CLINICAL AND POPULATION SCIENCES

Influence of the COVID-19 Pandemic on Treatment Times for Acute Ischemic Stroke

The Society of Vascular and Interventional Neurology Multicenter Collaboration

James E. Siegler, MD; Alicia M. Zha, MD; Alexandra L. Czap, MD; Santiago Ortega-Gutierrez, MD, MSc; Mudassir Farooqui, MD; David S. Liebeskind, MD; Shashvat M. Desai, MD; Ameer E. Hassan, DO; Amy K. Starosciak, PhD; Italo Linfante, MD; Vivek Rai, MD; Jesse M. Thon, MD; Ryna Then, MD; Mark E. Heslin, BS; Lauren Thau, BS; Priyank Khandelwal, MD; Mahmoud H. Mohammaden, MD, MSc; Diogo C. Haussen, MD; Raul G. Nogueira, MD; Dinesh V. Jillella, MD; Fadi Nahab, MD; Artem Kaliaev, MD; Thanh N. Nguyen, MD; Osama Zaidat, MD; Tudor G. Jovin, MD; Ashutosh P. Jadhav, MD, PhD

BACKGROUND AND PURPOSE: The pandemic caused by the novel coronavirus disease 2019 (COVID-19) has led to an unprecedented paradigm shift in medical care. We sought to evaluate whether the COVID-19 pandemic may have contributed to delays in acute stroke management at comprehensive stroke centers.

METHODS: Pooled clinical data of consecutive adult stroke patients from 14 US comprehensive stroke centers (January 1, 2019, to July 31, 2020) were queried. The rate of thrombolysis for nontransferred patients within the Target: Stroke goal of 60 minutes was compared between patients admitted from March 1, 2019, and July 31, 2019 (pre-COVID-19), and March 1, 2020, to July 31, 2020 (COVID-19). The time from arrival to imaging and treatment with thrombolysis or thrombectomy, as continuous variables, were also assessed.

RESULTS: Of the 2955 patients who met inclusion criteria, 1491 were admitted during the pre-COVID-19 period and 1464 were admitted during COVID-19, 15% of whom underwent intravenous thrombolysis. Patients treated during COVID-19 were at lower odds of receiving thrombolysis within 60 minutes of arrival (odds ratio, 0.61 [95% CI, 0.38–0.98]; \(P=0.04\)), with a median delay in door-to-needle time of 4 minutes (\(P=0.03\)). The lower odds of achieving treatment in the Target: Stroke goal persisted after adjustment for all variables associated with earlier treatment (adjusted odds ratio, 0.55 [95% CI, 0.35–0.85]; \(P<0.01\)). The delay in thrombolysis appeared driven by the longer delay from imaging to bolus (median, 29 [interquartile range, 18–41] versus 22 [interquartile range, 13–37] minutes; \(P=0.02\)). There was no significant delay in door-to-groin puncture for patients who underwent thrombectomy (median, 83 [interquartile range, 63–133] versus 90 [interquartile range, 73–129] minutes; \(P=0.30\)). Delays in thrombolysis were observed in the months of June and July.

CONCLUSIONS: Evaluation for acute ischemic stroke during the COVID-19 period was associated with a small but significant delay in intravenous thrombolysis but no significant delay in thrombectomy time metrics. Taking steps to reduce delays from imaging to bolus time has the potential to attenuate this collateral effect of the pandemic.

GRAPHIC ABSTRACT: An online graphic abstract is available for this article.

Key Words: goals ■ groin ■ pandemics ■ punctures ■ thrombectomy

Since December 2019, the novel human coronavirus severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) has led to >29 million worldwide infections and has claimed the lives of >900 000 people.\(^1\) In an attempt to prevent health care–associated transmission of SARS-CoV-2, health care administrators and legislative...
Nonstandard Abbreviations and Acronyms

COVID-19: coronavirus disease 2019
CSC: comprehensive stroke center
CT: computed tomography
IQR: interquartile range
LVO: large vessel occlusion
MSU: mobile stroke unit
SARS-CoV-2: severe acute respiratory syndrome coronavirus 2

officials have mandated stringent contact precautions leading to the consumption of personal protective equipment, implementation of decontamination procedures, and reduction in use of imaging-based diagnostic testing. Because of these and other responses, patients who present to the hospital with acute neurological symptoms may experience delays in their management as health care personnel make an effort to stem the spread of the virus.

In the present study, we evaluated the effect of the coronavirus disease 2019 (COVID-19) pandemic on systems of care in the management of acute stroke. We hypothesized that patients evaluated for acute stroke during this period would experience greater delays in time to imaging and treatment when compared with patients who were treated in identical months of the previous year.

