Patient Characteristics and Outcomes Associated with Decline in Stroke Volumes During the Early COVID-19 Pandemic

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Background and Purpose: Delayed evaluation of stroke may contribute to COVID-19 pandemic-related morbidity and mortality. This study evaluated patient characteristics, process measures and outcomes associated with the decline in stroke presentation during the early pandemic. *Methods:* Volumes of stroke presentations, intravenous thrombolytic administrations, and mechanical thrombectomies from 52 hospitals from January 1-June 30, 2020 were analyzed with piecewise linear regression and linear spline models. Univariate analysis compared pandemic (case) and pre-pandemic (control) groups defined in relation to the nadir of daily strokes during the study period. Significantly different patient characteristics were further evaluated with logistic regression, and significantly different process measures and outcomes were re-analyzed after propensity score matching. *Results:* Analysis of 7,389 patients found daily stroke volumes decreased 0.91/day from March 12−26 ($p < 0.0001$), reaching a nadir 35.0% less than expected, and increased 0.15 strokes/day from March 27-June 23, 2020 ($p < 0.0001$). Intravenous thrombolytic administrations decreased 3.3/week from February 19-March 31 ($p = 0.0023$), reaching a nadir 33.4% less than expected, and increased 1.4 administrations/week from April 1-June 23 ($p < 0.0001$). Mechanical thrombectomy volumes decreased by 1.5/week from February 19-March 31, 2020 ($p = 0.0039$), reaching a nadir 11.3% less than expected. The pandemic group was more likely to ambulate independently at baseline ($p = 0.02$, OR = 1.60, 95% CI = 1.08−2.42), and less likely to present with mild stroke symptoms (NIH Stroke Scale ≤ 5; $p = 0.04$, OR = 1.01, 95% CI = 1.00−1.02). Process measures and outcomes of each group did not differ, including door-to-needle time, door-to-puncture time, and successful mechanical thrombectomy rate. *Conclusion:* Stroke presentations and acute interventions decreased during the early COVID-19 pandemic, at least in part due to patients with lower baseline functional status and milder symptoms not seeking medical care. Public health messaging and initiatives should target these populations.

Abbreviations: CI, confidence interval; COVID-19, coronavirus disease 2019; ED, Emergency Department; IV tPA, intravenous tissue plasminogen activator; LKW, last known well; mRS, Modified Rankin Scale; MT, mechanical thrombectomy; NIHSS, National Institute of Health Stroke Scale; OR, odds ratio

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Introduction

Recent studies have documented a decrease in evaluations of stroke patients during the early weeks of the coronavirus disease 2019 (COVID-19) outbreak in the United States (US).[1−4] This phenomenon raises concern that delays in emergent treatment and implementation of secondary stroke prevention measures may contribute to the morbidity and mortality of the pandemic. As a second wave of COVID-19 sweeps through the country, there is an urgent need for public health communication that targets populations most likely to delay evaluation for acute stroke. The purpose of this study was to identify differences in stroke patient characteristics, process measures and outcomes corresponding with the decline in stroke presentations during the early weeks of the pandemic.

Methods

Study design

This was a retrospective case-control cohort analysis. This study was approved by our Institutional Review Board, which sanctioned a waiver of informed consent.

Study population

Ascension is the second largest health system in the United States by hospital count. A total of 52 Ascension hospitals located in 11 states (FL, IL, IN, KS, MD, MI, NY, OK, TN, TX, WI) contribute data to Get With The Guidelines®-Stroke database. The locations of each hospital are listed in Supplemental Table 1. The data set for this study included patients presenting to these hospitals who received a primary diagnosis of stroke from January 1 − June 30, 2020, including patients transferred to an Ascension hospital from outside the network. Data from January 1 − June 30, 2019 were also included to capture temporal variations in stroke volumes.

Volume Trend Analyses

Scatterplot of the 7-day moving average of daily stroke volumes from January 1 − June 30, 2020 was visually analyzed for time cut-points corresponding to inflection points on the curve. Piecewise linear regression was used to quantify the change in daily stroke volumes between each time cut point. The daily stroke volume data were fit with a piecewise linear spline model, the nadir of which was compared with an "expected" daily volume generated from a cubic spline model fit to the 7-day moving average of daily stroke volumes from January 1 − June 30, 2019 (Supplemental Figure 1). To ensure this comparison was not confounded by workflow changes from 2019 to 2020, the nadir of 2020 daily stroke volumes was also compared with the mean daily volume from January 1 − February 29, 2020. These analyses were repeated for the 3-week moving averages of weekly intravenous tissue plasminogen activator (IV tPA) administrations and mechanical thrombectomies (MTs), except that expected 2020 MT volumes could not be estimated from 2019 data because MT volumes have steadily increased over the last 2 years within the network of hospitals included in this study.

