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BRIEF COMMUNICATION

Racial Disparity in Mechanical Thrombectomy Utilization: Multicenter Registry Results From 2016 to 2020

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BACKGROUND: Previous studies on racial disparity in mechanical thrombectomy (MT) treatment of acute large vessel occlusion stroke lack individual patient data that influence treatment decision-making. We assessed patient-level data in a large US health care system from 2016 to 2020 for racial disparities in MT utilization and eligibility.

METHODS AND RESULTS: A retrospective study was performed of 34 596 patients admitted to 43 hospitals from January 2016 to September 2020. Data included patient age, sex, race, residential zip code median income and population density, presenting hospital stroke certification, baseline ambulation, and National Institutes of Health stroke scale. The cohort included 26 640 White, non-Hispanic (77.0%), and 7956 African American/Black (23.0%) patients. In multivariable logistic regression, Black patients were less likely to undergo MT (adjusted odds ratio [OR], 0.65; 95% CI, 0.54–0.76), arrive within 5 hours of "last known well" (adjusted OR, 0.73; 95% CI, 0.69–0.78), and have documented anterior circulation large vessel occlusion (adjusted OR, 0.78; 95% CI, 0.64–0.96). Race was not associated with MT rate among patients arriving within 5 hours of last known well with documented acute large vessel occlusion.

CONCLUSIONS: Black patients with stroke underwent MT less frequently than White patients, likely in part because of longer times from last known well to hospital arrival and a lower rate of documented acute large vessel occlusion. Further studies are needed to assess whether extending the MT time window and more aggressive large vessel occlusion screening protocols mitigate this disparity.

Key Words: disparities ■ race ■ stroke ■ thrombectomy

Racial disparity in the utilization of mechanical thrombectomy (MT) for treatment of acute ischemic stroke caused by large vessel occlusion (LVO) has been previously documented.[1,2] However, there is a paucity of data regarding the status of this disparity in recent years, during which health care infrastructure expansion has increased access to MT. In addition, previous studies utilized data from national databases that lacked the individual patent data necessary to determine eligibility for the procedure. The present study analyzed patient-level data from one of the largest health care systems in the United States to investigate the extent of, and potential reasons for, persistent racial disparity in MT utilization from 2016 to 2020.

METHODS

Institutional review board approval was obtained for this study, including waiver of informed consent. The data that support the findings of this study are available from the corresponding author on reasonable request, pending approval by the Ascension Data Science Institute.

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A system of 43 hospitals in 12 states (AL, FL, IL, IN, KS, MD, MI, NY, OK, TN, TX, WI) contributed to a collective stroke database (Table S1), from which data were extracted for all patients presenting between January 1, 2016, and September 30, 2020, with a diagnosis of ischemic stroke or transient ischemic attack. Table 1 lists the demographic and clinical variables of interest. Demographic data were obtained in accordance with hospital-specific registration protocols. The median income of a patient's residential zip code was derived from publicly available government data and used as a proxy for socioeconomic status.[3] Urban zip codes were defined in accordance with the US Census Bureau as a densely developed territory with a population of at least 50 000. High-volume stroke centers were defined as hospitals averaging >10 stroke admissions per month during the study period.

Demographic and clinical variables were dichotomized and subgroups were compared with respect to each of the following dependent variables: (1) overall rate of treatment with MT; (2) proportion of patients arriving at the hospital within 5 hours of "last known well" (LKW; "early arrival"); (3) proportion of early-arrival patients with documented anterior circulation LVO (aLVO), defined as internal carotid artery terminus, M1 or M2 occlusion on vascular imaging (computed tomographic angiography or magnetic resonance angiography, depending on hospital-specific stroke triage protocols); and (4) rate of MT among early-arrival patients with documented aLVO. An early-arrival threshold of 5 hours from LKW was used to allow for groin puncture within the MT "early time window" of 6 hours. Patients were selected for MT according to hospital-specific protocols. A mixed effects logistic regression model was then constructed for each dependent variable. Demographic and clinical variables with $P<0.20$ in univariable analysis were included as fixed effects, and presenting hospital was included as a random effect. A P value <0.05 was considered statistically significant.

Statistical methods for addressing missing data are detailed in Data S1. In particular, patients who initially presented to our hospital network and were then transferred to a hospital outside our network (out-of-network transfers) were excluded from the study

Table 1. Comparison of Demographics, Clinical Characteristics, and Outcomes of White and Black Patients

