affects post-stroke disability.

While individual measures of SES (such as income, education, and employment) have been associated with post-stroke disability, the distribution of financial resources in a community may have a unique impact on stroke recovery.[7–8] In particular, neighborhood income inequality may reflect the availability of stroke rehabilitation services, the ability to access those services, and the ability of caregivers to support patients with stroke in the post-hospitalization care phase. Understanding the relationship between post-stroke disability and income inequality is becoming increasingly important as both stroke survival and income inequality continue to rise in the United States.[9–10]

We sought to assess whether increased neighborhood income inequality was associated with post-stroke disability. Due to the location of our tertiary care center (Tufts Medical Center, TMC), we are ideally positioned to examine local income inequality and its potential effects on stroke recovery. Many neighborhoods in eastern Massachusetts report especially high levels of income inequality (above the national average). The Chinatown neighborhood encompassing TMC has the second highest Gini index in the state.[11] We hypothesized that patients living in high inequality neighborhoods are more likely to demonstrate higher levels of post-stroke disability at follow-up after adjustment for other major predictors of stroke recovery.

Methods

Study population

This was a retrospective cohort study of adult patients (age ≥ 18) hospitalized at a comprehensive stroke center (TMC) with acute ischemic stroke (AIS) between 1/1/2018-12/31/2019 with subsequent outpatient neurology, neurosurgery, or primary care follow-up. As the catchment area for TMC includes patients from neighboring states with the potential for variability in coverage by public insurance and in services covered by public insurance (e.g. Medicaid), only patients with a Massachusetts zip code were included. This study was approved by the TMC IRB (#12151).

Predictors and outcomes

Data collected from the electronic health record included demographics, preferred language, stroke risk factors, stroke severity (admission NIHSS), acute revascularization treatment (IV thrombolysis, thrombectomy), discharge destination, insurance status (private versus non-private), and neighborhood zip code. Information about discharge destination was collected as recommended destination (inpatient rehabilitation facility [IRF] versus other), actual destination (IRF versus other), and discharged as recommended (yes/no). A combination of private and public insurance was coded as private.

The primary predictor of interest was neighborhood income inequality, which was defined by the 2014–2018 Gini index listed for each patient's zip code. Zip code was obtained from registration data documented at the time of admission. Neighborhood Gini index was obtained from the American Community Survey (ACS), which is conducted annually by the United States Census Bureau (USCB). Results of the ACS are publicly available and include Gini index by zip code over a 5-year interval (e.g. 2014–2018).

The primary outcome of interest was functional independence (modified Rankin score, mRS ≤ 2). The mRS was estimated at two timepoints: hospital discharge and first outpatient follow-up. This was retrospectively estimated independently by two members of the research team (KC, MP, EJP, YA) using discharge summaries, physical therapy and occupational therapy notes, and outpatient follow-up notes. Discrepancies in estimated mRS were resolved by a third team member (LYL). All members of the research team underwent formal training on mRS assessment.

Statistical analysis

Mann-Whitney U and Chi-square tests were used for univariate analyses of all covariates (according to the structure of the data) to compare those living in zip codes above and below the median Gini index of the study cohort.

For the primary analysis, binary logistic regression was used to assess the relationship between zip code Gini index and independence (mRS ≤ 2) at discharge and follow-up. Each model adjusted for demographics, preferred language, stroke risk factors, insurance status, stroke severity, and acute revascularization treatment. The models for independence at follow-up also adjusted for discharge as recommended, actual discharge destination, and time to follow-up. A post-hoc sensitivity analyses included the Gini index as a binary variable (top quintile versus other).

A secondary analysis was performed using a subset of patients discharged to IRF to assess the possible predictors of being discharged as recommended (i.e. recommended and actual discharge destination were the same). It was suspected that socioeconomic disparities may be most apparent in this group compared to those recommended for other destinations (e.g. home) as these patients may have more notable functional limitations upon discharge from the hospital. Covariates included Gini index, demographics, preferred language, comorbidities, insurance status, stroke severity, and acute revascularization.

Statistical significance was defined as a p-value below 0.05. All analyses were complete case analyses (i.e. no missing data). All analyses were conducted in IBM SPSS Statistics Version 24.

Results

Three hundred and thirty-eight adult patients with AIS were included in this analysis (Fig. 1). Baseline characteristics are shown in Table 1, stratified into two groups by Gini index. The median zip code Gini index was 43.42% (ranging from 34.57–65.94%).