Patient-level case-control analyses

Subgroup cohorts

Time-based subgroup cohorts were established to assess for differences in patient characteristics process measures, and outcomes associated with the decline in stroke volumes during the early pandemic. The control group comprised strokes from January − February 2020. We chose this prepandemic comparator epoch since it was most proximal to onset of the pandemic, and therefore least likely to be confounded by temporal changes in workflow or referral patterns. We confirmed that these months were representative of a prepandemic time by comparing patient characteristics during January - February 2020 with those from November − December 2019, which were all similar with the exception of patient history of hyperlipidemia (Supplemental Table 2). The case or "pandemic" group was defined in relation to the time cut points identified by volume trend analysis as follows:

$$S(t) < \frac{t_{(1)} + t_{(2)}}{2}$$

where $S(t)$ = piecewise linear spline model of 2020 daily stroke volumes and $t_{(i)}$ = knot i.

Patient characteristics, process measures and outcomes

Patient characteristics used for patient-level analysis are listed in Table 1. These data were extracted from the Get With The Guidelines®-Stroke database. Median incomes of patients' residential zip codes were derived from publicly available government data.[5] Process measures and outcomes listed in Table 2 were extracted or calculated from data in the Get With The Guidelines®-Stroke database. Emergency Department (ED) arrival and IV tPA administration times were not available for patients initially presenting to hospitals outside the network. Unknown last known well (LKW), ED arrival, and IV tPA

Table 1. *Comparison of patient characteristics for control and pandemic groups. Categorical and continuous variables are presented as N (%) and median (interquartile range), respectively.*

Characteristic	Control group (Jan 1−Feb 29, 2020)	Pandemic group (Mar 20−Apr 25, 2020)	*p*-value
N	2,692	1,225	
Demographics			
Age, years	71 (60−81)	70 (59−81)	0.30
Female sex	1,373 (51.0)	636 (51.9)	0.63
Race/ethnicity			0.83
White, non-Hispanic	1,858 (69.0)	856 (70.0)	
Black/African American	514 (19.0)	233 (19.0)	
Hispanic	139 (5.2)	53 (4.3)	
Asian	56 (2.1)	28 (2.2)	
Other	125 (4.6)	55 (4.5)	
Public or no insurance	1,203 (46.9)	521 (44.3)	0.15
Median household income by ZIP code < \$50,000	1,049 (39.0)	417 (37.7)	0.50
Urban presenting hospital	1,381 (51.3)	616 (50.2)	0.57
State			0.97
FL	268 (10.0)	129 (10.5)	
IL	390 (14.5)	168 (13.7)	
IN	276 (10.2)	117 (9.5)	
KS	140 (5.2)	72 (5.9)	
MD	63 (2.3)	27 (2.2)	
MI	615 (22.8)	295 (24.1)	
NY	47 (1.8)	18 (1.5)	
OK	117 (4.3)	57 (4.6)	
TN	147 (5.5)	72 (5.9)	
TX	391 (14.5)	168 (13.7)	
WI	249 (9.2)	114 (9.3)	
Comorbidities			
Hypertension	1,989 (73.9)	906 (73.9)	0.99
Hyperlipidemia	1,444 (53.6)	740 (60.4)	<0.01
Diabetes mellitus	848 (31.5)	399 (32.5)	0.53
Atrial fibrillation/flutter	493 (18.3)	198 (16.2)	0.11
Prior stroke or transient ischemic attack	621 (23.1)	281 (22.9)	0.96
Coronary artery disease	576 (21.4)	255 (20.8)	0.71
Carotid stenosis	108 (4.0)	61 (5.0)	0.19
Renal insufficiency	263 (9.8)	135 (11.0)	0.25
Obesity	1,174 (43.6)	574 (46.8)	0.06
Depression	437 (16.2)	176 (14.3)	0.15
Tobacco use	569 (21.1)	263 (21.5)	0.85
Substance abuse	255 (9.5)	137 (11.1)	0.11
Pre-admission antithrombotics			
Anticoagulation	348 (12.9)	131 (10.7)	0.05
Antiplatelet agent(s)	1,029 (38.2)	445 (36.3)	0.27
Baseline ambulatory status			
Independent	2,063 (93.1)	1,014 (95.2)	0.02
With assistance	92 (4.1)	33 (3.1)	0.17
Unable	62 (2.8)	18 (1.7)	0.07
Stroke severit			
NIHSS	3 (1-9)	4 (1-10)	0.17
NIHSS ≤ 5	1,473 (65.1)	632 (61.0)	0.02
NIHSS > 15	308 (13.6)	168 (16.2)	0.06
Symptoms			
Weakness	1,511 (64.2)	754 (66.8)	0.13
Aphasia	1,097 (46.6)	568 (50.4)	0.04