METHODS

Study Design and Participants

Fully deidentified data will be made available upon reasonable request to the corresponding author. A retrospective observational registry involving prospectively maintained data from 14 comprehensive stroke centers (CSCs) across 9 US states was queried. As of September 16, 2020, these 9 states accounted for 47% of all COVID-19 cases in the United States and 37% of all COVID-19–associated deaths. Participating centers were recruited based on affiliation with the Society of Vascular and Interventional Neurology. Sites contributed patient-level data that were prospectively collected as part of their local stroke registry. All consecutive adult patients ≥18 years of age who were admitted on dates between January 1, 2019, and July 31, 2020 were eligible for inclusion. Eligible patients must have experienced an acute ischemic stroke based on the diagnosis of the treating physician. The use of neuroimaging to confirm an ischemic stroke diagnosis was made at the discretion of the treating physician. This study was approved under waiver of informed consent by the local institutional review board at each participating center, and it is reported in accordance with the Strengthening the Reporting of Observational Studies in Epidemiology statement.

Data Collection

Patient demographic information, including age, sex, race, and ethnicity, as well as pertinent medical history, stroke severity according to baseline National Institutes of Health Stroke Scale score, timing of imaging and treatment (including treatment with intravenous thrombolysis or endovascular recanalization), duration of hospitalization, and discharge disposition, were captured. To ensure consistency of practice paradigms across sites, endovascular recanalization was only counted for patients with a proximal large vessel occlusion (LVO). A proximal LVO was defined as an occlusion of the intracranial internal carotid artery, proximal segment of the middle cerebral artery (M1), or basilar artery. Sites were classified as high volume if the annual number of thrombectomies exceeded 50, as has been previously associated with faster treatment times.

Statistical Analysis

Descriptive statistics were used to summarize continuous and categorical variables. Normality of continuous data was assessed graphically and confirmed using the Shapiro-Wilk test. Continuous variables were reported as medians with interquartile range (IQR) or means with SD. Categorical variables were reported as proportions. Between-group comparisons for non-normally distributed continuous data were made using the Wilcoxon rank-sum test. To account for seasonal variations in treatment patterns and outcomes among patients with stroke, patients were categorized into the pre–COVID-19 period if they were evaluated between March 1, 2019, and July 31, 2019, while patients evaluated during the COVID-19 period were included if they were evaluated between March 1, 2020, and July 31, 2020. Time periods were also divided into weekly and monthly epochs between January 1, 2019, and July 31, 2020, as a separate analysis for illustrative purposes.

The primary outcome was selected as a ≤60-minute delay from hospital arrival to intravenous thrombolysis (door-to-needle time) for patients treated in the emergency department (not in-hospital strokes or patients transferred from an outside hospital—for whom time of outside hospital arrival was not available), in accordance with recommendations by the Target: Stroke campaign. Secondary outcomes included the absolute difference in the duration of hospitalization, and discharge disposition. Because all patients treated in a mobile stroke unit (MSU) had <0-minute door-to-needle times and transferred patients were originally triaged outside of the participating CSC, analyses for time to thrombolysis treatment were restricted to non-MSU nontransferred patients, unless otherwise specified. The difference in the mean number of weekly and monthly event rates was evaluated using an independent samples t test. Logistic and linear regression models were generated to estimate the effect of the COVID-19 period on the primary and secondary outcomes of interest, with adjustment for all variables associated with earlier thrombolysis (P<0.1) in univariate regression. Each regression model was clustered by site. All tests were 2 sided, with Ps≤0.05 considered statistically significant. As this was an exploratory analysis, P values are reported for convention and should be interpreted with caution. No adjustments were made for multiple comparisons. Missing data were not imputed.
RESULTS

Of the 12,187 patients with acute ischemic stroke presenting between January 1, 2019, and July 31, 2020, after excluding 4,579 who were transferred from an outside hospital, 197 brought in by an MSU, 1061 with unreported arrival method, 77 in-hospital strokes, and 3,318 patients admitted outside of the 2 study periods (pre–COVID-19 and COVID-19), 2,955 were included in the formal analyses. Compared with patients admitted during identical months in 2019, those admitted during the COVID-19 period were younger but had some differences in vascular comorbidities and more severe baseline deficits (Table 1). While a similar proportion of patients arrived to the hospital by private vehicle or walk-in during the study periods, a smaller proportion of patients arrived to the hospital by emergency medical services with a larger proportion of patients transferred from an outside hospital during the COVID-19 period.

