

Impact of COVID-19 Pandemic on a Regional Stroke Thrombectomy Service in the United Kingdom

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Keywords

Stroke · Thrombectomy · Coronavirus disease 2019 · Coronavirus · Pandemic · Health service

Abstract

Introduction: We examined the impact of the coronavirus disease 2019 (COVID-19) pandemic on our regional stroke thrombectomy service in the UK. **Methods:** This was a single-center health service evaluation. We began testing for COVID-19 on 3 March and introduced a modified "COVID Stroke Thrombectomy Pathway" on 18 March. We analyzed the clinical, procedural and outcome data for 61 consecutive stroke thrombectomy patients between 1 January and 30 April. We compared the data for January and February ("pre-COVID," $n = 33$) versus March and April ("during COVID," $n = 28$). **Results:** Patient demographics were similar between the 2 groups (mean age 71 ± 12.8 years, 39% female). During the COVID-19 pandemic, (a) total stroke admissions fell by 17% but the thrombectomy rate was maintained at 20% of ischemic strokes; (b) successful recanaliza-

tion rate was maintained at 81%; (c) early neurological outcomes (neurological improvement following thrombectomy and inpatient mortality) were not significantly different; (d) use of general anesthesia fell significantly from 85 to 32% as intended; and (e) time intervals from onset to arrival, groin puncture, and recanalization were not significantly different, whereas internal delays for external referrals significantly improved for door-to-groin puncture (48 [interquartile range (IQR) 39–57] vs. 33 [IQR 27–44] minutes, $p = 0.013$) and door-to-recanalization (82.5 [IQR 61–110] vs. 60 [IQR 55–70] minutes, $p = 0.018$). **Conclusion:** The COVID-19 pandemic has had a negative impact on the stroke admission numbers but not stroke thrombectomy rate, successful recanalization rate, or early neurological outcome. Internal delays actually improved during the COVID-19 pandemic. Further studies should examine the effects of the COVID-19 pandemic on longer term outcome.

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Introduction

From December 2019, coronavirus disease 2019 (COVID-19), which is caused by the severe acute respiratory syndrome coronavirus-2 (SARS-CoV-2), began to spread locally within China and then world-wide, becoming a global pandemic on March 11, 2020 [1]. In 1 reported series of 221 Chinese patients with confirmed COVID-19 patients, neurological symptoms were reported in 36.4% and acute ischemic stroke was reported in 5% of the patients [2]. In another series of 214 Chinese patients, acute cerebrovascular complications were reported in 0.8% and in 11.4% of the patients with non-severe and severe disease, respectively [3]. Moreover, it remained unclear whether COVID-19 could increase the risk of acute ischemic stroke resulting from large vessel occlusion (LVO) [4].

During this COVID-19 pandemic, many hospitals and clinics were prioritizing the protection of their frontline health-care staff and adapted to a resource-constrained environment, whilst aiming to maintain an optimal acute stroke pathway. The Society of Vascular & Interventional Neurology, Society of Neurointerventional Surgery, and Society for Neuroscience in Anesthesiology & Critical Care have all provided guidance on the management of LVO stroke during the COVID-19 pandemic [5–7]. We conducted a health service evaluation to examine the impact of the COVID-19 pandemic on stroke thrombectomy numbers, operation of the stroke thrombectomy pathway, and patient outcome [8].

Methods

Our hospital began performing diagnostic nasopharyngeal swabs for SARS-CoV-2 virus from March 3, 2020. On March 9, 2020, the Thrombectomy Management Board of the hospital started modifying the approved stroke thrombectomy pathway in the context of the COVID-19 pandemic; the final version of the new pathway was disseminated on March 18, 2020 to all relevant members locally and all external referring hospitals (shown in Table 1). Regionally, the agreement was not to transfer external stroke patients who were proven to have COVID-19 for thrombectomy at our hospital, but otherwise all external referral hospitals were instructed to continue referring patients for thrombectomy, including those with suspected COVID-19, via the same process as before the COVID-19 pandemic.