(*Continued*)

Table 1 (*Continued*)

Characteristic	Control group (Jan 1−Feb 29, 2020)	Pandemic group (Mar 20−Apr 25, 2020)	*p*-value
Altered mental status	548 (23.3)	232 (20.6)	0.08
Glasgow Coma Scale	14 (6-15)	14 (8-15)	0.56
Large vessel occlusion present	229 (8.5)	130 (10.6)	0.04
Large vessel occlusion site			0.47
Internal carotid artery	54 (24.7)	22 (17.9)	
M1	73 (33.3)	49 (39.8)	
M2	37 (16.9)	25 (20.3)	
Anterior cerebral artery	1 (0.5)	2 (1.6)	
Basilar artery	14 (6.4)	7 (5.7)	
Posterior cerebral artery	10 (4.6)	4 (3.3)	
Stroke-related diagnosis			0.07
Ischemic stroke	1,912 (71.0)	877 (71.5)	0.76
Transient ischemic attack	239 (8.9)	85 (6.9)	0.08
Intracranial hemorrhage	292 (10.8)	152 (12.4)	0.17
Subarachnoid hemorrhage	101 (3.8)	58 (4.7)	0.19

Abbreviations: mRS, modified Rankin scale; NIHSS, National Institute of Health Stroke Scale

administration times were considered missing and were not imputed.

Statistical analysis

Categorical and continuous variables are presented as N (%) and median (interquartile range), respectively. Categorical and continuous variables were compared using X^2 tests and the Kruskal-Wallis test, respectively. A *p*-value < 0.05 was considered statistically significant. Percentages of missing variables are detailed in Supplemental Table 3.

A multivariate logistic regression model was built with time-based subgroup (control vs pandemic) as the dependent variable and the following independent variables: age, gender, race, insurance (private vs public), median income of patient's residential zip code, presenting hospital location (state, urban vs non-urban[6]), history of depression, history of substance abuse, pre-stroke ambulatory status, pre-admission antithrombotic use, presentation National Institute of Health Stroke Scale (NIHSS) score, presence of large vessel occlusion, and diagnosis of hemorrhagic stroke (intracranial or subarachnoid hemorrhage). The odds ratio (OR) and 95% confidence interval (CI) were calculated for each independent variable.

Process measures and outcomes that differed between the two subgroups ($p < 0.10$) were further compared using propensity score analysis. Propensity scores were generated from the following covariates: age, gender, race, hospital location (state, urban vs non-urban), comorbidities listed in Table 1, pre-stroke independent ambulatory status, pre-admission anticoagulation and antiplatelet usage, LKW-to-ED arrival time, NIHSS on presentation, whether patient received IV tPA, and presence of large vessel occlusion. Propensity scores underwent 1:1 nearest neighbor (Greedy-type) matching of the logit of the propensity score with a caliper width of 0.25. Matching was performed without replacement and unpaired pandemic and control patients not meeting matching criteria were excluded. Multiple control cases matching a single pandemic case were included in the matched data set and weighted accordingly. Covariate balance was assessed before and after matching using the X^2 omnibus test described by Hansen and Bowers [7] and illustrated with split histograms. Outcomes were then compared between treatment and control propensity-matched patients using univariate statistics. Statistics were performed using R version 4.0.3.

Results

Volume trends

A total of 7,389 stroke patients presented from January 1 − June 30, 2020. Scatterplot visualization identified March 12, 2020 (day 72) and March 27, 2020 (day 87) as time cut points associated with declining and rising daily stroke volumes, respectively. Piecewise linear regression demonstrated a slope of -0.91 strokes/day from March 12−26, 2020 ($p < 0.0001$, $R^2 = 0.971$) and a slope of 0.15 strokes/day from March 27−June 23, 2020 ($p < 0.0001$, $R^2 = 0.877$) (Fig. 1A; Supplemental Table 4). A linear spline model generated with knots at days 72 and 87 is presented in Figure 2A with associated $R^2 = 0.823$. A nadir of 30.6 strokes occurred on March 27, 2020, a decrease of 35.0% compared with an expected volume of 47.1 strokes based on 2019 data and a 31.8% decrease compared with a mean of 44.9 strokes/day from January − February 2020.

