Shortening Door-to-Needle Time by Multidisciplinary Collaboration and Workflow Optimization During the COVID-19 Pandemic

Yimin Chen, MD,[a] Thanh N Nguyen, MD,[b] Jack Wellington, MSc,[c] Mohammad Mofatteh, PhD,[d] Weiping Yao, MD,[e] Zhaohui Hu, MD,[f] Qiuping Kuang, MD,[a] Weijuan Wu, MD,[a] Xuejun Wang, MD,[a] Yu Sun, MD,[a] Kexun Ouyang, MD,[g] Junmiao Xu,[a] Weiquan Huang,[h,i] and Shuiquan Yang, MD[a]

Objectives: This study aims to evaluate shortening door-to-needle time of intravenous recombinant tissue plasminogen activator of acute ischemic stroke patients by multidisciplinary collaboration and workflow optimization based on our hospital resources. *Materials and methods:* We included patients undergoing thrombolysis with intravenous recombinant tissue plasminogen activator from January 1, 2018, to September 30, 2020. Patients were divided into pre- (January 1, 2018, to December 31, 2019) and post-intervention groups (January 1, 2020, to September 31, 2020). We conducted multi-department collaboration and process optimization by implementing 16 different measures in prehospital, in-hospital, and post-acute feedback stages for acute ischemic stroke patients treated with intravenous thrombolysis. A comparison of outcomes between both groups was analyzed. *Results:* Two hundred and sixty-three patients received intravenous recombinant tissue plasminogen activator in our hospital during the study period, with 128 and 135 patients receiving treatment in the pre-intervention and post-intervention groups, respectively. The median (interquartile range) door-to-needle time decreased significantly from 57.0 (45.3−77.8) min to 37.0 (29.0−49.0) min. Door-to-needle time was shortened to 32 min in the post-intervention period in the 3rd quarter of 2020. The door-to-needle times at the metrics of $\leq$ 30 min, $\leq$ 45 min, $\leq$ 60 min improved considerably, and the DNT> 60 min metric exhibited a significant reduction. *Conclusions:* A multidisciplinary collaboration and continuous process optimization can result in overall shortened door-to-needle despite the challenges incurred by the COVID-19 pandemic.

Key Words: Acute ischemic stroke—Door-to-Needle Time—Thrombolysis—COVID-19 pandemic

From the [a]Department of Neurology and Advanced National Stroke Center, Foshan Sanshui District People's Hospital, No. 16, Guanghaidadaoxi, Sanshui District, Foshan, Guangdong Province 528100, China; [b]Thanh N. Nguyen Department of Neurology, Radiology, Boston University School of Medicine, Boston, MA, United States; [c]School of Medicine, Cardiff University, Wales, United Kingdom; [d]School of Medicine, Dentistry and Biomedical Sciences, Queen's University Belfast, United Kingdom; [e]Dean Office, Foshan Sanshui District People's Hospital, Foshan, Guangdong Province, China; [f]Medical Department, Foshan Sanshui District People's Hospital, Foshan, Guangdong Province, China; [g]Department of Radiology, Foshan Sanshui District People's Hospital, Foshan, Guangdong Province, China; [h]Medical Intern, Foshan Sanshui District People's Hospital, Foshan, Guangdong Province, China; and [i]School of Medicine, Shaoguan University, Shaoguan, Guangdong Province, China.

Received September 9, 2021; revision received October 10, 2021; accepted October 12, 2021.

Corresponding author. E-mail: yangshuiquan1969@126.com.

1052-3057/$ - see front matter

https://doi.org/10.1016/j.jstrokecerebrovasdis.2021.106179

Introduction

The effect of thrombolysis is time-dependent. Intravenous recombinant tissue plasminogen activator (IV-rtPA) has significantly improved patient outcomes when administrated within 4.5 h of symptom onset and in the extended time window.[1−3] To maximize clinical benefit, all efforts should be undertaken to shorten the treatment delay.[1−3] Patients affected by large vessel infarction lose approximately 1.9 million neurons every minute without reperfusion.[4] Previously, researchers at the Helsinki University Central Hospital implemented measures to reduce delays and shorten the median door-to-needle (DNT) to 20 min with an interquartile range (IQR) of 14−32 min.[5] However, less than 30% of patients had the recommended door-to-CT-time (DCT) of 20 min and DNT of 60 min by the American Medical Association (AMA).[7] The Canadian Stroke Best Practices Recommendations (CSBPR) advised DNT for acute stroke should be reduced to a median of 30 min.[6]