Data Collection

Clinical data for all acute stroke admissions were routinely collected and analyzed as part of a national audit program called the Sentinel Stroke National Audit Programme (SSNAP) and Pan-London Stroke Thrombectomy Report. We retrospectively extracted data for the period of January 1 to April 30, 2020, which

constituted the 2 months prior to, and 2 months since, COVID-19 testing began at our hospital (March 3, 2020). We extracted clinical data for (1) stroke admission and thrombectomy numbers; (2) patient demographics including age, sex, vascular risk factors, hospital of first contact, and pre-stroke functional status using the modified Rankin Scale; (3) the index stroke event including stroke severity using the National Institutes of Health Stroke Scale (NIHSS) and Glasgow Coma Scale on admission, neuroimaging findings from brain CT scanning or magnetic resonance imaging (MRI), and whether IV thrombolysis was administered; (4) the thrombectomy procedure parameters including the site of the LVO, use of general anesthesia, and successful recanalization rate; (5) time points in the stroke thrombectomy pathway including stroke onset, arrival to our hospital, arrival to interventional radiology (IR) suite, groin puncture and recanalization; and (6) early neurological outcomes, including changes in the NIHSS from baseline to 2 and 24 h post-procedure, presence of hemorrhagic transformation on repeat brain CT scan at 24 h, and in-hospital death.

Statistical Methods

We reported simple descriptions of mean (95% confidence intervals), medians (interquartile ranges, IQRs), frequencies, and proportions. Every continuous variable was examined for normality of distribution; if the Shapiro-Wilk test p value < 0.05 , nonparametric statistical tests were performed including the Mann-Whitney U test or Kruskal-Wallis test. Unpaired t tests or one-way ANOVA was used for normally distributed continuous variables, and χ^2 or Fisher's exact test for categorical variables. We made comparisons between the 2 epochs – January and February were labeled as “pre-COVID,” and March and April as “during COVID.” Statistical significance was defined as $p < 0.05$.

Results

We identified 61 consecutive stroke patients who underwent thrombectomy between January and April, 33 of whom were in the “pre-COVID” group and 28 in the “during COVID” group. The overall mean age was 70.5 (95% confidence interval 67.2–73.8) years and 39% were female. None of these patients tested positive for SARS-CoV-2 virus. During the COVID-19 pandemic, our hospital treated 758 COVID-19 patients in March and 941 COVID-19 patients in April; we found that stroke admissions fell from 196 to 168, and ischemic strokes from 177 to 142. However, the rate of stroke thrombectomy to ischemic strokes were well maintained throughout the 2 epochs ($33/177 = 18.6\%$ vs. $28/142 = 19.7\%$, $p = 0.808$). Table 2 summarizes the data on the patient demographics, thrombectomy procedure, time intervals in the stroke thrombectomy pathway, and early neurological outcomes for the 2 groups.

The patient demographics were similar between the 2 groups, with no significant differences in the admission NIHSS (18 [IQR 12–21] vs. 17.5 [IQR 12–19.5], $p = 0.401$),

Table 1. Modified COVID stroke thrombectomy pathway

Goals	Modifications
Protection of frontline health-care staff	Proven COVID-19-positive patients were not accepted from external referral centers All patients were assumed to be suspected COVID-19 cases until proven otherwise Surgical masks to be worn by patients General anesthesia and other aerosol generating procedures were avoided if appropriate Full PPE was used by all health-care staff and porters assuming every case was COVID-19 positive Full PPE was used from the Emergency Department front door to the IR suite General anesthesia required every staff to wear appropriate full PPE, including FFP3 masks All health-care staff must have passed the “fit test” for FFP3 masks At least 1 IR nurse who has passed “fit test” to be on duty for every shift, otherwise IR nurse must vacate IR suite during intubation or extubation and for 30 min afterward Clear donning and doffing areas allocated outside IR suite Strict instructions for all health-care staff to follow for donning and doffing PPE CT scanner and IR suite underwent “terminal enhanced clean” after every scan Rooms to be left empty for at least 20 min after every clean
Reducing footprint across the hospital	IV thrombolysis bolus was administered in CT scanning room Essential staff only escorted the patient, no relatives or visitors Essential staff only in the IR suite, e.g., no observers or trainees All non-essential equipment were removed from IR suite Patients were transferred from ED front door directly to IR suite, bypassing ED Patients were transferred from IR suite directly to HASU or ICU, bypassing IR Recovery
Maintaining communication between team members	Early notification of all team members including anesthetist, porters, and HASU nurse If general anesthesia was considered, ICU bed must be secured prior to accepting patient Enhanced consultant-to-consultant direct telephone handover