IV tPA was administered to 922 patients from January 1−June 30, 2020. Scatterplot visualization identified week

Table 2. *Comparison of process measures and outcomes for control and pandemic groups. Categorical and continuous variables are presented as N (%) and median (interquartile range), respectively.*

Process Measure/Outcome	Control group (Jan 1−Feb 29, 2020)	Pandemic group (Mar 20−Apr 25, 2020)	*p*-value
Last-known-well-to-ED arrival (hours)	9.2 (1.5−29.0)	10.0 (2.0−28.4)	0.18
IV tPA administered	339 (12.6)	145 (11.8)	0.54
Door-to-needle (minutes)	60 (42-79)	58 (35-87)	0.24
Mechanical thrombectomy pursued*	174 (79.5)	91 (74.0)	0.30
Door-to-arterial puncture (minutes)	93 (43−132)	100 (56−128)	0.70
TICI≥2b recanalization	157 (85.3)	87 (83.7)	0.83
Length of stay (days)	3 (2−6)	3 (2−6)	0.79
Disposition			<0.01
Home	1,320 (53.9)	573 (50.5)	
Rehabilitation	454 (18.5)	281 (24.8)	
Skilled nursing facility	403 (16.4)	141 (12.4)	
Deceased/hospice	314 (12.8)	160 (14.1)	

Abbreviations: ED, emergency department; mRS, modified Rankin Scale; Thrombolysis in Cerebral Infarction (TICI).
*Calculated as percentage of large vessel occlusions

8 (February 19-25, 2020) and week 13 (March 25-31, 2020) as inflection points. IV tPA administrations decreased by 3.3 administrations/week from February 19−March 31, 2020 ($P = 0.0023$, $R^2 = 0.945$) and increased by 1.4 administrations/week from April 1−June 23, 2020 ($p < 0.0001$, $R^2 = 0.8652$) (Fig. 1B, Supplemental Table 4). A linear spline model generated with knots at weeks 8 and 13 (Fig. 2B, $R^2 = 0.885$) demonstrated a nadir of 24.5 IV tPA administrations during week 13 (March 25−31, 2020), a 33.4% decrease compared with an expected volume of 36.8 tPA administrations based on 2019 data and 37.0% decrease compared with a mean of 38.9 tPA administrations/week for the first 8 weeks of 2020.

A total of 677 MTs were performed from January 1−June 30, 2020. Scatterplot visualization identified weeks 8 and 13 as inflection points. MT volumes decreased by 1.5 MTs/week from February 19−March 31, 2020 ($p = 0.0039$, $R^2 = 0.899$, Fig. 1C, Supplemental Table 4). Weekly MT volumes from April 1−June 23, 2020 could not be adequately fit to a linear regression model. A linear spline model generated with knots at weeks 8 and 13 (Fig. 2C, $R^2 = 0.302$), demonstrated a nadir of 23.5 MTs during week 13, an 11.3% decrease compared with a mean of 26.5 MTs/week during the first 8 weeks of 2020.

Patient characteristics, process measures and outcomes

Patient-level analysis of daily stroke volumes included a pandemic group of 1,225 strokes from March 20−April 25, 2020 (days 80−116; Fig. 2A) and a control group of 2,692 strokes from January − February 2020. Characteristics of each group are presented in Table 1. The pandemic group had a higher percentage of patients with hyperlipidemia (60.4 vs 53.6%, $p < 0.01$), trended toward higher incidence of obesity (46.8 vs 43.6%, $p = 0.06$), trended toward a lower percentage of patients on anticoagulation prior to admission (10.7 vs 12.9%, $p = 0.05$), and had a higher rate of pre-stroke independent ambulation (95.2 vs 93.1, $p = 0.02$). The pandemic group had higher percentages of patients presenting with aphasia (50.4 vs 46.6%, $p = 0.04$) and large vessel occlusion (10.6 vs 8.5%, $p = 0.04$),), and trended toward a higher percentage of patients presenting with NIHSS > 15 (16.2 vs 13.6%, $p = 0.06$). Conversely, patients in the pandemic group less commonly presented with NIHSS ≤ 5 (61.0 vs 65.1%, $p = 0.02$) and trended toward a lower incidence of transient ischemic attack (6.9 vs 8.9%, $p = 0.08$). After logistic regression, the pandemic group demonstrated a statistically significant higher rate of pre-stroke independent ambulation ($p = 0.02$, OR = 1.60, 95% CI = 1.08−2.42) and higher NIHSS scores on presentation ($p = 0.04$, OR = 1.01, 95% CI = 1.00−1.02; Supplemental Table 5).