	Total cohort (N=34 596)	White patients (n=26 640)	Black patients (n=7956)	*P* value
Demographics				
Age (mean±SD), y	71.3±14.3	73.1±13.9	65.0±14.0	<0.01
Sex				<0.01
Male	16 669	12 983 (48.7)	3686 (46.3)	
Female	17 927	13 657 (51.3)	4270 (53.7)	
Residential zip code median income <$50 000	24 023	17 098 (64.2)	6925 (87.0)	<0.01
Urban residential zip code	8064	4160 (15.6)	3904 (49.1)	<0.01
Presenting hospital, CSC/TSC	20 329	15 369 (57.7)	4960 (62.3)	<0.01
Presenting hospital, high-volume	30 784	23 792 (89.3)	6992 (87.9)	<0.01
Region				<0.01
Midwest	21 114	15 843 (59.5)	5271 (66.3)	
South	9312	8000 (30.0)	1312 (16.5)	
East	4170	2797 (10.5)	1373 (17.3)	
Clinical characteristics				
Baseline ambulation				<0.01
Independent	31 302	24 086 (90.4)	7216 (90.7)	
With assistance	2169	1725 (6.5)	444 (5.6)	
Unable	1125	829 (3.1)	296 (3.7)	
NIHSS, median (IQR)	3.0 (1.0–8.0)	3.0 (1.0–7.0)	3.0 (1.0–8.0)	0.22
Outcomes				
Treated with mechanical thrombectomy	1190 (3.4)	957 (3.6)	233 (2.9)	<0.01
Early arrival*	11 475 (33.2)	9289 (34.9)	2186 (27.5)	<0.01
Early-arrival patients with documented aLVO	1112 (9.7)	924 (9.9)	188 (8.6)	0.06
Early-arrival patients with documented aLVO treated with mechanical thrombectomy	726 (65.3)	602 (65.2)	124 (66.0)	0.87

aLVO indicates anterior circulation large vessel occlusion; CSC, comprehensive stroke center; IQR, interquartile range; NIHSS, National Institute of Health Stroke Scale; and TSC, thrombectomy-capable stroke center.

*Early arrival was defined as hospital presentation within 5 h of "last known well."

cohort because it is unknown whether these patients underwent MT, and sensitivity analysis confirmed that exclusion of these patients did not qualitatively affect our results with respect to race. All statistical analyses were performed using R version 4.0.3 (The R Foundation).

RESULTS

Cohort characteristics stratified by race are summarized in Table 1. The study included 34 596 patients with a mean age of 71.2 years (interquartile range, 62–82 years); 16 669 were men (48.2%) and 17 927 were women (51.8%); 26 640 were White, non-Hispanic (77.0%) and 7956 were African American or Black (23.0%). Black patients were more likely than White patients to be women (53.7 versus 51.3, $P<0.01$), reside in a zip code with an annual median income <$50 000 (87.0% versus 64.2%, $P<0.01$), reside in an urban zip code (49.1% versus 15.6%, $P<0.01$), present to a comprehensive or thrombectomy-capable stroke center (62.4% versus 57.7%, $P<0.01$), present to hospitals in the Midwest and East Coast (66.3% versus 59.5% and 17.3% versus 10.5%, respectively), ambulate independently (90.7% versus 90.4%), or be unable to ambulate (3.7% versus 3.1%) at baseline. Black patients were less likely to present to a high-volume stroke center (87.9% versus 89.3%, $P<0.01$), present to hospitals in the South (16.5% versus 30.0%), and ambulate with assistance at baseline (5.6% versus 6.5%).

The overall rate of MT was 3.4% (1190 of 34 596). Overall, MT utilization rates for demographic and clinical subgroups are listed in Table S2. In multivariable analysis, significantly lower rates of MT were seen among Black patients compared with White patients (adjusted odds ratio [OR], 0.65; 95% CI, 0.54–0.76) (Table 2). The cohort included 11 475 patients (33.2%) who arrived within 5 hours of LKW (Table S3). In multivariable analysis, Black patients were less likely than White patients to arrive at the hospital within 5 hours of LKW (adjusted OR, 0.73; 95% CI, 0.69–0.78) (Table 2). Among early-arrival patients, 1112 (9.7%) had vascular imaging that showed an aLVO (Table S4). In multivariable analysis, aLVO was less commonly documented in Black patients compared with White patients (adjusted OR, 0.78; 95% CI, 0.64–0.96) (Table 2). Among early-arrival patients with documented aLVO, 726 (65.3%) underwent MT (Table S5). In univariable analysis, rates of MT among White and Black patients were comparable (65.2% versus 66.0%, respectively; $P=0.83$).

DISCUSSION

Previous studies have shown that Black patients were less likely than White patients to be treated with MT before the landmark MT clinical trials.[1,2] For example, using diagnosis and procedure codes in the Nationwide Inpatient Sample from 2006 to 2014, Esenwa et al[2] found that MT rates were a third lower in Black patients compared with White patients (OR, 0.67; 95% CI, 0.58–0.76). A more recent analysis of a national database that included billing records and diagnosis codes from 2016 to 2018 similarly found that even in the thrombectomy era, Black race was independently associated with lower institutional utilization of MT.[1] Our study shows that despite recognition of this racial disparity and increased access to MT in recent years, this problem has persisted, with Black patients still ≈35% less likely than White patients to be treated with MT. In addition, while prior studies could not control for clinical factors because of a lack of patient-level data, our multivariable analysis shows that this racial disparity is independent of baseline ambulatory status and stroke severity.

Our study identifies two potential targets for interventions to minimize racial disparity in MT utilization. First, Black patients were almost 30% less likely than White patients to arrive at the hospital within 5 hours of LKW. Longer LKW-to-arrival times among Black patients, primarily attributed to lower stroke literacy and lack of trust in the health care system owing to historic inequalities, is hypothesized to be a driver of racial disparity in intravenous tissue plasminogen activator administration[4,5] and likely also contributes to

Table 2. Adjusted ORs of Study Outcomes for Black Patients Relative to White Patients

Outcome	Adjusted OR (95% CI)	*P* value
Treatment with mechanical thrombectomy*	0.65 (0.54–0.76)	<0.01
Early arrival (within 5 h of "last known well")†	0.73 (0.69–0.78)	<0.01
Documented anterior circulation large vessel occlusion among early-arrival patients‡	0.78 (0.64–0.96)	0.02

OR indicates odds ratio.