COVID-19, coronavirus disease 2019.

or Glasgow Coma Scale (13 [IQR 11–14] vs. 13 [IQR 11–15], $p = 0.337$). There was a nonsignificant drop in the proportion of stroke thrombectomy patients referred from external hospitals from 82 to 61% during the COVID-19 pandemic ($p = 0.067$).

Thrombectomy procedure parameters were similar between the 2 groups except for a significant reduction in the use of general anesthesia during thrombectomy (85 vs. 32%, $p < 0.0001$) as intended, but the post-procedure admission rates to the intensive care unit were similar (18 vs. 14%). Successful recanalization, as defined by a modified Treatment In Cerebral Infarction grades of 2b and 3 [9], was similarly achieved in both groups (76 vs. 81%). We questioned whether the intentional reduction in general anesthesia cases could have affected the successful recanalization rate for the severe strokes [10]. We therefore examined the patients with NIHSS ≥ 15 during the COVID-19 pandemic, and we found that 80% of general anesthesia cases ($n = 6$) and 90% of no-anesthesia cases ($n = 10$) resulted in successful recanalization (non-significant).

For the time intervals in the stroke thrombectomy pathway, there were no significant differences in the over-

all delays from onset-to-IR, onset-to-groin puncture, and onset-to-recanalization between the 2 groups. However, the trends for all 3 of these parameters indicated nonsignificant increases in median delays by 19, 31, and 38 min, respectively, during the COVID-19 pandemic. Internal delays at our hospitals were indicated by door-to-IR, door-to-groin puncture, and door-to-recanalization times; these data were analyzed together as well as separately for the external referrals. This was because of the differences in the 2 patient pathways; for example, externally referred patients usually did not require repeat neuroimaging at our hospital and were transferred directly to the IR suite. Our results showed significantly improved median delays from door-to-groin puncture (48 [IQR 39–57] vs. 33 [IQR 27–44] min, $p = 0.013$) and door-to-recanalization (82.5 [IQR 61–110] vs. 60 [IQR 55–70] min, $p = 0.018$). There was no significant difference in the time taken for the external referral to be accepted by our hospital. However, we questioned whether the external referrals were taking longer to reach our hospital, so we compared the onset-to-IR delay between the 2 groups and found a non-significant increase in median delay by 53