Process measures for each group are presented in Table 2. LKW-to-ED arrival time, door-to-needle time, door-to-puncture time, Thrombolysis in Cerebral Infarction (TICI) ≥2b recanalization rate, and length of stay did not differ between the pandemic and control groups. Univariate analysis showed a statistically significant difference between the two groups in terms of disposition ($p < 0.01$). After excluding cases with missing data, 1,780 patients were used to generate 577 matches comprised of 1,419 unweighted observations. After propensity score matching, pandemic and control groups did not differ in terms of discharge home ($p = 0.48$), discharge to home or acute rehab ($p = 0.36$), or in-hospital mortality or discharge to hospice ($p = 0.48$; Supplemental Figure 2).

Discussion

Our analysis of stroke presentations to one of the largest hospital networks in the United States found a steep decline in 7-day moving average daily stroke volumes

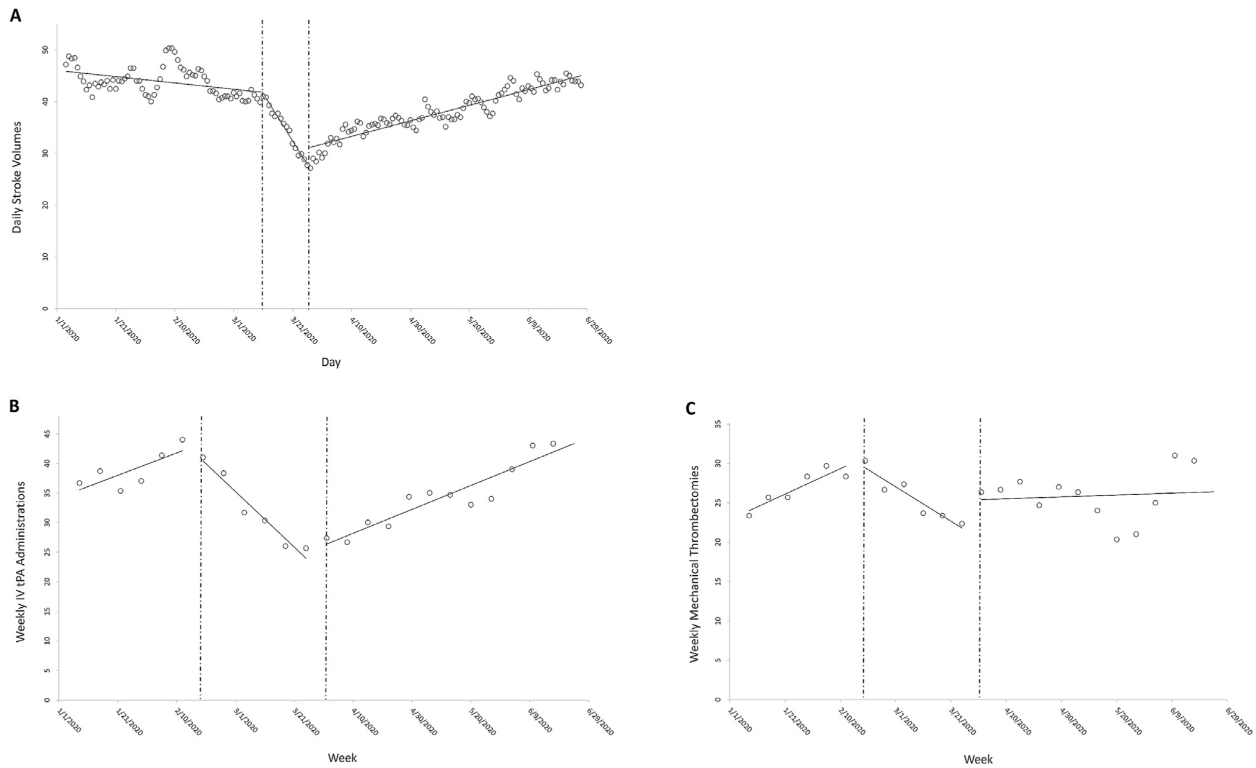

Fig. 1. *Piecewise linear regression models of (A) 7-day moving average of daily stroke volumes, (B) 3-week moving average of weekly IV tPA administrations, and (C) 3-week moving average of weekly MTs from January 1−June 30. Dashed vertical lines = time cut points.*