Three hundred ninety patients (15%) received intravenous thrombolysis, with 386 having available imaging and treatment times (99% of treated). There was a decrease in the odds of the primary outcome (door-to-needle time, ≤60 minutes) among patients treated during the COVID-19 period versus patients treated during the pre–COVID-19 period (odds ratio, 0.61 [95% CI, 0.38–0.98]; P=0.04; Table 2). After adjustment for variables associated with the primary outcome in univariate regression (P<0.1: arrival by Emergency Medical Services, White race, Hispanic ethnicity, history of dyslipidemia, higher National Institutes of Health Stroke Scale score, and treatment at a high-volume CSC) and clustering by site, there remained a significantly lower odds of achieving a door-to-needle time ≤60 minutes during the COVID-19 period (adjusted odds ratio, 0.55 [95% CI, 0.35–0.85]; P<0.01; Table I in the Data Supplement). After multivariable adjustment and clustering by site,  

Table 1. Demographics by Seasonal Period

| Age group, n (%) | Pre–COVID-19 | COVID-19 | P value |
|-----------------|--------------|----------|---------|
| <50             | 357/2942 (12%) | 179/1491 (12%) | 178/1451 (12%) | 0.03 |
| 50–69           | 1252/2942 (43%) | 602/1491 (40%) | 650/1451 (45%) |
| ≥70             | 1333/2942 (45%) | 710/1491 (48%) | 623/1451 (43%) |
| Sex: female, n (%) | 1398/2942 (48%) | 723/1491 (48%) | 675/1451 (43%) | 0.28 |

| Race, n (%) | Pre–COVID-19 | COVID-19 | P value |
|-------------|--------------|----------|---------|
| White       | 1501 (51%) | 832 (56%) | 669 (49%) | <0.01 |
| Black       | 1000 (34%) | 422 (28%) | 578 (39%) |
| Asian       | 56 (2%) | 33 (2%) | 23 (2%) |
| Other/unknown | 398 (13%) | 204 (14%) | 194 (13%) |
| Hispanic, n (%) | 688/2892 (24%) | 381/1449 (26%) | 307/1443 (21%) | <0.01 |

| Arrival route, n (%) | Pre–COVID-19 | COVID-19 | P value |
|----------------------|--------------|----------|---------|
| Emergency medical services | 2006 (68%) | 898 (60%) | 1108 (76%) | <0.01 |
| Private vehicle/walk-in | 949 (32%) | 593 (40%) | 358 (24%) |

| Medical history, n (%) | Pre–COVID-19 | COVID-19 | P value |
|-----------------------|--------------|----------|---------|
| Prior ischemic stroke | 740 (25%) | 321 (22%) | 419 (29%) | <0.01 |
| Hypertension          | 2272 (77%) | 1173 (79%) | 1099 (75%) | 0.02 |
| Diabetes              | 1152 (39%) | 583 (39%) | 569 (39%) | 0.90 |
| Dyslipidemia          | 1328 (45%) | 709 (48%) | 619 (42%) | <0.01 |
| Atrial fibrillation/flutter | 436 (15%) | 243 (16%) | 193 (13%) | 0.02 |
| Coronary artery disease | 525 (18%) | 286 (19%) | 239 (16%) | 0.04 |
| Congestive heart failure | 332 (11%) | 143 (10%) | 189 (13%) | <0.01 |
| Active tobacco use    | 515 (17%) | 243 (16%) | 272 (19%) | 0.10 |
| NIHSS on admission, median (IQR) | 4 (1–10) | 3 (1–9) | 4 (1–11) | <0.01 |
| Treatment with intravenous thrombolysis, n (%) | 391/2675 (15%) | 205/1491 (14%) | 186/1184 (16%) | 0.15 |
| Proximal LVO, n (%)   | 178/1513 (12%) | 124/1118 (11%) | 54/395 (14%) | 0.17 |
| Endovascular thrombectomy, n (%) | 114/178 (64%) | 76/124 (61%) | 38/54 (70%) | 0.25 |

COVID-19 indicates coronavirus disease 2019; IQR, interquartile range; LVO, large vessel occlusion; and NIHSS, National Institutes of Health Stroke Scale.

*Analysis limited to patients with internal carotid, proximal middle cerebral (M1), or basilar artery occlusions.
The COVID-19 pandemic has created unprecedented challenges to our global and national health care systems, stressing our resources and shifting the paradigm for many clinical management strategies. One such consequence of the pandemic is delayed throughput and acute management of patients with acute ischemic stroke. In this observational study of 14 CSCs across 9 sites in the United States, we observed a small but persistent delay in time from patient arrival to treatment with standard-of-care intravenous thrombolysis. This delay appears, at least in part, due to delays from imaging to treatment initiation rather than arrival to imaging. Earlier imaging in patients with suspected acute stroke and Texas, which contributed 33% of the patients in this cohort). There remained a significantly shorter door-to-needle time among patients brought in by emergency medical services versus private vehicle/walk-in during either period (pre–COVID-19: median, 38 [IQR, 26–55] versus 46 [IQR, 35–60] minutes, P=0.04; COVID-19: median, 46 [IQR, 30–61] versus 65 [IQR, 47–73] minutes, P<0.01; Figure 2).