Chao et al. reported the median DNT in the China Stroke Prevention Project Committee (CSPPC) program of 380 Chinese stroke centers to be 48 min (add IQR if available).[8] Previous studies demonstrated that door-to-needle time could be shortened in most centers by understanding the causes of delays to rapid treatment and the implementation of parallel workflow strategies.[9]

Our hospital in Foshan, Guangdong province, China, is an 898-bed tertiary hospital. Suspected acute stroke patients arriving at our emergency department enter our stroke priority green pathway. Emergency physicians receive patients as a priority and request urgent neurological consultation. This study aimed to evaluate whether a multi-department collaboration and workflow optimization protocol could shorten the DNT of IV rt-PA in patients presenting with acute ischemic stroke.

Subjects and methods

Patients

Our respective emergency department included patients undergoing thrombolysis with IV rt-PA from January 1, 2018, to September 30, 2020. All other patients diagnosed with ischemic stroke but who did not receive thrombolysis with IV rt-PA were excluded. In anticipation of stroke protocol changes that would be necessary at the beginning of the COVID-19 pandemic,[10] we continuously refined and disseminated our protocol since its implementation in January of 2020. Patients were divided into pre-intervention (from January 1, 2018, to December 31, 2019) and post-intervention groups (January 1, 2020, to September 31, 2020). It is worth mentioning that the post-intervention group coincided with the start of the COVID-19 pandemic. Patient demographics, including associated risk factors of stroke, NIHSS score on emergency department arrival, symptom onset-to-door time (ODT), DCT, CT-to-needle-time (CNT), DNT, onset-to-needle time (ONT), and intracranial hemorrhagic complications, were recorded. A comparison of outcomes between both groups was analyzed. The hospital ethics committee approved this study.

Interventions

To shorten DNT at our hospital via multidisciplinary and workflow optimization in prehospital, in-hospital, and feedback stages, we implemented the following measures:

(1) Engaging the Hospital chief in the study to facilitate improving DNT.
(2) Hospital notification via the establishment of a secure web communication platform (*i.e.*, WeChat, a Chinese messaging and social app) - hospital providers acquire patient history from family members while at the same time informing patients and their families regarding thrombolysis treatment benefits and risks.
(3) Ensuring suspected stroke patients are prioritized for evaluation by an emergency room nurse and physician.
(4) Monthly training to stroke and emergency nurses to promptly recognize stroke symptoms and signs, as well as education regarding the therapeutic window for acute stroke patients, by neurologists.
(5) Monthly training to emergency room physicians to recognize symptoms and signs of stroke by neurologists.
(6) Notifying relevant stroke teams, including emergency healthcare, via a prenotification service before performing head CT scans.
(7) Prioritizing CT scan and transfer to radiology.
(8) Prioritizing relevant laboratory examination results, especially International Normalized Ratio (INR) for patients prescribed anticoagulants.
(9) Facilitating interpretation of head CT by stroke team physicians without requiring formal radiology reports (radiology reports can be given priority in certain circumstances).
(10) Training physicians to effectively communicate propositions for thrombolysis with promptly signed informed consent from patients or their families undergoing thrombolysis (family members were allowed to enter the emergency department during the COVID-19 pandemic to sign consent forms).
(11) Training nurses to prepare IV rtPA quickly and effectively.
(12) Encouraging neurologists to provide immediate feedback if DNT is delayed.
(13) Inviting the Hospital chief, along with the staff of neurology, radiology, and emergency departments,

to attend monthly stroke meetings to analyze the etiology of DNT-delayed cases.

(14) Rewarding associated staff of emergency, neurology, and radiology departments financially if DNT was less than or equal to 60 min.

(15) Connecting with the regional Health Bureau and media department of the hospital to raise awareness and public education of acute stroke.