(0.91 strokes/day) starting around March 12, 2020, the day COVID-19 was declared a national emergency.[8] Daily stroke volumes ultimately reached a nadir of 30.6 strokes/day on March 27, 2020, a decrease of 35.0% compared with the expected volume based on 2019 data. These findings are comparable to those from other parts of the country [1,2] and world.[9−12] This analysis also included more recent data, which demonstrated recovery of stroke volumes from March 27−June 23, 2020, though at a more gradual rate of 0.15 strokes/day.

Several hypotheses have been proposed to explain the decrease in stroke presentations during the early pandemic, including concerns of hospital overcrowding,[10,12] patient anxiety over contracting COVID-19 at the hospital,[1,10,12] social isolation [1,9] and decreased exposure to pollution due to stay-at-home measures.[13,14] A subject of debate is whether the decrease in stroke volumes during the early pandemic was primarily the result of patients with relatively mild symptoms not seeking medical care. An analysis of 378 stroke codes at three hospitals in Connecticut from January−April, 2020 found no significant difference in presenting NIHSS or neurological symptoms before and during the pandemic.[1] Similarly, a study involving 19 EDs in northeast Ohio did not find any change in presenting stroke severity during the pandemic.[15] However, another study of 691 patients presenting to five comprehensive stroke centers on the east and west coasts found a statistically significant increase in median NIHSS from 7 to 10 for patients presenting from March 23−April 19 2020 compared with similar dates in 2019.[2] Higher presenting NIHSS has also been reported in other countries.[12] In our univariate analysis, patients in the pandemic group were less likely to present with mild stroke (NIHSS $\leq$ 5; 61.0 vs 65.1%, p = 0.02) and more likely to present with severe stroke (NIHSS > 15; 16.2 vs 13.6%, p = 0.06). Our logistic regression model included NIHSS as a continuous variable and found that patients in the pandemic group presented with significantly lower NIHSS scores (p = 0.04, OR = 1.01, 95% CI = 1.00−1.02). The hypothesis that patients with milder stroke symptoms in our hospital network were less likely to seek care is further supported by our pandemic group's higher incidence of aphasia (50.4 vs 46.6%, p = 0.04), higher rate of large vessel occlusion (10.6 vs 8.5%, p = 0.04), and trend toward a lower incidence of transient ischemic attack (6.9 vs 8.9%, p = 0.08). While relatively mild weakness or transient symptoms may be ignored, one might expect that the debilitating nature of aphasia would prompt patients to seek treatment. Differing results among this and previous studies may be due to regional differences in fear of contracting COVID-19 at the hospital. Additionally, the larger sample size of our study allowed for detection of smaller statistical differences, as well as use of logistic regression to control for demographic and clinical covariates. Lastly, inclusion of more recent data allowed us to define the pandemic group in relation to the nadir of