For patients who underwent thrombectomy for an occlusion of the ICA, M1, or basilar artery, patients admitted during the COVID-19 period had no significant delay from time from arrival to skin puncture when compared with patients admitted in the pre–COVID-19 period (Table 2).

**DISCUSSION**

The COVID-19 pandemic has created unprecedented challenges to our global and national health care systems, stressing our resources and shifting the paradigm for many clinical management strategies. One such consequence of the pandemic is delayed throughput and acute management of patients with acute ischemic stroke. In this observational study of 14 CSCs across 9 sites in the United States, we observed a small but persistent delay in time from patient arrival to treatment with standard-of-care intravenous thrombolysis. This delay appears, at least in part, due to delays from imaging to treatment initiation rather than arrival to imaging. Earlier imaging in patients with suspected acute stroke

---

**Table 2. Outcomes by Seasonal Period**

|                              | All patients (n=2955) | Pre–COVID-19 March to July 2019 (n=1491) | COVID-19 March to July 2020 (n=1464) | P value |
|------------------------------|-----------------------|------------------------------------------|-------------------------------------|--------|
| Door-to-needle ≤60 min, n (%)| 295/386 (77%)         | 164/203 (81%)                           | 131/183 (72%)                       | 0.03   |
| Door-to-needle, min; median (IQR) | 42 (27–59)           | 42 (27–55)                              | 46 (31–64)                          | 0.03   |
| Door-to-CT time, min; median (IQR) | 30 (13–90)           | 37 (15–101)                             | 29 (14–77)                          | <0.01  |
| CT-to-needle time, min; median (IQR) | 23 (13–36)           | 22 (13–37)                              | 29 (18–41)                          | 0.02   |
| Door-to-skin puncture,* min; median (IQR) | 97 (77–134)          | 100 (80–151)                            | 102 (87–127)                        | 0.82   |
| CT-to-skin puncture,* min; median (IQR) | 87 (65–121)          | 90 (73–129)                             | 83 (63–133)                         | 0.30   |
| Length of hospital stay, d; median (IQR) | 4 (3–8)              | 4 (2–7)                                 | 4 (2–8)                             | 0.46   |
| Discharge disposition, n (%)  |                       |                                         |                                     | <0.01  |
| Home/against medical advice   | 1707/2920 (58%)       | 872/1491 (58%)                          | 835/1429 (58%)                      |        |
| Acute rehabilitation facility | 310/2920 (11%)        | 213/1491 (14%)                          | 97/1429 (7%)                        |        |
| Skilled nursing facility      | 185/2920 (6%)         | 150/1491 (10%)                          | 35/1429 (2%)                        |        |
| Long-term acute-care facility | 11/2920 (<1%)         | 5/1491 (<1%)                            | 6/1429 (<1%)                        |        |
| Other/unspecified health care facility | 401/2920 (14%) | 95/1491 (6%)                           | 306/1429 (21%)                      |        |
| Hospice                      | 117/2920 (4%)         | 59/1491 (4%)                            | 58/1429 (4%)                        |        |
| Expired                      | 131/2920 (4%)         | 51/1491 (3%)                            | 80/1429 (6%)                        |        |
| Modified Rankin Scale at discharge, median (IQR) | 3 (1–4)             | 3 (1–4)                                 | 4 (2–5)                             | <0.01  |

COVID-19 indicates coronavirus disease 2019; CT, computed tomography; and IQR interquartile range.

*Analysis limited to patients with internal carotid, proximal middle cerebral (M1), or basilar artery occlusions who were evaluated in the emergency department and not transferred from an outside hospital.
may have been influenced by the higher proportion of patients with comorbid vascular risk factors (specifically atrial fibrillation), which confounded the observation of earlier imaging in patients treated during the COVID-19 period. As anticipated, the donning and doffing of personal protective equipment and decontamination of critical health care resources (eg, CT and magnetic resonance imaging scanners)—among other workflow changes—likely contributed to delays in the care of critically ill patients with acute stroke. Due to the large scale of this study and its retrospective nature, we were unable to report which specific components of stroke workflow may have contributed to the delay from imaging to treatment. Unsurprisingly, patients who were brought in by emergency medical services were more rapidly treated during the COVID-19 period, and they were more rapidly treated during the seasonal control period, as demonstrated in prior studies.10,11

While this study did not capture data on the presence of infection with the novel human coronavirus SARS-CoV-2, a small number of included patients evaluated during the COVID-19 period were infected with the virus. The treatment times, complications, and outcomes of these patients are being reported separately. Nevertheless, it is expected that health care providers would take additional precautions in caring for these patients whether the diagnosis of COVID-19 is known, unknown, or suspected. However, if such precautions contributed to the delay in thrombolysis observed in this study, it was not a delay in imaging acquisition but rather a delay in thrombolysis initiation.