Table 1
Baseline characteristics.

Trait	Below or at Median GI (n = 172)	Above Median GI (n = 166)	P Value
Median age	69 (IQR = 24)	71 (IQR = 23)	0.303
Sex			
Female	77 (44.8%)	75 (45.2%)	0.939
Male	95 (55.2%)	91 (54.8%)	
Race	12 (7.0%)	57 (34.3%)	< 0.001
Asian	10 (5.8%)	19 (11.4%)	
Black	5 (2.9%)	10 (6.0%)	
Other	145 (84.3%)	80 (48.2%)	
White			
Ethnicity	4 (2.3%)	15 (9.0%)	0.007
Hispanic	168 (97.7%)	151 (91.0%)	
Non-Hispanic			
Preferred language	159 (92.4%)	98 (59.0%)	< 0.001
English	13 (7.6%)	68 (41.0%)	0.062
Other	32 (18.6%)	45 (27.1%)	0.763
Smoking status	35 (20.3%)	36 (21.7%)	
Current smoker			
Former smoker			
Alcohol use	51 (29.7%)	33 (19.9%)	0.038
Current alcohol use	6 (3.5%)	7 (4.2%)	0.728
Former alcohol use			

Trait	Below or at Median GI (n = 172)	Above Median GI (n = 166)	P Value
Comorbidities	50 (29.1%)	35 (21.1%)	0.091
Atrial fibrillation	27 (15.7%)	26 (15.7%)	0.993
Carotid atherosclerosis	24 (14.0%)	20 (12.0%)	0.603
Coronary artery disease	46 (26.7%)	52 (31.3%)	0.353
Diabetes mellitus	72 (41.9%)	69 (41.6%)	0.956
Hyperlipidemia	124 (72.1%)	117 (70.5%)	0.743
Hypertension			
Stroke history	141 (82.0%)	128 (77.1%)	0.267
No previous strokes			
Stroke treatment	49 (28.5%)	33 (19.9%)	0.065
Received tPA	43 (25.0%)	17 (10.2%)	< 0.001
Received EVT			
Stroke severity			
Median initial NIHSS	8 (IQR = 15)	4 (IQR = 10)	0.038
Insurance status	96 (55.8%)	59 (35.5%)	< 0.001
Private insurance	76 (44.2%)	107 (64.5%)	
No private insurance			
Discharge planning	85 (49.4%)	70 (42.2%)	0.165
Recommended for IRF	70 (40.7%)	45 (27.1%)	0.008
Discharged to IRF	155 (90.1%)	131 (78.9%)	0.004
Discharged as recommended			
Follow-up	116 (67.4%)	117 (70.5%)	0.546
Returned for outpatient follow-up			
Median days to follow-up	36 (IQR = 25)	34 (IQR = 18)	0.313

Compared to those living in zip codes below or at the median Gini index, those living above the median Gini index were more likely to be Asian, Black, or Hispanic. Those living above the median Gini index were also less likely to speak English as their preferred language, to report currently drinking alcohol, to receive mechanical thrombectomy, to have private health insurance, to be discharged to an IRF facility, and to be

discharged as recommended. The median NIHSS was lower among those living above the median Gini index. The median NIHSS was also lower for Asians compared to other races (7 vs 9, p = 0.021).

Age, sex, comorbidities, tobacco use, and history of stroke were similar between the two groups. The proportion of patients recommended for discharge to IRF was also similar between the groups. Of the total 338 patients (of which 21 died during the hospitalization), 233 (74% of survivors) returned for follow-up. The two groups were equally likely to return for follow-up and returned after a similar length of time.

Gini index and functional independence at discharge and follow-up

In multivariate analyses, higher zip code Gini index was not associated with functional independence at discharge (OR = 0.977, 95% CI: 0.932–1.025) (Table 2). Predictors of a lower likelihood of independence at discharge included coronary artery disease (OR = 0.315, 95% CI: 0.122–0.814), higher initial NIHSS (OR = 0.786, 95% CI: 0.729–0.848), and receiving tPA (OR = 0.449, 95% CI: 0.210–0.963). Asian race was associated with an increased likelihood of independence at discharge (OR = 3.988, 95% CI: 1.041–15.278).

Table 2
Primary analysis: predictors of functional independence at discharge and follow-up.