Table 2. Comparison of patients between “pre-COVID” versus “during COVID” epochs

	Pre-COVID (Jan–Feb), N = 33	During COVID (Mar–Apr), N = 28	Pre-COVID vs. during COVID p value
<i>Stroke admissions</i>			
Total number of stroke, n	196	168	–
Ischemic strokes, n	177	142	–
Thrombectomy procedures, n	33	28	–
Thrombectomy:ischemic stroke rate (%)	33/177 (18.6)	28/142 (19.7)	0.965
<i>Patient demographics</i>			
Mean age (95% CI), years	71.3 (66.7–75.9)	69.5 (64.5–74.6)	0.596
Young strokes <50 years, n (%)	2 (6%) – 47 to 48 years	3 (10.7%) – 42 to 48 years	0.653
Female, n (%)	14 (42)	10 (36)	0.593
Hypertension, n (%)	21 (64)	16 (57)	0.605
Diabetes mellitus, n (%)	7 (21)	6 (21)	0.984
Hyperlipidemia, n (%)	11 (33)	6 (21)	0.301
Previous stroke or TIA, n (%)	6 (18)	2 (7)	0.269
Atrial fibrillation, n (%)	8 (24)	7 (25)	0.945
Smoker, n (%)	4 (12)	0 (0)	0.118
Inter-hospital transfer, n (%)	27 (82)	17 (61)	0.067
Intravenous thrombolysis, n (%)	25 (76)	22 (79)	0.795
Pre-stroke mRS, n (%) mRS 0	22 (67)	20 (71)	
mRS 1, n (%)	7 (21)	6 (21)	0.806
mRS 2, n (%)	4 (12)	2 (7)	
GCS (median, IQR)	13 (11–14)	13 (11–15)	0.337
NIHSS on arrival (median, IQR)	18 (12–21)	17.5 (12–19.5)	0.401
<i>Thrombectomy procedure</i>			
Site of LVO, n (%)			
Middle cerebral artery – M1	19 (58)	18 (64)	
Middle cerebral artery – M2	5 (15)	3 (11)	
Internal carotid artery	8 (24)	6 (21)	0.901
Basilar artery	1 (3)	1 (4)	
General anesthesia, n (%)	28 (85)	9 (32)	<0.0001
ICU admission post-procedure, n (%)	6 (18)	4 (14)	0.741
Successful recanalization TIC12b/3, n (%)	25 (76)	21 (81)	0.645
<i>Delays in thrombectomy pathway (min)</i>			
Onset-to-IR (median, IQR)	246.5 (189–293.5)	265 (207.5–318.5)	0.407
Onset-to-IR for external referrals (median, IQR)	252 (230–299)	305 (260–325)	0.060
Onset-to-groin puncture (median, IQR)	280.5 (234.5–329.5)	311.5 (239.5–354.5)	0.244
Onset-to-recanalization (median, IQR)	305 (279–355)	343 (255–371)	0.650
Door-to-IR (median, IQR)	10 (5–25)	10.5 (4–72.5)	0.451
External referral*	8 (4–17)	4 (4–8)	0.148
Local patient	58.5 (41–131)	80 (65–129)	0.389
Door-to-groin puncture (median, IQR)	50 (41–69)	49 (30.5–126)	0.928
External referral*	48 (39–57)	33 (27–44)	0.013
Local patient	91 (74–167)	127 (98–158)	0.313
Door-to-recanalization (median, IQR)	99 (66–118)	70.5 (58–156)	0.650
External referral*	82.5 (61–110)	60 (55–70)	0.018
Local patient	177 (151–226)	159 (153–197.5)	0.436
External referral to acceptance (median, IQR)	15 (8–30)	20 (7–29)	0.770
<i>Early neurological outcome</i>			
NIHSS at 2 h (median, IQR)	14 (8–20)	13.5 (9–18)	0.734**
NIHSS improved at 2 h (by ≥1 points), n (%)	18 (64)	14 (54)	0.435**
NIHSS improved at 2 h (by ≥4 points), n (%)	11 (33)	10 (37)	0.845**
NIHSS at 24 h (median, IQR)	11 (8–16)	9.5 (6–19)	0.906**
NIHSS improved at 24 h (by ≥1 points), n (%)	16 (67)	14 (64)	0.829**
NIHSS improved at 24 h (by ≥4 points), n (%)	12 (36)	10 (37)	0.958**
Hemorrhagic transformation on 24-h CT, n (%)	7 (23)	5 (21)	0.876
Inpatient death, n (%)	9 (27)	6 (21)	0.597

CI, confidence interval; GCS, Glasgow Coma Scale; HASU, Hyper Acute Stroke Unit; LVO, large vessel occlusion; ICU, intensive care unit; IR, interventional radiology; NIHSS, National Institute of Health Stroke Score; mRS, modified Rankin Scale; TIA, transient ischemic attack; IQR, interquartile range; TIC1, Treatment In Cerebral Infarction. * Number of external referrals/total for group = 27/33 “pre-COVID,” 17/28 “during COVID.” ** Excluded patients who had been repatriated back to external referring hospital <24 h or sedated and intubated in the ICU (see under Methods).

min (252 [IQR 230–299] vs. 305 [IQR 260–325] min, $p = 0.0602$) during the COVID-19 pandemic.

Early neurological outcomes for the 2 groups were similar in terms of changes in NIHSS from baseline to 2 h (64 vs. 54%) and from baseline to 24 h (67 vs. 64%) after thrombectomy (similar results when comparing changes in NIHSS by 1 or more vs. 4 or more points), hemorrhagic transformation on the repeat CT scan at 24 h (23 vs. 21%), and in-hospital death (27 vs. 21%). NIHSS data were not available for patients who had been repatriated back to the referring hospital within 24 h (5 patients in the “pre-COVID” and 3 patients in the “during COVID group) or sedated and intubated in the ICU (also 5 patients in the “pre-COVID” and 3 patients in the “during COVID” group). There were no missing data for hemorrhagic transformation and in-hospital death.