One site included in this analysis utilized an MSU, which has been shown to facilitate earlier CT imaging and thrombolysis initiation.12 Because of the uniqueness of an MSU (notably its lack of universal availability and door-to-needle times of <0 minutes), we excluded imaging and treatment data for the 2% of the total cohort who were treated in the MSU. Data from the MSU site and other sites equipped with MSUs are being reported separately.

Our results are consistent with one retrospective analysis of patients treated at the Xuanwu Hospital in Beijing, in which the investigators observed a ≈1-hour delay in door-to-skin puncture of the 55 patients with LVO when compared with patients treated in the 2 months prior (174 versus 126 minutes; \(P=0.047\)).13 At the onset of the pandemic in the United States, one New York Comprehensive Stroke Center reported longer arrival-to-CT times (16 versus 12 minutes; \(P=0.05\)) and longer door-to-puncture times (80 versus 71 minutes; \(P=0.06\)) but no difference in door-to-needle times (36 versus 35 minutes; \(P=0.83\)).14 In this larger, multicenter cohort, we found no delays in the treatment using endovascular thrombectomy for proximal LVO. The time from arrival to imaging in patients who underwent thrombectomy was no different between the two periods (\(P=0.55\), data not available).

**Figure 1.** Door-to-needle times by month of arrival among nontransferred patients evaluated in the emergency department (not in-hospital strokes).

Boxes represent medians with interquartile range. Note that outliers have been excluded from the figure. Reference line (dashed) indicates Target: Stroke goal of 60-min door-to-needle time. COVID-19 indicates coronavirus disease 2019.
shown) while the time from imaging to groin puncture was significantly shorter during the COVID-19 period ($P<0.01$, data not shown). Based on rapidly published consensus recommendations,15,16 it is likely that neurointerventionalists in our network were able to quickly react to the pandemic without slowing throughput of patients with acute LVO.

Our findings are inconsistent with other observational data from 2 Egyptian centers, which reported no delay in thrombolysis.17 In that letter, Roushdy et al reported their experience with 242 patients (93 of whom were evaluated during the COVID-19 period) and found the door-to-needle times were similar among patients treated during or before COVID-19 (mean, 29.6±10.5 versus 29.6±4.9 minutes; $P=0.22$). In a larger retrospective cohort of >1200 patients in Barcelona, the investigators also reported no significant delay in acute care, although rates of stroke presentation fell during the COVID-19 pandemic.18 It is likely that since such differences in treatment times are small (on the order of a median of 4 minutes, according to our experience), smaller cohorts are unlikely to detect significant differences between treatment periods. Our results also do not corroborate early indications of a rapid rise in the number of patients with acute stroke or LVO as a consequence of the pandemic. Early reports out of Wuhan, China,19 and other case series,20,21 suggested that the coronavirus may increase the number of patients with embolic cerebral infarctions (as high as 5%). While we and others have certainly seen strokes in the setting of COVID-19, the early reports suggesting that there would be a dramatic spike in the number of LVOs may have been overstated. A comprehensive analysis of consecutive COVID-19 patients treated in the New York City was recently published, which estimated the risk of imaging-proven ischemic stroke in this population to be <1%.22 We have observed a similar rate of radiography-proven cerebral infarctions in hospitalized patients with COVID-19.23 While we4 and others24,25 have found that the rate of acute strokes may be falling during the COVID-19 pandemic, it is not likely to be the consequence of improved health care and primary prevention. On the contrary, it seems to be an unfortunate collateral effect of social distancing, the avoidance of health care institutions due to fear of contracting the virus,26 and perhaps the downplay of milder neurological symptoms.6,25

**Limitations**

While this study is the largest observational cohort to evaluate the collateral effect of the COVID-19 pandemic on acute stroke treatment, it has several limitations. Because of the retrospective nature of this investigation, not all data fields were captured with 100% completion. That said, the primary outcome of door-to-needle treatment time within 60 minutes was available for 99% of treated patients.

---

**Figure 2. Door-to-needle time according to patient method of arrival.**

Boxes represent medians with interquartile range. Note that outliers have been excluded from the figure. Patients were excluded from this analysis if they were transferred from an outside hospital, treated in a mobile stroke unit, or experienced an in-hospital stroke. Reference line (dashed) indicates Target: Stroke goal of 60-min door-to-needle time. COVID-19 indicates coronavirus disease 2019; and EMS, emergency medical services. *$P<0.05$, **$P<0.01$. 