	Independent at Discharge (n = 338)		Independent at Follow-up (n = 231)	
Predictor	**OR (95% CI)**	**P Value**	**OR (95% CI)**	**P Value**
Age	0.977 (0.954–1.001)	0.059	1.014 (0.984–1.045)	0.363
Sex	1.052 (0.569–1.944)	0.872	0.729 (0.334–1.592)	0.427
Female				
Male (Ref)				
Race	3.988 (1.041–15.278)	0.044	6.735 (1.077–42.128)	0.041
Asian	1.417 (0.464–4.327)	0.541	0.935 (0.196–4.467)	0.933
Black	3.874 (0.752–19.968)	0.105	2.319 (0.326–16.480)	0.400
Other				
White (Ref)				
Ethnicity	0.339 (0.056–2.053)	0.239	0.501 (0.063–4.011)	0.515
Hispanic	2.295 (0.624–8.441)	0.211	8.254 (1.461–46.621)	0.017
Non-Hispanic (Ref)				
Preferred language				
English				
Smoking status	0.535 (0.246–1.164)	0.115	0.950 (0.368–2.451)	0.916
Current smoker	1.464 (0.686–3.121)	0.324	2.132 (0.771–5.891)	0.144
Former smoker				
Alcohol	1.058 (0.532–2.101)	0.873	1.846 (0.706–4.825)	0.211
Current alcohol use	1.284 (0.325–5.074)	0.721	1.000 (0.163–6.153)	1.000
Former alcohol use				

	Independent at Discharge (n = 338)		Independent at Follow-up (n = 231)	
Predictor	**OR (95% CI)**	**P Value**	**OR (95% CI)**	**P Value**
Comorbidities	0.601 (0.248–1.459)	0.261	1.154 (0.362–3.679)	0.808
Atrial fibrillation	2.197 (0.978–4.959)	0.058	1.911 (0.672–5.435)	0.225
Carotid atherosclerosis	0.315 (0.122–0.814)	0.017	0.249 (0.058–1.063)	0.060
Coronary artery disease	0.620 (0.308–1.245)	0.179	1.035 (0.451–2.373)	0.936
Diabetes mellitus	1.337 (0.695–2.574)	0.384	1.402 (0.597–3.293)	0.438
Hyperlipidemia	0.806 (0.388–1.675)	0.564	0.142 (0.049–0.411)	< 0.001
Hypertension				
Stroke history	1.969 (0.878–4.414)	0.100	4.979 (1.840-13.474)	0.002
No previous strokes				
Stroke treatment	0.449 (0.210–0.963)	0.040	1.320 (0.535–3.262)	0.547
Received tPA	0.511 (0.168–1.556)	0.237	0.809 (0.249–2.634)	0.725
Received EVT				
Stroke severity	0.786 (0.729–0.848)	< 0.001	0.847 (0.791–0.908)	< 0.001
NIHSS at presentation				
Insurance status	0.833 (0.418–1.663)	0.605	0.550 (0.222–1.363)	0.196
Private insurance				
Discharge planning	N/A	N/A	0.150 (0.062–0.366)	< 0.001
D/c to IRF				
D/c as recommended	N/A	N/A	3.377 (1.087–10.493)	0.035
Time to follow-up	N/A	N/A	1.000 (1.000–1.000)	0.184
Gini index	0.977 (0.932–1.025)	0.346	0.926 (0.866–0.989)	0.022

Higher Gini index was associated with a lower likelihood of independence at follow-up (OR = 0.926, 95% CI: 0.866–0.989) (Table 2). Other predictors of a lower likelihood of independence at follow-up included hypertension (OR = 0.142, 95% CI: 0.049–0.411), higher initial NIHSS (OR = 0.847, 95% CI: 0.791–0.908), and discharge to an IRF facility (OR = 0.150, 95% CI: 0.062–0.366). Predictors of increased likelihood of independence at follow-up were Asian race, (OR = 6.735, 95% CI: 1.077–42.128), English preferred language (OR = 8.254, 95% CI: 1.461–46.621), no prior history of stroke (OR = 4.979, 95% CI: 1.840-13.474), and being discharged as recommended (OR = 3.377, 95% CI: 1.087–10.493).

A post-hoc sensitivity analysis assessed associations between Gini index quintile and the likelihood of functional independence at follow-up. Living in the zip code within the top Gini index quintile was associated with a lower likelihood of independence at follow-up (OR = 0.328, 95% CI: 0.108–0.993) (Supplemental Appendix Table 1). Gini index quintile was not associated with independence at discharge. An additional analysis included an interaction term between Gini index and being discharged as recommended, but this was not associated with functional independence at follow-up (not shown).