Discussion

This is the first detailed report on the impact of COVID-19 pandemic on a regional stroke thrombectomy service based in the UK. During the pandemic, there were 14% fewer stroke admissions and 20% fewer ischemic strokes arriving at our hospital, in line with observations across the rest of the UK [11], and in the USA [12]. Interestingly, we found a nonsignificant 21% drop in external stroke thrombectomy referrals despite the referring hospitals being instructed to continue referring as before; the reasons for this were unclear; for example, patients might have presented to the referring hospitals outside the treatment window for thrombectomy, or perhaps health-care staff might have been so overwhelmed by COVID-19 admissions that their internal response times for acute stroke were slower.

In response to the COVID-19 pandemic, we swiftly modified our stroke thrombectomy pathway. At the same time, several professional bodies issued temporary emergency guidance for the COVID-10 pandemic and recommended that every new stroke admission should be treated as potentially infected [13]. One report from Saudi Arabia also described how they introduced a new “Protected Stroke Mechanical Thrombectomy Code” to enhance safe and timely care for stroke thrombectomy patients; however, these authors did not report any clinical or process data for comparison [14]. Interestingly, the authors of this report also described prophylactically intubating all stroke patients with LVO on arrival at the emergency department [14], whereas another proposed algorithm recommended that stroke thrombectomy pa-

tients who require general anesthesia should be electively intubated before arrival at the IR suite, whereas those who do not require general anesthesia should proceed to IR suite wearing only a surgical mask [15]. Concurrently, our hospital had substantial personnel changes including redeployment of 5 of our 8 stroke consultants to the medical wards and numerous rehabilitation therapists to the ICU, and many health-care staff became infected or had to be quarantined. The more junior neurology trainees who were on-call overnight had less training on acute stroke management and the thrombectomy pathway, which would have added to the pressure of a highly time-critical intervention. Despite these upheavals, every effort was made by our hospital to ensure the optimal emergency stroke care pathway continued to function as normal.

We did not find a significant negative impact of the COVID-19 pandemic on our regional stroke thrombectomy service and patient outcome. Importantly, the stroke thrombectomy rate was well maintained at 20% of ischemic strokes, successful recanalization rate was maintained at over 80%, and the chance of a favorable early neurological outcome following thrombectomy was maintained with no change in in-hospital mortality. Our findings are very similar to the Spanish experience where their ischemic stroke admissions fell by 17% but their thrombectomy rate was maintained at 40% [16]; whereas another study from the USA found their ischemic stroke admissions fell by 25% but their thrombectomy rate actually doubled from 17.5 to 34.3%, with a nonsignificant 50-min worsening of their onset-to-groin puncture delay [17]. However, our findings should be interpreted with caution as there might have been a potential degree of “selection bias” when selecting thrombectomy cases during the COVID-19 pandemic, such as avoiding very severe strokes (median NIHSS 18 vs. 17.5) or M2 occlusions (15 vs. 11%), both of which normally would have warranted the use of general anesthesia (an aerosol generating procedure). During the early peak of the pandemic, there were a small number of external referrals who required general anesthesia but were unable to be accepted due to a scarcity of ICU beds [18], or the time of transfer would have exceeded the recommended 6 h from onset-to-groin puncture.

We found no significant differences in the overall delays from onset-to-IR, onset-to-groin puncture, and onset-to-recanalization between the 2 groups. We anticipated worsening time intervals due to our modified COVID stroke thrombectomy pathway that had added a large number of additional safety checks and procedures in

place, especially regarding the strict donning and doffing regimen of PPE, which could have slowed down the process of transfers and interventions. Furthermore, only having minimal (just the essential) staff in the IR suite also meant that the thrombectomy procedure could theoretically have taken longer to perform. On the other hand, for external referrals, who were usually transferred directly from the base hospital to the IR suite for thrombectomy procedure, the road traffic in London during the pandemic was freely flowing; furthermore our new internal pathway recommended minimizing of footprint which could in turn have sped up patient transfers.