*Fixed effects included in the model: race, median income of residential zip code, presentation to a comprehensive stroke center/thrombectomy-capable stroke center (CSC/TSC), presenting hospital region, presentation to a high-volume stroke center, baseline ambulatory function, and stroke severity.

†Fixed effects included in the model: median income and population density of residential zip code, presenting hospital region, baseline ambulatory function, and stroke severity.

‡Fixed effects included in the model: age, sex, median income and population density of residential zip code, presentation to a CSC/TSC, presenting hospital region, presentation to a high-volume stroke center, baseline ambulatory function, and stroke severity.

racial disparity in MT eligibility. Randomized controlled trials have shown that education initiatives such as the HipHop Stroke intervention and Black beautician stroke education effectively reduce racial disparities in timely hospital arrival after stroke onset.[6] Moreover, studies are needed to assess whether advances that extend the MT time window, such as perfusion imaging, impact racial disparity in MT utilization.

Second, our study also shows that Black patients less frequently underwent MT because of a lower incidence of documented aLVO (adjusted OR, 0.78; 95% CI, 0.64–0.96). The rate of aLVO may have been lower among Black patients because of racial differences in stroke cause, including a higher prevalence of cardioembolic stroke in White patients and a higher prevalence of intracranial atherosclerosis in Blacks.[7,8] However, studies have also shown that Black patients with stroke experience longer times between hospital arrival and head computed tomography scan[9] and are less likely to undergo noninvasive cerebrovascular testing.[10] It is unknown whether emergent vascular imaging was obtained at comparable rates in Black and White patients because our data set lacked consistent documentation of the timing of vascular imaging. Well-documented racial disparities in stroke prevention, treatment, and recovery have been attributed to implicit bias, as well as structural factors such as long-standing inequities in health care access.[11] Therefore, it is entirely possible that systemic racial bias contributes to lower rates of LVO screening of Black patients with resultant underreporting of MT eligibility. Further studies are needed to assess for racial disparities in LVO screening among patients arriving within the MT time window, in which case racial disparity may be mitigated by more aggressive LVO screening protocols.

This study has limitations to acknowledge. First, as with any large multicenter registry, our data are subject to biases and recording error, including racial designations. While self-reporting of race and ethnicity is recommended, some patients' races may have been documented by observation of admitting or registration staff. We also acknowledge that the broad racial categories utilized in this and other publications on demographic disparities in health care poses a potential limitation. Similarly, our results may be confounded by changes in hospital-specific protocols during the study period, as is always the case with temporal data. Second, our study focused on patients with aLVO presenting during the early time window because American Heart Association guidelines regarding MT utilization in this population are supported by level I evidence. Still, we acknowledge that variation in MT utilization as a result of the discretion of treating physicians, unrelated to implicit racial bias, is a potential study limitation. Third, while our study included data from 43 hospitals in 12 states, our results may not be generalizable to states not represented. Fourth, 11.6% of baseline ambulatory data and 9.2% of presenting National Institute of Health Stroke Scale scores were imputed. However, a key strength of this study is the overall availability of clinical data, which unlike prior studies, allowed us to control for these variables when analyzing demographic disparities. Last, patients transferred out of our network were excluded from this analysis because their subsequent treatment is unknown. As detailed in Data S1, exclusion of these patients did not qualitatively affect our results regarding racial disparities. However, out-of-network transfers were disproportionately from low-income, nonurban residential zip codes. Therefore, our data cannot be used to draw independent conclusions regarding the impact of patient residential zip code median income and population density on MT rates.

CONCLUSIONS

Recent data from a large multicenter cohort show Black patients with stroke are still treated with MT less frequently than White patients. Contributing factors likely include longer times from LKW to hospital arrival and a lower rate of documented aLVO among Black patients. Further studies are needed to assess whether racial disparity in MT treatment may be mitigated by advances in stroke care that extend the MT time window or more aggressive LVO screening protocols.

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Supplemental Material

Data S1. Supplemental Methods
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Supplemental Material

Data S1.

Supplemental Methods – Missing Data Analysis

From January 2016 – September 2020, 39,645 patients presented to our network of 43 hospitals with a diagnosis of ischemic stroke or transient ischemic attack (TIA). Missing data were handled according to the methods described by Jakobsen, et al.[12] If the missing proportion of a data element was <5% and could be plausibly considered to be missing at random, then the missing data were ignored. The following missing data met these criteria:

Data Element	Missing, N (%)
Race	4 (0.010)
Sex	12 (0.030)
Residential Zip Code	279 (0.78)
Median Income of Residential Zip Code	139 (0.035)
Middle Cerebral Artery Occlusion Site	452 (1.1)

Race, sex and residential zip code data were missing due to lack of documentation. Residential zip code median income data were not available for patients residing outside the Unites States. Middle cerebral artery occlusion site was considered missing when the site of large vessel occlusion was documented as "middle cerebral artery" without specification of the occluded segment (e.g. M1, M2 or distal branch).