---

*Stroke. 2021;52:40–47. DOI: 10.1161/STROKEAHA.120.032789*
during the 2 study periods. It is possible that the incompleteness of reported data (eg, missing cases from July 2020) could have contributed to a type II error. Missed cases from the end of the study period may have also contributed to the fall in reported stroke rates across included sites. However, several groups have already observed a smaller number of patients presenting to the hospital with stroke during the COVID-19 pandemic. Therefore, the incompleteness of data in later months is unlikely to explain the entire decrement of new stroke diagnoses. Furthermore, because the analyses in this investigation were limited by the available data from each center’s prospectively maintained stroke registries, comparisons could only be made for variables with identical definitions. This limited any secondary analyses as to exclusions for intravenous thrombolysis or endovascular recanalization and prevented us from evaluating imaging modalities, imaging findings, and effects of treatment (eg, hemorrhagic complications). Because infection with the coronavirus was not captured as part of each center’s prospective registry—and COVID-19 carries a high risk of in-hospital mortality—we did not explore in greater detail the functional outcomes of patients in this study. Outcomes in COVID-19–associated stroke have been reported separately as part of a larger, multinational study. Whether delays in thrombolysis contribute meaningfully to patient outcomes should be explored in larger studies or by pooling the data published to date.

Conclusions

From our multicenter observational study of 14 CSCs in the United States, we observed a significant decrease in the number of patients presenting with acute ischemic stroke and a small but significant decrease in timing of acute thrombolysis. The delay in thrombolysis appeared to persist through the months of June and July, as the later wave of the pandemic spread beyond New York and east coast centers. Because the delay in care appears driven largely by the time from image acquisition to thrombolysis initiation, centers are encouraged to reevaluate their local paradigms to expedite stroke treatment once intracranial hemorrhage has been excluded.

ARTICLE INFORMATION

Received June 16, 2020; final revision received October 15, 2020; accepted November 5, 2020.

Affiliations

Cooper Neurological Institute, Cooper University Hospital, Camden, NJ (U.E.S., L.M.T., R.T., M.E.H., L.T., T.G.J.). Department of Neurology, University of Texas Health Science Center at Houston, TX (A.M.Z., A.L.C.). Department of Neurology, Neurosurgery and Radiology, University of Iowa Hospitals and Clinics (S.O.-G., M.F.). Department of Neurology, Ronald Reagan University of California at Los Angeles (D.S.L.). Department of Neurology, University of Pittsburgh Medical Center Mercy Hospital, PA (S.M.D., A.P.J.). Department of Neurology, University of Pittsburgh Medical Center Presbyterian Medical Center, PA (S.M.D., A.P.J.). Department of Neurology, University of Texas Rio Grande Valley, Valley Baptist Medical Center, Harlingen, TX (A.E.H.). Center for Research (A.K.S.) and Department of Interventional Neuroradiology and Endovascular Neurosurgery (J.L.), Baptist Health South Florida, Coral Gables, Ohio-Health Neuroscience Center, Riverside Methodist Hospital, Columbus (V.R.). Department of Endovascular Neurological Surgery and Neurology, Robert Wood Johnson University Hospital, New Brunswick, NJ (P.K.). Marcus Stroke and Neuroscience Center, Grady Memorial Hospital, Atlanta, GA (M.H.M., D.C.H., R.G.N.). Department of Neurology, Emory University Hospital, Atlanta, GA (D.V.J., F.N.). Department of Interventional Neurology and Neuroradiology, Boston Medical Center, MA (A.K., T.N.N.). Department of Neurology, Mercy Health St. Vincent Hospital, Toledo, OH (O.Z.).

Acknowledgments

We would like to thank the following people for their assistance in gathering the data for this study: Ainsley Smith, Ameena Rana, Jessica Sweeney, Racheal McCoy, Judith Clark, and Leonardo Pisanu. We would also like to thank Patricia Feinigie for coordinating all study-related efforts.

Sources of Funding

None.