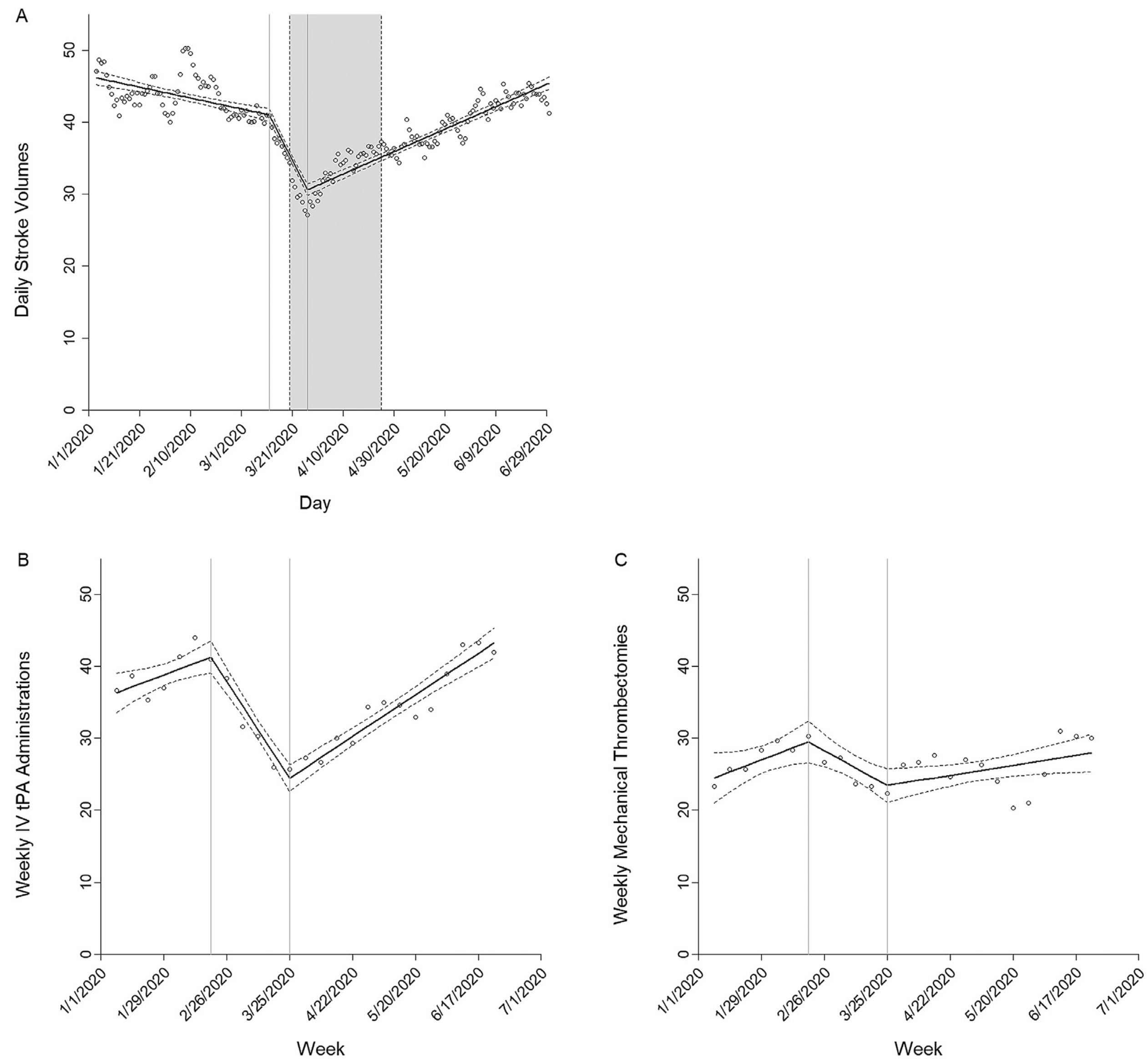

Fig. 2. *Linear splines of (A) daily stroke volumes, (B) weekly IV tPA administrations, and (C) weekly MTs from January 1–June 30, 2020. Knots (time cut points) delineated by vertical gray lines. Time-period defining the pandemic group shaded in gray and bracketed by vertical dashed lines.*

daily stroke volumes and exclude the initial decline and later recovery periods when patient characteristics may have more closely resembled those before the pandemic.

Another key finding of this study is that patients in the pandemic group were more likely to ambulate independently at baseline (95.2 vs 93.1%), a difference that remained statistically significant after logistic regression ($p = 0.02$, OR = 1.60, 95% CI = 1.08–2.42). This finding raises concern that the social isolation caused by the pandemic is disproportionately impacting people with lower functional status. As others have suggested,[1] routine virtual contact and telehealth resources may help mitigate harm caused by patient inability to access healthcare through traditional means.

The lack of acute medical care for stroke patients during the early pandemic has important public health implications. IV tPA administration volumes in our study sharply declined and gradually recovered in parallel with overall stroke volumes. The nadir of the 3-week moving average of IV tPA administrations from March 25–31, 2020 was 33.4% less than expected based on data from the previous year. The number needed to treat for IV tPA to achieve one additional patient with excellent functional outcome [modified Rankin scale (mRS) 0–1] is 10 for LKW-to-needle time of 0–3 h and 19 for 3–4.5 h.[8] Therefore, lack of IV tPA administration to acute ischemic stroke patients may be an important source of collateral morbidity associated with the COVID-19 pandemic and underscores the importance of informing the public that the potential benefits of time-sensitive stroke interventions far outweigh the risks of COVID-19 infection. Notably, our data suggest that the decrease in IV tPA administrations was primarily due to patients not seeking care at all, rather than arriving to the ED beyond the tPA window. Although patients in the pandemic group had a longer mean LKW-to-ED arrival time (10.0 vs 9.2 h, p = 0.18), the difference was not statistically significant, which is consistent with other studies.[16]