Missing baseline ambulatory status and presenting National Institute of Health Stroke Scale

(NIHSS) could not be ignored because the missing proportions were 10.3% (4,089/39,645) and 8.2% (3,269/39,645), respectively. These data were assumed to be missing at random, but both are known to correlate with age, race, and sex[13-15]. Consequently, missing values were imputed using Multiple Imputation by Chained Equations, as described by Jakobsen, et al.[12] Polynomial regression and predictive mean matching were used to impute missing baseline ambulatory status (categorized as "independent", "with assistance" or "unable") and presenting NIHSS values, respectively, with age, race and sex as covariates.

Clinical outcomes were not available for 0.82% (324/39,645) of the cohort because these patients were transferred to hospitals not included in our registry ("out-of-network transfers"). Outcome data for these patients cannot be considered missing at random, because some of these patients may have been transferred for higher-level stroke care, including mechanical thrombectomy (MT). To determine the impact of these missing data on our results, best-worst case sensitivity analysis was performed, as described by Jakobsen, et al.[12] First, all out-of-network transfers were assumed to have been treated with MT. Demographic and clinical variables were dichotomized and subgroups were compared with respect to rates of MT, hospital arrival within 5 hours of last known well ("early arrival"), rates of documented anterior circulation large vessel occlusion (aLVO) among early arrival patients, and rates of MT among early arrival patients with documented aLVO. Mixed effects logistic regression models were then constructed for each dependent variable using demographic and clinical variables with $P<0.20$ in univariable analysis as fixed effects and presenting hospital as a random effect. A P-value ≤ 0.05 was considered statistically significant in univariable and multivariable analyses. The analysis was then repeated

assuming no out-of-network transfers underwent MT. The results of the sensitivity analysis were as follows:

Adjusted odds ratios of study outcomes for Black patients assuming all out-of-network transfers were treated with MT ("Best-case")

Outcome	Adjusted Odds Ratio (95% Confidence Interval)
Treatment with mechanical thrombectomy	0.74 (0.54 - 0.76)
Early arrival (within 5 hours of last known well)	0.76 (0.71 - 0.78)
Documented anterior circulation large vessel occlusion among early arrival patients	0.78 (0.64 - 0.95)

Adjusted odds ratios of study outcomes for Black patients assuming no out-of-network transfers were treated with MT ("Worst-case")

Outcome	Adjusted Odds Ratio (95% Confidence Interval)
Treatment with mechanical thrombectomy	0.67 (0.56 - 0.81)
Early arrival (within 5 hours of last known well)	0.76 (0.71 - 0.81)
Documented anterior circulation large vessel occlusion among early arrival patients	0.78 (0.64 - 0.95)

The multivariable models for treatment with MT included the following fixed effects: race, median income of residential zip code, presentation to CSC/TSC, presenting hospital region,

presentation to high-volume stroke center, baseline ambulatory function, and stroke severity. The multivariable models for early arrival included the following fixed effects: median income and population density of residential zip code, presenting hospital region, baseline ambulatory function, stroke severity. The multivariable model of documented aLVO among early arrival patients included the following fixed effects: age, sex, median income and population density of residential zip code, presentation to CSC/TSC, presenting hospital region, presentation to high-volume stroke center, baseline ambulatory function, stroke severity. Rates of MT among early arriving patients with documented aLVO were not significantly different between Black and white patients in univariable analysis regardless of whether all out-of-network transfers were assumed to have been treated with MT (White, 66.0%; Black, 67.2%; P=0.75) or no out-of-network transfers were assumed to have been treated with MT (White, 63.8%; Black, 64.6%; P=0.83). Consequently, out-of-network transfers were excluded from the final analysis because our results with regards to racial disparities did not qualitatively change when all or none of these patients were assumed to have been treated with MT.

Table S1. Demographics of hospitals contributing data to this study.

	Ascension Providence Hospital (Mobile, AL)	Ascension Sacred Heart Hospital (Pensacola, FL)	Ascension St. Vincent's Clay County (Middleburg, FL)	AMITA Health Saint Joseph Medical Center (Joliet, IL)
Age, mean +/- SD	70.4 +/- 13.1	69.5 +/- 14.4	69.0 +/- 13.6	71.5 +/- 14.7
Sex				
Male	411 (50.2)	728 (51.1)	116 (52.5)	315 (49.2)
Female	407 (49.8)	698 (48.9)	105 (47.5)	325 (50.8)
Race				
White, non-Hispanic	652 (79.7)	1,098 (77.0)	191 (86.4)	540 (84.4)
Black/African American	166 (20.3)	328 (23.0)	30 (13.6)	100 (15.6)
Residential zip code median income < $50k	713 (87.2)	1,073 (75.2)	143 (64.7)	145 (22.7)
Urban residential zip code	0 (0.0)	2 (0.14)	42 (19.0)	2 (0.31)
Ambulation				
Independent	747 (91.3)	1,312 (92.0)	202 (91.4)	364 (56.9)
with Assistance	37 (4.5)	67 (4.7)	12 (5.4)	254 (39.7)
NIHSS, median (IQR)	3 (1.0-8.0)	4 (1.0-10.0)	2 (1.0-5.0)	3 (1.0-9.0)
CSC or TSC	No	Yes	No	Yes
Stroke presentations/month	14.4	25.0	3.9	11.2