Also unexpectedly, we found significant improvements in the median internal delays for door-to-groin puncture (by 15 min) and door-to-recanalization (by 22.5 min) for external referrals. This concurs with the Hong Kong experience which found a 21-min improvement in their median door-to-groin puncture time during the COVID-19 pandemic [19], but in contrast to the French experience which found an 18-min worsening of their mean imaging-to-groin puncture delay [20], as well as the Chinese experience which found a 50-min worsening of their median door-to-groin puncture delay, and a 41-min worsening of their median door-to-recanalization delay [21]. Several factors could potentially have explained these findings. Importantly, a much lower proportion of thrombectomy procedures were performed under general anesthesia during the COVID-19 pandemic, which would have shortened the door-to-groin puncture and door-to-recanalization delays. Furthermore, in order to protect the service, none of the interventional neuroradiology staff were redeployed, and as all elective procedures were canceled in the hospital, and with fewer emergency procedures to perform, the department became more responsive and efficient for the stroke thrombectomy cases; this could also have shortened our internal delays.

The main limitation of this service evaluation is the retrospective nature and the short period of data collection, resulting in small numbers in each comparison group. However, since we are already seeing a fall in the number of COVID-19 admissions in the month of May 2020, we expect the main months for a meaningful comparison would still be January to April 2020. We also did not collect medium or long-term neurological outcome data. Many other clinical and non-clinical confounding factors could have been at play during the COVID-19 pandemic; hence, it would be impossible to explain our findings fully, and any potential associations described here should remain purely speculative. Further service

evaluations from other stroke thrombectomy centers would be helpful to compare how the COVID-19 pandemic has impacted on their referral patterns, process of care, and patient outcomes.

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Statement of Ethics

The paper is exempt from Ethical Committee approval, as decided by the Department of Stroke Medicine, Imperial College Healthcare NHS Trust. This health service evaluation is exempt because all clinical data were extracted from routinely collected source as part of an ongoing national audit program (SSNAP www.strokeaudit.org) and Pan-London Stroke Thrombectomy Report. No new intervention was used or tested.

Conflicts of Interests Statement

Dr. Kwan has received funding from Boehringer-Ingelheim and Bayer for educational events. Dr. Rane has received NIHR Biomedical Research Centre and Industry funding (Amgen) for interventional carotid studies and provided consultancy for industry device partners. Drs. M. Brown, Bentley, Z. Brown, D'Anna, Hall, Halse, Jamil, Jenkins, Kalladka, Patel, Singh, Taylor, Venter, Lobotesis, and Banerjee have no conflicts of interest to declare.

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Author Contributions

Dr. Kwan designed and conceptualized the study, analyzed the data, and drafted the manuscript for intellectual content. Dr. M. Brown had a major role in the data acquisition. Dr. Taylor had a major role in data analysis. Drs. Bentley, Z. Brown, D'Anna, Hall, Halse, Jamil, Jenkins, Kalladka, Patel, Rane, Singh, Venter, Lobotesis, and Banerjee interpreted the data and revised the manuscript for intellectual content.