Gini index and odds of being discharged as recommended

In a secondary analysis of patients recommended for discharge to IRF, higher Gini index was associated with a lower likelihood of being discharged as recommended (OR = 0.909, 95% CI 0.841–0.983) (Table 3). Asian race was associated with a reduced likelihood of being discharged as recommended (OR = 0.093, 95% CI 0.011–0.766); this finding was robust to coding of race as a categorical or binary variable (Asian vs. other, Black vs. other, white vs. other). Private insurance was associated with an increased likelihood of being discharged as recommended (OR = 3.240, 95% CI: 1.057–9.931). An additional analysis included an interaction term between Gini index and race, but this was not associated with being discharged as recommended (not shown).

Table 3
Secondary analysis: predictors of being discharged as recommended among those recommended for IRF.

	Discharged as Recommended (n = 155)	
Predictor	**OR (95% CI)**	**P Value**
Age	0.970 (0.931–1.011)	0.153
Sex	0.363 (0.125–1.056)	0.063
Female		
Male (Ref)		
Race	0.093 (0.011–0.766)	0.027
Asian	1.255 (0.108–14.646)	0.856
Black	1.326 (0.085–20.695)	0.841
Other		
White (Ref)		
Ethnicity	1.067 (0.108–10.525)	0.955
Hispanic		
Non-Hispanic (Ref)		
Preferred language	0.283 (0.036–2.211)	0.229
English	1.354 (0.323–5.682)	0.679
Smoking status	0.508 (0.155–1.664)	0.263
Current smoker		
Former smoker		
Alcohol	0.627 (0.194–2.025)	0.435
Current alcohol	1.025 (0.084–12.510)	0.985
Former alcohol		

	Discharged as Recommended (n = 155)	
Predictor	**OR (95% CI)**	**P Value**
Comorbidities	0.484 (0.153–1.534)	0.218
Atrial fibrillation	0.721 (0.220–2.357)	0.588
Carotid atherosclerosis	0.489 (0.119–2.015)	0.322
Coronary artery disease	0.809 (0.274–2.393)	0.702
Diabetes mellitus	1.096 (0.394–3.048)	0.861
Hyperlipidemia	1.491 (0.444–5.004)	0.518
Hypertension		
Stroke history	0.694 (0.216–2.229)	0.539
No previous strokes		
Stroke treatment	1.302 (0.381–4.458)	0.674
Received tPA	0.615 (0.147–2.565)	0.504
Received EVT		
Stroke severity	1.065 (0.984–1.153)	0.121
NIHSS at presentation		
Insurance status	3.240 (1.057–9.931)	0.040
Private insurance		
Gini index	0.909 (0.841–0.983)	0.017

Discussion

To our knowledge, this is the first study to assess an association between neighborhood income inequality and post-stroke outcomes. This study demonstrates that increased income inequality as indicated by zip code Gini index is associated with a lower likelihood of achieving functional independence by the time of outpatient follow-up. Specifically, each 1% increase in neighborhood Gini index decreased the likelihood of independence at follow-up by over 7%. Accounting for the range of income inequality in our sample of Massachusetts residents, patients living in the highest income inequality neighborhoods were 220% less likely to achieve functional independence by follow-up compared to those in the lowest inequality neighborhoods. Living in a zip code within the top inequality quintile was associated with a 67% decreased likelihood of independence at follow-up compared to all other zip codes. The dissociation between Gini index and functional independence at discharge versus

follow-up indicates that the effect of neighborhood inequality is occurring during the post-hospitalization phase of care. Considering the importance of post-stroke rehabilitation in accelerating recovery from stroke deficits, this association may reflect a previously unappreciated source of disparity that could affect access to or availability of rehabilitation resources for stroke survivors.[12]

This disparity in functional outcomes may be driven by discharge destination. The primary analysis indicated that patients who were discharged to the recommended setting were 240% more likely to be independent at follow-up. However, patients from high inequality neighborhoods were less likely to be discharged as recommended. Univariate analysis indicated that these patients were equally likely to be recommended for IRF, but less likely to actually be discharged to an IRF. The secondary analysis (including only patients recommended for IRF) corroborated this finding, such that each 1% increase in Gini index was associated with a 9% decreased likelihood of being discharged to the recommended setting. As such, patients living in high inequality neighborhoods appear to be less likely to receive recommended care following discharge. This is consistent with previous studies that identified SES as a predictor for discharge destination in other clinical settings and conditions.[13–14] Given that rehabilitation care is associated with improved functional outcomes after stroke, this disparity in discharge destination likely contributes substantially to the disparity in functional outcomes.[12] Accordingly, identifying and addressing barriers to accessing optimal post-stroke rehabilitation services among people living in high income inequality neighborhoods is a priority in improving the functional outcomes of patients in an equitable manner.