	AMITA Health Saint Francis Hospital (Evanston, IL)	AMITA Health St. Alexius Medical Center (Hoffman Estates, IL)	AMITA Health Alexian Brothers Medical Center (Elk Grove, IL)	AMITA Health Saint Joseph Hospital (Chicago, IL)
Age, mean +/- SD	72.4 +/- 14.8	72.2 +/- 13.9	73.0 +/- 13.7	75.1 +/- 14.2
Sex				
Male	104 (43.7)	333 (49.3)	444 (48.1)	62 (44.0)
Female	134 (56.3)	343 (50.7)	480 (51.9)	79 (56.0)
Race				
White, non-Hispanic	139 (58.4)	626 (92.6)	884 (95.7)	102 (72.3)
Black/African American	99 (41.6)	50 (7.4)	40 (4.3)	39 (27.7)
Residential zip code median income < $50k	89 (37.4)	94 (13.9)	145 (15.7)	24 (17.0)
Urban residential zip code	167 (70.2)	10 (1.5)	21 (2.3)	132 (93.6)
Ambulation				
Independent	188 (79.0)	623 (92.2)	851 (92.1)	123 (87.2)
with Assistance	30 (12.6)	27 (4.0)	48 (5.2)	14 (9.9)
NIHSS, median (IQR)	3 (1.0-7.0)	2 (1.0-6.0)	3 (1.0-8.0)	2 (1.0-6.0)
CSC or TSC	No	No	Yes	No
Stroke presentations/month	4.2	11.9	16.2	2.5

	AMITA Health Resurrection Medical Center (Chicago, IL)	AMITA Health Saints Mary and Elizabeth Medical Center (Chicago, IL)	AMITA Health Adventist Medical Center (Hinsdale, IL)	AMITA Health Adventist Medical Center (Glendale Heights, IL)
Age, mean +/- SD	75.1 +/- 14.3	66.8 +/- 12.5	76.4 +/- 13.8	72.0 +/- 14.4
Sex				
Male	323 (51.2)	79 (58.1)	273 (45.9)	116 (46.4)
Female	308 (48.8)	57 (41.9)	322 (54.1)	134 (53.6)
Race				
White, non-Hispanic	600 (95.1)	42 (30.9)	559 (93.9)	217 (86.8)
Black/African American	31 (4.9)	94 (69.1)	36 (6.1)	33 (13.2)
Residential zip code median income < $50k	65 (10.3)	65 (47.8)	280 (47.1)	49 (19.6)
Urban residential zip code	382 (60.5)	123 (90.4)	15 (2.5)	4 (1.6)
Ambulation				
Independent	571 (90.5)	120 (88.2)	543 (91.3)	226 (90.4)
with Assistance	43 (6.8)	6 (4.4)	21 (3.5)	14 (5.6)
NIHSS, median (IQR)	2 (1.0-6.0)	2 (1.0-6.0)	1 (0.0-5.0)	4 (1.0-10.0)
CSC or TSC	Yes	No	No	No
Stroke presentations/month	11.1	2.4	10.4	4.4

	AMITA Health Adventist Medical Center (La Grange, IL)	AMITA Health Adventist Medical Center (Bolingbrook, IL)	Ascension St. Vincent Hospital (Evansville, IN)	Ascension St. Vincent Hospital (Indianapolis, IN)
Age, mean +/- SD	75.9 +/- 13.5	70.3 +/- 15.1	70.4 +/- 14.3	72.1 +/- 14.6
Sex				
Male	290 (46.6)	173 (45.1)	444 (49.2)	916 (45.7)
Female	332 (53.4)	211 (54.9)	459 (50.8)	1,088 (54.3)
Race				
White, non-Hispanic	581 (93.4)	295 (76.8)	807 (89.4)	1,466 (73.2)
Black/African American	41 (6.6)	89 (23.2)	96 (10.6)	538 (26.8)
Residential zip code median income < $50k	266 (42.8)	32 (8.3)	756 (83.7)	1,430 (71.4)
Urban residential zip code	27 (4.3)	5 (1.3)	0 (0.0)	36 (1.8)
Ambulation				
Independent	576 (92.6)	353 (91.9)	859 (95.1)	1,860 (92.8)
with Assistance	26 (4.2)	9 (2.3)	31 (3.4)	62 (3.1)
NIHSS, median (IQR)	2 (0.0-5.0)	2 (0.0-7.0)	3 (1.0-7.0)	3 (1.0-8.0)
CSC or TSC	No	No	No	Yes
Stroke presentations/month	10.9	6.7	15.8	35.2