In contrast with overall stroke and IV tPA administration volumes, our results showed a less pronounced decrease in MTs. The 3-week moving average of MT volumes decreased by only 1.5 MTs/week from February 19−March 31, 2020, reaching a nadir that was only 11.3% less than the pre-pandemic mean. Univariate analysis found a higher proportion of patients in the pandemic group with large vessel occlusions (10.6 vs 8.5%, p = 0.04), though the difference did not remain statistically significant after logistic regression. The most likely explanation is that patients with large vessel occlusions also had higher NIHSS scores and were therefore less likely to forego emergent evaluation. However, approximately 10% of patients with mild stroke symptoms have a large vessel occlusion.[17] Further research is needed to determine whether the decline in MT volumes was due to patients with large vessel occlusion and mild symptoms not seeking medical care, and if so, the associated morbidity.

An important issue that remains unaddressed is the extent to which lack of acute medical care translated into inadequate secondary stroke prevention and rehabilitation. The cohort for this study only included patients discharged from our network of hospitals with a primary diagnosis of stroke. Some patients who avoided presenting to the hospital may have sought outpatient care, particularly those with mild symptoms. However, since the risk of recurrent stroke is highest in the weeks following an initial event,[18] public health communications should urge patients that may not have initially sought medical care for mild or transient stroke symptoms to contact a healthcare professional for initiation of appropriate diagnostic testing, medical therapy and rehabilitation services to optimize functional recovery.

The added strain the pandemic has placed on our healthcare system has generated concern that treatment of other health emergencies may suffer. However, our study found no difference in process measures or outcomes before and after the pandemic, including door-to-needle and door-to-puncture times, successful MT reperfusion rates, and mortality rates. This is an encouraging sign that the infrastructure developed in recent years to quickly triage and deliver time-sensitive treatments to stroke patients can withstand the workflow disruptions caused by the pandemic.

In addition to its retrospective design, this study has other limitations to acknowledge. First, due to the broad scope of this study with inclusion of multiple hospitals, data were collected by multiple abstractors who may have interpreted abstraction guidelines differently. Also, some data elements were not routinely documented at every site or not available for patients transferred into our network. In particular, hospital arrival and door-to-needle times were only available for patients initially presenting within our network, so analyses including these process measures may have been biased by significant differences between patients initially presenting within versus outside our hospital network. Likewise, some process measure and outcome data were not available for patients transferred outside our network. Because propensity score matching requires a complete data set, missing data must either be imputed or patients with missing data elements must be excluded. We chose the latter approach to avoid introducing bias related to imputed data, and we used preadmission ambulatory status and disposition as surrogates for baseline and discharge mRS, respectively, because the former were more frequently documented. Second, regional variation in prevalence and timing of COVID-19 infections, as well as differing responses by state and local governments and populations to the pandemic, is a potential confounding variable. However, we found that the state in which a hospital was located did not influence our results. Other national studies similarly found no significant differences in regional pandemic-related volume trends.[4] This is likely because the spiking infection numbers in New York City and Seattle that overwhelmed local hospital capacities were widely reported via national media outlets. Still, our results may not be generalizable to regions of the United States outside our hospital network. Third, our analysis only included ED visits and hospital admissions and did not account for patients accessing healthcare in other ways, such as ambulatory clinics, urgent care, or virtual visits. Lastly, changes in practice and referral patterns may have changed between the case and control epochs of this study, as is always the case with temporal data.

Conclusion

Analysis of volume trends from one of the largest hospital networks in the United States showed decreased stroke presentations, IV tPA administrations, and MTs associated with the early COVID-19 pandemic. Patients with milder stroke symptoms and lower functional status were less likely to seek medical care during the early pandemic. Public health messaging and initiatives should target these populations to ensure they receive time-sensitive acute intervention, secondary stroke prevention, and rehabilitation. Stroke process measures such IV tPA door-to-needle and MT door-to-puncture times did not deteriorate during the pandemic.

Declaration of Competing Interest

ANW, KSA, SJW, TM, EFL, SG, KDK, MPL, JTM, KA − None; DHS − consultant (Medtronic, Stryker, Microvention, Phenox), speaker and proctor (Medtronic); DPG − consultant (iSchemaView, Medtronic, Siemens Healthineers A.G.).

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Supplementary materials

Supplementary material associated with this article can be found in the online version at doi:10.1016/j.jstrokecerebrovasdis.2020.105569.

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