Despite all non-white races being more likely to live in high inequality neighborhoods, only Asian race was associated with a disparate outcome in adjusted analyses: lower likelihood of being discharged as recommended. The reasons for this observation and the impact on functional outcome are unclear, however. We initially suspected based on clinical experience at our center that Asian patients would be more likely to select lower intensity rehabilitation facilities with staff that speak Asian languages, but this analysis indicates that preferred language was not a predictor. Additionally, Asian patients were more likely to be functionally independent at discharge and at follow-up, potentially due to lower stroke severity observed in this subset of our study population. As a result, with fewer Asian patients being recommended to be discharged to IRF, our study was likely not sufficiently statistically powered to detect the impact of not being discharged as recommended on functional outcomes for this subgroup.

The city of Boston, which has one of the highest Gini indices as compared to other cities in the United States,[15] was a major site of income inequality in our study cohort (Supplemental Appendix Table 2). Nearly a quarter of the cohort (24%) lived in Boston and 28 of the 30 Boston zip codes included in our analysis had Gini indices above the study median (43%). The four highest inequality neighborhoods (South End, Back Bay, Chinatown, and Fenway-Kenmore) were all located in Boston and had Gini indices over 60% (well above the national and state averages of 48%).[16] Over 12% of the cohort lived in one of these four neighborhoods. Given the high rates of income inequality in these neighborhoods, it is likely that socioeconomic factors within the city of Boston are significant drivers of the aforementioned

associations. Accordingly, gentrification is important to consider because the observed association between income inequality and post-stroke disability may be mediated by availability and access to neighborhood resources (i.e. rehabilitation care) and race.

Boston has one of the highest rates of gentrification in the United States.[17] While existing research regarding the causes and consequences of gentrification is highly varied, gentrification has been associated with both high rates of income inequality and negative health outcomes.[18–20] Importantly, gentrification has also been associated with demographic changes.[21] This may play a role in stroke recovery because the resources available within a community may not reflect the needs of those with less disposable income. Chinatown, for instance, is currently home to both a longstanding East Asian immigrant community (which is older and low income on average) and a recent influx of white professionals (which is younger and high income on average).[22] Neighborhood investment in post-stroke rehabilitation services is likely not a priority for the high income young professionals, and thus, these needed services may not be available or accessible to the low income immigrant community. Similar demographic and economic dichotomies are likely seen in other high inequality neighborhoods in Boston (such as South End, Back Bay, and Kenmore).[23]

This study has some important strengths and limitations. First, this study used a novel measure of socioeconomic status, neighborhood income inequality, that has not (to our knowledge) been previously used to assess disparities in post-stroke care. Of note, this measure uses community level data, so it does not entirely account for personal measures of socioeconomic status (although insurance status was included in multivariate analyses). This measure of SES extends beyond the individual patient's resources and may reflect the influence of caregiver and community resources, planning, and priorities. This study did not adjust for other community level measures of socioeconomic status (e.g. area deprivation index) because some measures are not valid at the zip code level or may obscure relevant disparities in income distribution. Second, our study's diverse sample draws from a broad catchment area including an urban, metropolitan area and several suburban communities throughout Eastern and Central Massachusetts. Based on our center's proximity in Boston's Chinatown, the sample did have a disproportionally large representation of East Asian immigrants, limiting generalizability of these results but also offering an opportunity to better understand outcomes for this subgroup. Finally, our center's standard follow-up interval was 4–6 weeks post-stroke as opposed to 90 days, so these results are not comparable to other stroke outcome studies with 90 days mRS assessments. However, based on the natural history of recovery from ischemic stroke, we anticipated that we would be able to detect differences in recovery trajectories. Our analyses were indeed able to detect different trajectories of recovery based on Gini index, and we accounted for variance in follow-up times by adjusting for time-to-follow-up in our regression analyses.