	Ascension St. Vincent Anderson Regional Hospital (Anderson, IN)	Ascension Via Christi St. Francis Hospital (Wichita, KS)	Ascension Via Christi St. Joseph Hospital (Wichita, KS)	St. Agnes Hospital (Baltimore, MD)
Age, mean +/- SD	71.1 +/- 14.5	71.9 +/- 14.5	67.5 +/- 14.1	70.9 +/- 14.7
Sex				
Male	278 (45.7)	786 (47.9)	71 (49.3)	850 (46.8)
Female	330 (54.3)	854 (52.1)	73 (50.7)	967 (53.2)
Race				
White, non-Hispanic	547 (90.0)	1,448 (88.3)	113 (78.5)	837 (46.1)
Black/African American	61 (10.0)	192 (11.7)	31 (21.5)	980 (53.9)
Residential zip code median income < $50k	570 (93.8)	1,474 (89.9)	142 (98.6)	1,286 (70.8)
Urban residential zip code	0 (0.0)	1 (0.061)	0 (0.0)	776 (42.7)
Ambulation				
Independent	543 (89.3)	1,507 (91.9)	139 (96.5)	1,585 (87.2)
with Assistance	44 (7.2)	66 (4.0)	3 (2.1)	166 (9.1)
NIHSS, median (IQR)	3 (1.0-8.0)	5 (2.0-11.0)	2 (1.0-4.0)	3 (1.0-6.0)
CSC or TSC	No	Yes	No	No
Stroke presentations/month	10.7	28.8	2.5	31.9

	Ascension Saint Mary's Hospital (Livonia, MI)	Ascension Macomb Oakland Hospital (Warren, MI)	Ascension St. John Hospital and Medical Center (Detroit, MI)	Ascension Genesys Hospital (Grand Blanc, MI)
Age, mean +/- SD	69.8 +/- 13.7	69.2 +/- 14.9	67.3 +/- 14.9	71.7 +/- 14.0
Sex				
Male	339 (49.1)	389 (48.3)	749 (48.4)	853 (47.3)
Female	351 (50.9)	417 (51.7)	797 (51.6)	951 (52.7)
Race				
White, non-Hispanic	550 (79.7)	600 (74.4)	623 (40.3)	1,682 (93.2)
Black/African American	140 (20.3)	206 (25.6)	923 (59.7)	122 (6.8)
Residential zip code median income < $50k	563 (81.6)	678 (84.1)	1,156 (74.8)	1,183 (65.6)
Urban residential zip code	0 (0.0)	63 (7.8)	748 (48.4)	1 (0.055)
Ambulation				
Independent	614 (89.0)	737 (91.4)	1,417 (91.7)	1,720 (95.3)
with Assistance	56 (8.1)	40 (5.0)	100 (6.5)	47 (2.6)
NIHSS, median (IQR)	3 (1.0-7.0)	3 (1.0-6.0)	4 (1.0-8.0)	3 (1.0-8.0)
CSC or TSC	Yes	No	Yes	No
Stroke presentations/month	12.1	14.1	27.1	31.6

	Ascension Providence Rochester Hospital (Rochester Hills, MI)	Ascension Borgess Allegan Hospital (Allegan, MI)	Ascension Providence Hospital (Southfield, MI)	Ascension Providence Hospital (Novi, MI)
Age, mean +/- SD	74.0 +/- 14.7	70.6 +/- 14.7	69.0 +/- 13.7	73.0 +/- 14.0
Sex				
Male	186 (49.2)	14 (48.3)	278 (42.3)	292 (50.7)
Female	192 (50.8)	15 (51.7)	379 (57.7)	284 (49.3)
Race				
White, non-Hispanic	358 (94.7)	29 (100.0)	68 (10.4)	526 (91.3)
Black/African American	20 (5.3)	0 (0.0)	589 (89.6)	50 (8.7)
Residential zip code median income < $50k	274 (72.5)	6 (20.7)	623 (94.8)	178 (30.9)
Urban residential zip code	4 (1.1)	0 (0.0)	287 (43.7)	11 (1.9)
Ambulation				
Independent	354 (93.7)	26 (89.7)	600 (91.3)	531 (92.2)
with Assistance	15 (4.0)	1 (3.5)	37 (5.6)	28 (4.9)
NIHSS, median (IQR)	2 (0.0-5.0)	2 (0.0-5.0)	3 (1.0-6.0)	2 (1.0-5.0)
CSC or TSC	No	No	Yes	Yes
Stroke presentations/month	6.6	0.51	11.5	10.1

	Our Lady of Lourdes Memorial Hospital (Binghamton, NY)	Ascension St. John Medical Center (Tulsa, OK)	Ascension St. Thomas Rutherford Hospital (Murfreesboro, TN)	Ascension St. Thomas Midtown Hospital (Nashville, TN)
Age, mean +/- SD	74.7 +/- 13.0	72.1 +/- 13.3	68.8 +/- 13.9	67.5 +/- 13.6
Sex				
Male	336 (47.6)	1,327 (48.2)	614 (48.2)	409 (48.0)
Female	370 (52.4)	1,424 (51.8)	661 (51.8)	443 (52.0)
Race				
White, non-Hispanic	671 (95.0)	2,398 (87.2)	1,108 (86.9)	431 (50.6)
Black/African American	35 (5.0)	353 (12.8)	167 (13.1)	421 (49.4)
Residential zip code median income < $50k	587 (83.1)	1,934 (70.3)	1,120 (87.8)	753 (88.4)
Urban residential zip code	0 (0.0)	1,297 (47.1)	10 (0.78)	504 (59.2)
Ambulation				
Independent	451 (63.9)	2,527 (91.9)	1,185 (92.9)	789 (92.6)
with Assistance	221 (31.3)	126 (4.6)	57 (4.5)	33 (3.9)
NIHSS, median (IQR)	2 (0.0-5.0)	4 (1.0-10.0)	3 (1.0-6.0)	3 (1.0-6.0)
CSC or TSC	No	Yes	Yes	Yes
Stroke presentations/month	12.4	48.3	22.4	14.9