(16) Reinforcing standard procedures for acute stroke management after the post-intervention period to achieve a sustainable patient outcome.

Statistical analysis

The results are reported as the median with IQR and the mean ± standard deviation or frequency (displayed in percentages). The relationships of the baseline characteristics and clinical factors between the pre-intervention and post-intervention groups were assessed using an independent sample *t*-test, Mann−Whitney *U*-test, Pearson chi-square test, or Nonparameter test. All statistical analyzes were performed using Statistical Package for Social Sciences (SPSS) version 26.0 (Released 2019, IBM SPSS Statistics for Windows, Version; IBM Corp, Armonk, NY). "*P*" values of < 0.05 were considered significant.

Results

Baseline characteristics

In our hospital, two hundred and sixty-three patients received IV rt-PA, with 128 and 135 patients receiving IV rtPA in the pre-intervention and post-intervention groups, respectively. The baseline characteristics of both patient groups are exhibited in Table 1.

When comparing baseline characteristics in both groups, the pre-intervention group consisted of a higher proportion of patients admitted with previous stroke (*p*-value = 0.001). Mean age, sex ratio, and median admission NIHSS scores showed no significant differences. Prior history of hypertension, atrial fibrillation, diabetes mellitus, coronary heart disease, hyperlipidemia, and thrombectomy displayed no difference between the two groups.

The comparison of clinical outcomes is shown in Table 2. The median (IQR) DNT decreased significantly

Table 1. *Baseline characteristics of patients between pre-intervention and post-intervention.*

Total number	pre-intervention*n* 128	post-intervention*n* 135	t/z/χ^2	*P* value
Mean age (SE)	62.27 ± 12.89	65.20 ± 12.71	-1.854	0.07
Men, n (%)	90 (70.31)	90 (66.67)	0.404	0.53
NIHSS score, median (IQR)	6.0 (3.0−12.0)	6.0 (3.0−12.0)	-0.607	0.54
Hypertension, *n* (%)	91 (71.1)	95 (70.4)	0.06	0.81
Atrial fibrillation, *n* (%)	13 (10.48)	18(13.43)	0.53	0.47
Diabetes mellitus, *n* (%)	13 (10.32)	24 (17.91)	3.067	0.08
Previous stroke/TIA, *n* (%)	8 (6.35)	28 (20.90)	11.519	0.001
Previous coronary heart disease, *n* (%)	16 (12.70)	15 (11.19)	0.14	0.708
Hyperlipidemia, *n* (%)	36 (28.57)	43 (32.09)	0.38	0.538
Thrombectomy, *n* (%)	6 (4.84)	15 (11.19)	3.479	0.062

Table 2. *Outcome of two groups.*

Total number	pre-intervention 128	post-intervention 135	t/z/χ^2	*P* value
median DNT	57.0 (45.3−77.8)	37.0 (29.0−49.0)	-7.794	< 0.001
DNT≤ 30 min	6 (4.7%)	40 (29.6%)	28.324	< 0.001
DNT≤ 45 min	32 (25%)	96 (71.1%)	55.92	< 0.001
DNT≤ 60 min	73 (57.0%)	116 (85.9%)	27.129	< 0.001
DNT> 60 min	55 (43.0%)	19 (14.1%)	27.129	< 0.001
Median ODT	85.0 (59.0−120.0)	86.5 (52.5−141.3)	-0.69	0.49
Median DCT	13.0 (7.0−22.5)	15.0(10.0−19.0)	-1.058	0.29
DCT≤ 20 min	94 (73.4%)	109 (80.7%)	1.99	0.158
Median CNT	45.0 (34.5−58.0)	23.0 (17.0−31.8)	-8.7	< 0.001
Median ONT	154.0 (120.0−186.0)	138.5 (98.0−184.5)	-2.289	0.022
HT	7 (5.79%)	6 (4.48%)	0.225	0.635
sICH	4 (3.1%)	3 (2.22%)	0.005	0.943

ODT: onset-to-door time, DCT: door-to-CT time, DNT: door-to-needle time, CNT: CT-to-needle time, ONT: onset-to-needle time, HT: Hemorrhagic Transformation, sICH: symptomatic intracranial hemorrhage.