Disclosures

Dr Liebeskind reports other from Cerenovus, Genentech, Medtronic, and Stryker outside the submitted work. Dr Ortega-Guitierrez reports grants and personal fees from Stryker and personal fees from Medtronic outside the submitted work. Dr Hassan reports personal fees from Genetech during the conduct of the study and personal fees from Medtronic, Stryker, Penumbra, Microvention, Cerenovus, Vitai, Balt, and GE Healthcare outside the submitted work. Dr Haussen reports other from Stryker, Vasalo, Cerenovus, and VisAi outside the submitted work. Dr Nogueira reports consulting fees for advisory roles with Anaconda, Biogen, Cerenovus, Genentech, Imperative Care, Medtronic, Phenox, Prolong Pharmacueticals, and Stryker Neurovascular and stock options for advisory roles with Astrocryx, Brainomix, Ceretech, Ceretrieve, Corindus Vascular Robotics, Vasalio, VisAi, and Perfuz. Dr Jovin reports other from Anaconda, Route92, VisAi, Cerenovus, FreeOx, Stryker Neurovascular, Corindus, Methinks, and Contego Medical outside the submitted work. The other authors report no conflicts.

Supplemental Materials

Table I

REFERENCES

1. Dong E, Du H, Gardner L. An interactive web-based dashboard to track COVID-19 in real time. Lancet Infect Dis. 2020;20:533–534. doi: 10.1016/S1473-3099(20)30120-1
2. Gostin LO, Wiley LF. Governmental public health powers during the COVID-19 pandemic: stay-at-home orders, business closures, and travel restrictions. JAMA. 2020;323:2137–2138.
3. Cook TM. Personal protective equipment during the coronavirus disease (COVID) 2019 pandemic - a narrative review. Anaesthesia. 2020;75:920–927.
4. Morelli N, Rota E, Terracciano C, Immovilli P, Spallazzi M, Colombi D, Zaino, D., Michelleti E, Gueddett D. The baffling case of ischemic stroke disappearance from the casualty department in the COVID-19 era. Eur Neurol. 2020;83:213–215.
5. Naidich JJ, Bolytenkov A, Wang JJ, Chusid J, Hughes D, Saneli PC. Impact of the coronavirus disease 2019 (COVID-19) pandemic on imaging case volumes. J Am Coll Radiol. 2020;17:865–872. doi: 10.1016/j.jacr.2020.05.004
6. Siegel JE, Heslin ME, Thau L, Smith A, Jovin TG. Falling stroke rates during COVID-19 pandemic at a comprehensive stroke center. J Stroke Cerebrovasc Dis. 2020:29:104953. doi: 10.1016/j.jstrokecerebrovasdis.2020.104953
7. Gupta R, Horev A, Nguyen T, Gandhi D, Wisco D, Glenn BA, Tayal AH, Ludwig B, Terry JB, Gershon RY, et al. Higher volume endovascular stroke centers have faster times to treatment, higher reversal rates and higher rates of good clinical outcomes. J Neurointerv Surg. 2013;5:294–297. doi: 10.1136/neurintsurg-2011-010245
8. Lanska DJ, Hoffmann RG. Seasonal variation in stroke mortality rates. Neurology. 1999;52:984–990.
9. Fonarow GC, Smith EE, Saver JL, Reeves MJ, Hernandez AF, Peterson ED, Sacco RL, Schwamm LH. Improving door-to-needle times in acute ischemic stroke: the design and rationale for the American Heart Association/American Stroke Association’s Target: Stroke initiative. Stroke. 2011;42:2983–2989. doi: 10.1161/STROKEAHA.111.21342
10. Ekundayo OJ, Saver JL, Fonarow GC, Schwamm LH, Xian Y, Zhao X, Hernandez AF, Peterson ED, Cheng EM. Patterns of emergency medical services use and its association with timely stroke treatment;
findings from get with the guidelines-stroke. Circ Cardiovasc Qual Outcomes. 2013;6:262–269.
11. Gu HQ, Rao ZZ, Yang X, Wang CJ, Zhao XQ, Wang YL, Liu LP, Wang CY, Liu C, Li H, et al; Chinese Stroke Center Alliance Investigators. Use of emergency medical services and timely treatment among ischemic stroke. Stroke. 2019;50:1013–1016. doi: 10.1161/STROKEAHA.118.032789
12. Walter S, Kostopoulos P, Haass A, Keller I, Lesmeister M, Schlechtriemen T, Roth C, Papapanagiotou P, Grunwald I, Schumacher H, et al. Diagnosis and treatment of patients with stroke in a mobile stroke unit versus in hospital: a randomised controlled trial. Lancet Neurol. 2012;11:397–404. doi: 10.1016/S1474-4422(12)70057-1