	Ascension St. Thomas West Hospital (Nashville, TN)	Seton Medical Center (Round Rock, TX)	Seton Medical Center (Austin, TX)	Dell Seton Medical Center (Austin, TX)
Age, mean +/- SD	72.7 +/- 13.2	70.6 +/- 14.3	72.4 +/- 15.1	67.4 +/- 15.3
Sex				
Male	674 (50.0)	349 (45.7)	585 (48.9)	381 (54.7)
Female	675 (50.0)	414 (54.3)	611 (51.1)	316 (45.3)
Race				
White, non-Hispanic	1,221 (90.5)	666 (87.3)	1,031 (86.2)	506 (72.6)
Black/African American	128 (9.5)	97 (12.7)	165 (13.8)	191 (27.4)
Residential zip code median income < $50k	1,124 (83.3)	494 (64.7)	1,061 (88.7)	583 (83.6)
Urban residential zip code	510 (37.8)	29 (3.8)	880 (73.6)	439 (63.0)
Ambulation				
Independent	1,244 (92.2)	699 (91.6)	1,046 (87.5)	662 (95.0)
with Assistance	72 (5.3)	49 (6.4)	101 (8.4)	28 (4.0)
NIHSS, median (IQR)	4 (1.0-9.0)	3 (1.0-9.0)	3 (1.0-8.0)	5 (2.0-10.0)
CSC or TSC	Yes	Yes	Yes	Yes
Stroke presentations/month	23.7	13.4	21.0	12.2

	Seton Medical Center (Kyle, TX)	Ascension Columbia St. Mary's Hospital (Milwaukee, WI)	Ascension Columbia St. Mary's Hospital (Mequon, WI)	Ascension St. Joseph Hospital (Milwaukee, WI)
Age, mean +/- SD	69.3 +/- 13.4	69.5 +/- 15.0	78.8 +/- 12.0	63.4 +/- 14.2
Sex				
Male	233 (50.3)	404 (46.2)	244 (50.5)	237 (48.4)
Female	230 (49.7)	470 (53.8)	239 (49.5)	253 (51.6)
Race				
White, non-Hispanic	418 (90.3)	340 (38.9)	430 (89.0)	75 (15.3)
Black/African American	45 (9.7)	534 (61.1)	53 (11.0)	415 (84.7)
Residential zip code median income < $50k	424 (91.6)	613 (70.1)	152 (31.5)	468 (95.5)
Urban residential zip code	24 (5.2)	806 (92.2)	132 (27.3)	487 (99.4)
Ambulation				
Independent	422 (91.1)	789 (90.3)	471 (97.5)	465 (94.9)
with Assistance	27 (5.8)	54 (6.2)	9 (1.9)	11 (2.2)
NIHSS, median (IQR)	2 (0.0-5.0)	4 (1.0-8.0)	2 (1.0-6.0)	4 (2.0-8.0)
CSC or TSC	No	Yes	No	No
Stroke presentations/month	8.1	15.3	8.5	8.6

	Ascension Southeast Wisconsin Hospital (Elmbrook, WI)	Ascension Southeast Wisconsin Hospital (Franklin, WI)	Ascension All Saints Hospital (Racine, WI)
Age, mean +/- SD	78.9 +/- 12.2	73.9 +/- 12.1	72.4 +/- 14.0
Sex			
Male	134 (38.6)	65 (60.2)	460 (49.8)
Female	213 (61.4)	43 (39.8)	464 (50.2)
Race			
White, non-Hispanic	332 (95.7)	107 (99.1)	715 (77.4)
Black/African American	15 (4.3)	1 (0.93)	209 (22.6)
Residential zip code median income < $50k	255 (73.5)	65 (60.2)	875 (94.7)
Urban residential zip code	67 (19.3)	14 (13.0)	3 (0.32)
Ambulation			
Independent	318 (91.6)	102 (94.4)	827 (89.5)
with Assistance	20 (5.8)	3 (2.8)	54 (5.8)
NIHSS, median (IQR)	2 (0.0-6.0)	1 (0.0-3.0)	4 (1.0-9.0)
CSC or TSC	No	No	No
Stroke presentations/month	6.1	1.9	16.2

Table S2. **Overall mechanical thrombectomy rates by demographic and clinical subgroup.**

	N (%)	P-value
Age, years		0.66
Age < 80	817 (3.5)	
Age ≥ 80	373 (3.4)	
Sex		0.43
Male	560 (3.4)	
Female	630 (3.5)	
Race/ethnicity		<0.01
White, Non-Hispanic	957 (3.6)	
African American/Black	233 (2.9)	
Residential zip code median income		<0.01
> $50,000	331 (3.1)	
< $50,000	859 (3.6)	
Residential zip code population density		0.80
Urban	281 (3.5)	
Non-urban	909 (3.4)	
Presenting hospital stroke certification		<0.01
CSC/TSC	961 (4.7)	
PSC	229 (1.6)	
Presenting hospital region		<0.01
Midwest	775 (3.7)	
South	356 (3.8)	
East	59 (1.4)	
Hospital stroke volume		<0.01
High	1,136 (3.7)	
Low	54 (1.4)	

	N (%)	P-value
Baseline Ambulation		<0.01
Independent	1,126 (3.6)	
with Assistance	46 (2.1)	
Stroke severity		<0.01
NIHSS ≤ 5	172 (0.8)	
NIHSS > 5	1,018 (8.8)	

CSC, Comprehensive Stroke Center; MT, mechanical thrombectomy; NIHSS, National Institute of Health Stroke Scale; PSC, Primary Stroke Center; TSC, Thrombectomy-capable Stroke Center.