from 57.0 (45.3−77.8) min to 37.0 (29.0−49.0) min ($P < 0.001$). The benchmark metrics of DNT≤ 30 min, DNT≤ 45 min, and DNT≤ 60 min improved considerably, and the DNT> 60 min metric exhibited a significant reduction($P < 0.001$). Median DCT increased from 13.0 (7.0−22.5) min to 15.0 (10.0−19.0) min ($p = 0.290$). The door to CT increase was not significant. However, DCT≤ 20 min improved from 73.4% to 80.7%($P = 0.158$). Median CNT reduced significantly from 45.0 (34.5−58.0) min to 23.0 (17.0−31.8) min ($p < 0.001$). There was no difference in the rates of hemorrhagic transformation (5.8% vs 4.5%, $p = 0.94$) and symptomatic intracranial hemorrhage (3.1% vs 2.2%, $p = 0.94$). A summary of Median DNT, ODT, DCT, CNT, and ONT from 2018 January to 2020 September is shown in Table 3.

Discussion

Our study showed that multidisciplinary collaboration and workflow optimization could be considered an effective strategy to reduce DNT (Fig. 1). The highest median DNT was 73.5 (46.25−86.00) min in the pre-intervention group in the Q1 of 2019 (Fig. 2). DNT was shortened to 32 min in the post-intervention period in the Q3 of 2020. DNT from 2018 to 2020 was decreased significantly from the highest of 73.5 (46.25−86.00) min to 32 (25.0−43.0) min (Fig. 2). Median DTN 2018 68 min, Q 1 2019 73.5 min - vs Q2 and Q3 2020, 35 min and 32 min respectively, all P-value < 0.001. The benchmark metrics of meeting DNT to less than 30, 45, and 60 min were improved (Fig. 2). Median CNT was reduced from 51.5 to 19 min. However, we found that ODT in the pre-intervention group was 85.0 min compared to the ODT in the post-intervention group, which was 86.5 min (p-value 0.49). We speculate that potential explanations for this delay could be due to the effects of the COVID-19 outbreak in China in the first quarter of 2020. Our hospital was designated to manage patients diagnosed with COVID-19 from the end of January 2020. Though there were only 13 COVID-19 cases reported in our district in 2020, The COVID-19 outbreak had impacted stroke care in several dimensions, including

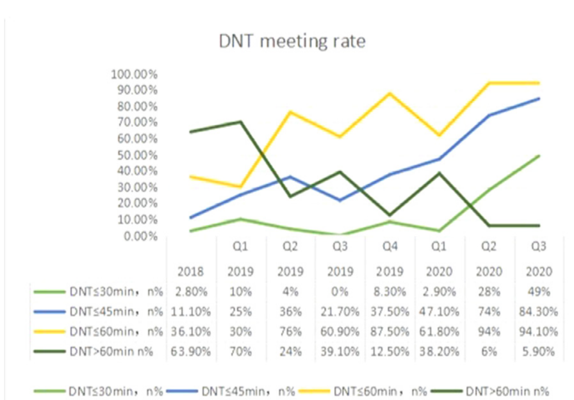

Fig. 1. *DNT meeting rate from 2018 to Q3 of 2020.*

Table 3. *Median DNT, ODT, DCT, CNT and ONT from 2018 January to 2020 September.*