13. Yang B, Wang T, Chen J, Chen Y, Wang Y, Gao P, Li G, Chen F, Li L, Wang Z, et al. Impact of the COVID-19 pandemic on the process and outcome of thrombectomy for acute ischemic stroke. J Neurointerv Surg. 2020;12:664–668. doi: 10.1136/neurintsurg-2020-016177
14. Agarwal S, Scher E, Rossan-Raghunath N, Marolia D, Butnari M, Torres J, Zhang C, Kim S, Sanger M, Humbert K, et al. Acute stroke care in a New York City comprehensive stroke center during the COVID-19 pandemic. J Stroke Cerebrovasc Dis. 2020;29:105068. doi: 10.1016/j.jstrokecerebrovasdis.2020.105068
15. AHA/ASA Stroke Council Leadership. Temporary emergency guidance to us stroke centers during the coronavirus disease 2019 (COVID-19) pandemic: on behalf of the American Heart Association/American Stroke Association Stroke Council Leadership. Stroke. 2020;51:1910–1912. doi: 10.1161/STROKEAHA.120.030023
16. Nguyen TN, Abdalkader M, Jovin TG, Nogueira RG, Jadhav AP, Haussen DC, Hassan AE, Novakovic R, Sheth SA, Ohtega-Gutierrez S, et al. Mechanical thrombectomy in the era of the COVID-19 pandemic: emergency preparedness for neuroscience teams: a guidance statement from the Society of Vascular and Interventional Neurology. Stroke. 2020;51:1896–1901. doi: 10.1161/STROKEAHA.120.030023
17. Roushdy TM, El Nahas NM, Aref HM, Georgy SS, Zaki AS, Bedros RY, Shokri HM. Stroke in the time of coronavirus disease 2019: experience of two university stroke centers in Egypt. J Stroke. 2020;22:275–277.
18. Rurollosso S, Laredo C, Vera V, Vargas M, Renu A, Liul L, Obach V, Amaro A, Utra X, Torres F, et al. Acute stroke care is at risk in the era of COVID-19: experience at a comprehensive stroke center in Barcelona. Stroke. 2020;51:1991–1995.
19. Mao L, Wang M, Chen S, He Q, Chang J, Hong C, Zhou Y, Wang D, Miao X, Hu Y, et al. Neurological manifestations of hospitalized patients with COVID-19 in wuhan, china: a retrospective case series study. JAMA Neurol. 2020;77:683–690.
20. Escalard S, Maier B, Redjemi H, Delvoye F, Hébert S, Smajda S, Ciccio G, Desilles JP, Mazighi M, Blanc R, et al. Treatment of acute ischemic stroke due to large vessel occlusion with COVID-19: experience from Paris. Stroke. 2020;51:2540–2543. doi: 10.1161/STROKEAHA.120.030574
21. Oxley TJ, Mocco J, Majidi S, Kelner CP, Shoirah H, Singh IP, De Leacy RA, Shimematsu T, Ladner TR, Yaeger KA, et al. Large-vessel stroke as a presenting feature of COVID-19 in the young. N Engl J Med. 2020;382:e60. doi: 10.1056/NEJMc2009787
22. Yaghi S, Ishida K, Torres J, Mac Grory B, Raz E, Humbert K, Henninger N, Trivedi T, Lillemoe K, Alam S, et al. SARS-CoV-2 and stroke in a New York healthcare system. Stroke. 2020;51:2002–2011. doi: 10.1161/STROKEAHA.120.030335
23. Siegler JE, Cardona P, Arenillas JF, Talavera B, Nunez Guillen A, Chavarría-Miranda A, De Lera M, Khandelwal P, Bach I, Patel P, et al. Express: cerebrovascular events and outcomes in hospitalized patients with COVID-19: the SVIN COVID-19 multinational registry [published online August 27, 2020]. Int J Stroke doi: 10.1177/1747493020959216 https://journals.sagepub.com/doi/10.1177/1747493020959216?url_ver=Z39.88-2003&rfr_id=ori:rid:crossref.org&rfr_dat=cr_pub%20%200pubmed.
24. Desai SM, Gujeyte FX, Martin-Gill C, Jadhav AP. Collateral damage — impact of a pandemic on stroke emergency services. J Stroke Cerebrovasc Dis. 2020;29:104988. doi: 10.1016/j.jstrokecerebrovasdis.2020.104988
25. Diegoli H, Magalhães PSC, Martins SCO, Moro CHC, Franca PHC, Safaneli J, Nagel V, Venancio VG, Liberato RB, Longo AL. Decrease in hospital admissions for transient ischemic attack, mild, and moderate stroke during the COVID-19 era. Stroke. 2020;51:2315–2321. doi: 10.1161/STROKEAHA.120.030481
26. Zhao J, Li H, Kung D, Fisher M, Shen Y, Liu R. Impact of the COVID-19 epidemic on stroke care and potential solutions. Stroke. 2020;51:1996–2001. doi: 10.1161/STROKEAHA.120.030225
27. Kansagra AP, Goyal MS, Hamilton S, Albers GW. Collateral effect of COVID-19 on stroke evaluation in the united states. N Engl J Med. 2020;383:400–401.