References

- 1 Guan WJ, Ni ZY, Hu Y, Liang WH, Ou CQ, He JX, et al. Clinical characteristics of coronavirus disease 2019 in China. *N Engl J Med*. 2020;382(18):1708–20.
- 2 Li Y, Wang M, Zhou Y, Chang J, Xian Y, Mao L, et al. Acute cerebrovascular disease following COVID-19: a single centre, retrospective, observational study. *Lancet*. 2020 Sep;5(3):279–84. : https://papers.ssrn.com/sol3/papers.cfm?abstract_id=3550025.
- 3 Mao L, Jin H, Wang M, Hu Y, Chen S, He Q, et al. Neurologic manifestations of hospitalized patients with coronavirus disease 2019 in Wuhan, China. *JAMA Neurol*. 2020 Jun 1;77(6):683–90.
- 4 Oxley TJ, Mocco J, Majidi S, Kellner CP, Shoirah H, Singh IP, et al. Large-vessel stroke as a presenting feature of COVID-19 in the young. *N Engl J Med*. 2020 May 14;382(20):e60.
- 5 Nguyen TN, Abdalkader M, Jovin TG, Nogueira RG, Jadhav AP, Haussen DC, 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 Jun;51(6):1896–901.
- 6 Fraser JF, Arthur AS, Chen M, Levitt M, Mocco J, Albuquerque FC, et al. Society of neurointerventional surgery recommendations for the care of emergent neurointerventional patients in the setting of covid-19. *J Neurointerv Surg*. 2020 Jun;12(6):539–41.
- 7 Sharma D, Rasmussen M, Han R, Whalin M, Davis M, Kofke WA, et al. Anesthetic management of endovascular treatment of acute ischemic stroke during COVID-19 pandemic: consensus statement from society for neurosurgery in anesthesiology & critical care (SNACC). *J Neurosurg Anesthesiol*. 2020 Jul;32(3):193–201.
- 8 Khosravani H, Rajendram P, Notario L, Chapman MG, Menon BK. Protected code stroke: hyperacute stroke management during the coronavirus disease 2019 (COVID-19) pandemic. *Stroke*. 2020 Jun;51(6):1891–95.
- 9 Zaidat OO, Yoo AJ, Khatri P, Tomsick TA, von Kummer R, Saver JL, et al. Recommendations on angiographic revascularization grading standards for acute ischemic stroke: a consensus statement. *Stroke*. 2013;44(9):2650–63.
- 10 Schonenberger S, Henden PL, Simonsen CZ, Uhlmann L, Klose C, Pfaff JAR, et al. Association of general anesthesia vs procedural sedation with functional outcome among patients with acute ischemic stroke undergoing thrombectomy: a systematic review and meta-analysis. *JAMA*. 2019;322:1283–93.
- 11 Thornton J. Stroke: “striking reductions” are seen in number of people with symptoms seeking help. *BMJ*. 2020;369:m1406.
- 12 Kansagara AP, Goyal MS, Hamilton S, Albers GW. Collateral effects of Covid-19 on stroke evaluation in the United States. *N Engl J Med*. 2020 Jul 23;383(4):400–1.
- 13 Temporary emergency guidance to US stroke centers during the COVID-19 pandemic. *Stroke*. 2020.
- 14 Alqahtani SA, Alnaami I, Alhazzani A. Protected stroke mechanical thrombectomy code during the coronavirus (COVID-19) pandemic: Southwestern part of Saudi Arabia stroke unit local protocol. *Cureus*. 2020;12(4):e7808.
- 15 Smith MS, Bonomo J, Knight WA 4th, Prestigiacomo CJ, Richards CT, Ramser E, et al. Endovascular therapy for patients with acute ischemic stroke during the COVID-19 pandemic: a proposed algorithm. *Stroke*. 2020;51(6):1902–9.
- 16 Rudilosso S, Laredo C, Vera V, Vargas M, Renú A, Llull L, 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(7):1991–5.
- 17 Sweid A, Jabbour P, Tjoumakaris S. Letter to the editor: incidence of acute ischemic stroke and rate of mechanical thrombectomy during the COVID-19 pandemic in a large tertiary care telemedicine network. *World Neurosurg*. 2020;140:491–2.
- 18 Martin D, Platt S, Hampshire P, Meadows C. COVID-19: an update from England’s high consequence infectious diseases intensive care unit leads. *J Intensive Care Soc*. 2020;21:99–101.
- 19 Teo KC, Leung WCY, Wong YK, Liu RKC, Chan AHY, Choi OMY, et al. Delays in stroke onset to hospital arrival time during COVID-19. *Stroke*. 2020;51(7):2228–31.
- 20 Kerleroux B, Fabacher T, Bricout N, Moise M, Testud B, Vingadassalom S, et al. Mechanical thrombectomy for acute ischemic stroke amid the COVID-19 outbreak: decreased activity, and increased care delays. *Stroke*. 2020;51(7):2012–7.
- 21 Yang B, Wang T, Chen J, Chen Y, Wang Y, Gao P, et al. Impact of the COVID-19 pandemic on the process and outcome of thrombectomy for acute ischemic stroke. *J Neurointerv Surg*. 2020;12(7):664–8.