Table S3. **Rates of early arrival (within 5 hours of last known well) by demographic and clinical subgroup.**

	N (%)	P-value
Age, years		<0.01
Age < 80	7,627 (32.4)	
Age ≥ 80	3,848 (34.8)	
Sex		0.70
Male	5,546 (33.3)	
Female	5,929 (33.1)	
Race/ethnicity		<0.01
White, Non-Hispanic	9,289 (34.9)	
African American/Black	2,186 (27.5)	
Residential zip code median income		<0.01
> $50,000	3,651 (34.5)	
< $50,000	7,824 (32.6)	
Residential zip code population density		<0.01
Urban	2,506 (31.1)	
Non-urban	8,969 (33.8)	
Presenting hospital stroke certification		0.53
CSC/TSC	6,770 (33.3)	
PSC	4,705 (33.0)	
Presenting hospital region		<0.01
Midwest	7,164 (33.9)	
South	3,160 (33.9)	
East	1,151 (27.6)	
Hospital stroke volume		0.23
High	10,178 (33.1)	
Low	1,297 (34.0)	

	N (%)	P-value
Baseline Ambulation		0.02
Independent	10,455 (33.4)	
with Assistance	673 (31.0)	
Stroke severity		<0.01
NIHSS ≤ 5	6,971 (30.2)	
NIHSS > 5	4,504 (39.1)	

CSC, Comprehensive Stroke Center; MT, mechanical thrombectomy; NIHSS, National Institute of Health Stroke Scale; PSC, Primary Stroke Center; TSC, Thrombectomy-capable Stroke Center.

Table S4. **Rates of documented anterior circulation large vessel occlusion among early arrival patients**

	N (%)	P-value
Age, years		<0.01
Age < 80	698 (9.2)	
Age ≥ 80	414 (10.8)	
Sex		<0.01
Male	478 (8.6)	
Female	634 (10.7)	
Race/ethnicity		0.05
White, Non-Hispanic	924 (9.9)	
African American/Black	188 (8.6)	
Residential zip code median income		<0.01
> $50,000	306 (8.4)	
< $50,000	806 (10.3)	
Residential zip code population density		0.14
Urban	262 (10.5)	
Non-urban	850 (9.5)	
Presenting hospital stroke certification		<0.01
CSC/TSC	906 (13.4)	
PSC	206 (4.4)	
Presenting hospital region		<0.01
Midwest	615 (8.6)	
South	429 (13.6)	
East	68 (5.9)	
Hospital stroke volume		<0.01
High	1,051 (10.3)	
Low	61 (4.7)	

	N (%)	P-value
Baseline Ambulation		<0.01
Independent	1,035 (9.9)	
with Assistance	44 (6.5)	
Stroke severity		<0.01
NIHSS ≤ 5	181 (2.6)	
NIHSS > 5	931 (20.7)	

CSC, Comprehensive Stroke Center; MT, mechanical thrombectomy; NIHSS, National Institute of Health Stroke Scale; PSC, Primary Stroke Center; TSC, Thrombectomy-capable Stroke Center.

Table S5. **Rates of mechanical thrombectomy among early arrival patients with documented anterior circulation large vessel occlusion**.

	N (%)	P-value
Age, years		<0.01
Age < 80	476 (68.2)	
Age ≥ 80	250 (60.4)	
Sex		0.45
Male	318 (66.5)	
Female	408 (64.4)	
Race/ethnicity		0.83
White, Non-Hispanic	602 (65.2)	
African American/Black	124 (66.0)	
Residential zip code median income		0.12
> $50,000	204 (66.7)	
< $50,000	522 (64.8)	
Residential zip code population density		
Urban	158 (60.3)	0.05
Non-urban	568 (66.8)	
Presenting hospital stroke certification		
CSC/TSC	594 (65.6)	0.69
PSC	132 (64.1)	
Presenting hospital region		<0.01
Midwest	448 (72.8)	
South	247 (57.6)	
East	31 (45.6)	
Hospital stroke volume		
High	693 (65.9)	0.06
Low	33 (54.1)	

	N (%)	P-value
Baseline Ambulation		0.10
Independent	690 (66.7)	
with Assistance	24 (54.5)	
Stroke severity		<0.01
NIHSS ≤ 5	70 (38.7)	
NIHSS > 5	656 (70.5)	

CSC, Comprehensive Stroke Center; MT, mechanical thrombectomy; NIHSS, National Institute of Health Stroke Scale; PSC, Primary Stroke Center; TSC, Thrombectomy-capable Stroke Center.