Time	2018	2019 Q1	2019 Q2	2019 Q3	2019 Q4	2020 Q1	2020 Q2	2020 Q3
Median DNT	68.0 (53.50-93.25)	73.5 (46.25-86.00)	50.0 (44.50-59.50)	57.0 (46.00-80.00)	50.0 (40.00-57.75)	50.5 (38.00-82.00)	35.0 (30.00-46.25)	32.0 (25.00-43.00)
Median ODT	67.5 (50.00-106.50)	75.0 (39.75-111.00)	85.0 (60.00-120.00)	120.0 (64.00-150.00)	83.0 (62.00-109.50)	69.0 (48.00-138.50)	106.5 (60.75-141.25)	79.0 (49.00-160.00)
Median DCT	19.0 (9.00-25.00)	13.5 (8.50-26.75)	11.0 (7.00-16.00)	10.0 (7.00-26.00)	13.0 (9.25-22.25)	15.0 (10.00-21.00)	16.0 (11.00-19.75)	14.0 (10.00-17.75)
Median CNT	50.0 (41.00-70.00)	51.5 (38.00-74.75)	38.0 (30.00-51.00)	47.0 (35.00-58.00)	36.5 (29.00-45.00)	31.0 (24.00-61.00)	21.0 (17.50-26.50)	19.5 (12.25-27.00)
Median ONT	155.0 (129.75-177.75)	148.5 (120.50-195.25)	152.0 (111.75-184.75)	186.0 (133.00-230.00)	136.5 (99.50-172.50)	136.0 (102.50-185.50)	142.5 (95.75-192.50)	123.0 (83.00-184.00)

Q1= first quarter of the year.Q2= second quarter of the year. Q3= third quarter of the year. Q4= fourth quarter of the year. DNT, door-to-needle-time; ODT, onset-to-door time; DCT, door-to-CT-time; CNT, CT-to-needle-time.

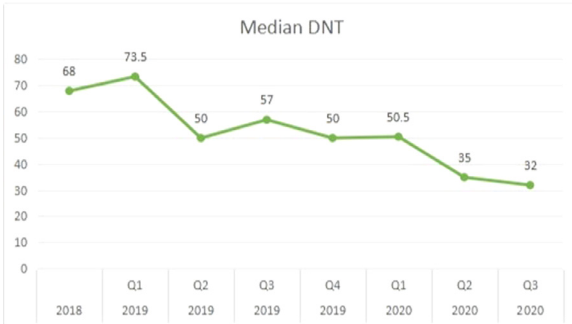

Fig. 2. *Median DNT from 2018 to Q3 of 2020.*

a global decline in stroke and cerebrovascular admissions.[11–15]

In our study, we noted the median DCT increased from 13.0 (9.3−22.3) min in the Q4 of 2019 to 15.0 (10.0−21.0) min in the Q1 of 2020 and 15.0 (10.0−21.0) min in the Q2 of 2020 (Fig. 3). These longer times could have been attributed to our hospital being a COVID-19-designated clinical environment with rigorous COVID-19 screening in place. If a patient was found to have a fever or suspected COVID-19, patients requiring CT completed sterilization and disinfection protocols contributing to DCT delays in the 1st and 2nd quarter of 2020. Despite the COVID-19 pandemic period, the median CNT shortened to 19 min. As a result, the median DNT had reduced to 32 (25.0−43.0) min (Fig. 2).

Our findings of shorter DNT times with stroke protocol implementation during the pandemic are in contrast with other studies. A multicenter, retrospective cohort study showed that the mean DNT was 74.2 min in 2020 during the pandemic, which was longer than the time of 46.4 min before the pandemic in 2019.[16] A study involving nine comprehensive stroke centers in the United States demonstrated longer time to IV thrombolysis treatment delay during the COVID-19 pandemic may have lead to more hospice care and early mortality.[17] While several segments in the stroke metric pathway were delayed in our study, the overall DNT was shorter, despite the challenges of stroke care amidst the pandemic. Therefore, healthcare professionals should make every minute count, from prehospital to inpatient processing, alongside immediate clinical feedback to shorten DNT.