Conclusions

Higher neighborhood income inequality is associated with a lower likelihood of achieving functional independence at the time of follow-up after ischemic stroke. This disparity may be driven by discharge destination (e.g. when IRF is recommended). Additional research is needed to assess the role of gentrification and demographic shifts in shaping community prioritization of availability and access to post-stroke rehabilitation services.

Declarations

Disclosures

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Figures

Figure 1 Study Population

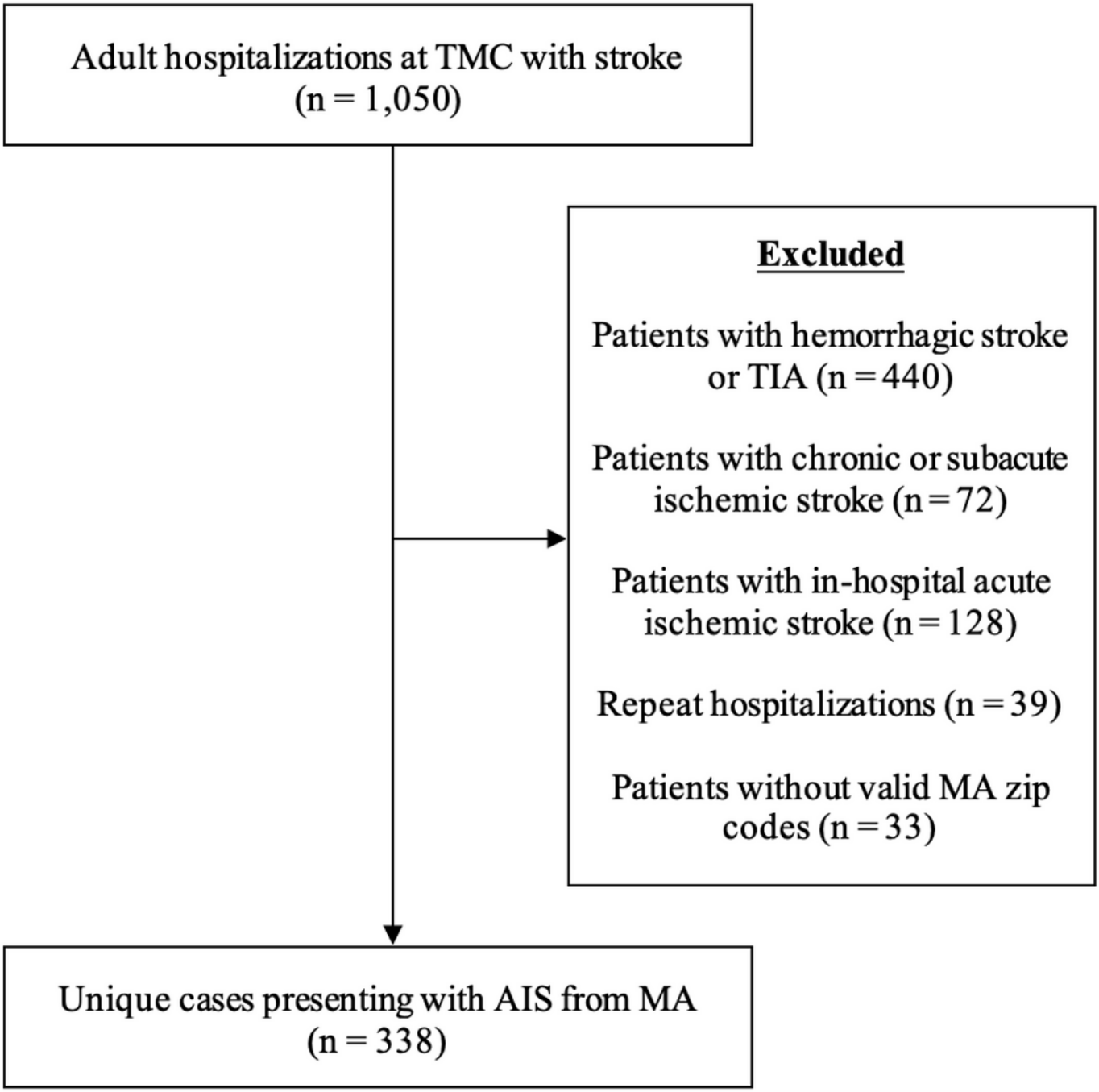

Figure 1

Study Population

Supplementary Files

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- cotetable4app1.docx
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