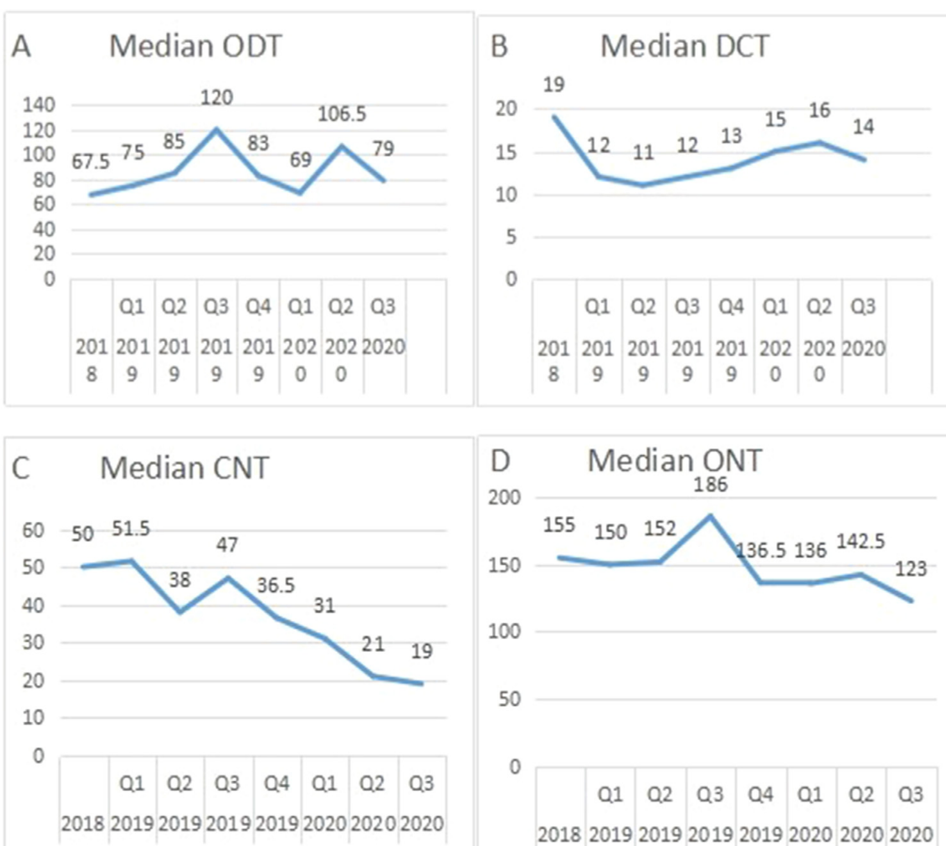

Fig. 3. *A - Median ODT from 2018 to Q3 of 2020; B - Median DCT from 2018 to 2020 Q3; C - Median CNT from 2018 to 2020 Q3; D - Median ONT from 2018 to 2020 Q3.*

Limitations

This study consists of a single-center retrospective design with a lack of reporting of patients' outcomes at 90 days. Future multicenter studies, including patient outcomes, will be essential to monitor for continued stroke quality improvement.

Conclusion

Our study demonstrated that multidisciplinary collaboration and process optimization could shorten DNT significantly during the COVID-19 pandemic period. Adaptations to workflow optimization and multidisciplinary case management may further benefit healthcare professionals during events of unforeseeable precedences, such as the COVID-19 pandemic and other emergencies in the future. Therefore, as healthcare professionals trained in the management of acute stroke, we should make every minute count, from prehospital to inpatient processing, alongside immediate clinical feedback.

Funding

Not applicable.

Availability of data and materials

The data will be available upon request from the corresponding author.

Ethics approval and consent to participate

This study was approved by the Foshan Sanshui District People's Hospital Research Ethics Committee, and informed consents were waived because of the minimal risk of harm to the patients.

Declarations of Competing Interest

All authors have no conflict of interest.

CRediT authorship contribution statement

Yimin Chen: Writing – original draft, Writing – review & editing. **Thanh N Nguyen:** Formal analysis, Writing – review & editing. **Jack Wellington:** Formal analysis, Writing – review & editing. **Mohammad Mofatteh:** Formal analysis, Writing – review & editing. **Weiping Yao:** Conceptualization, Writing – review & editing. **Zhaohui Hu:** Conceptualization, Writing – review & editing. **Qiuping Kuang:** Data curation, Formal analysis, Writing – review & editing. **Weijuan Wu:** Data curation, Formal analysis, Writing – review & editing. **Xuejun Wang:** Data curation, Formal analysis, Writing – review & editing. **Yu Sun:** Data curation, Formal analysis, Writing – review & editing. **Kexun Ouyang:** Data curation, Formal analysis, Writing – review & editing. **Junmiao Xu:** Data curation, Formal analysis, Writing – review & editing. **Weiquan Huang:** Data curation, Formal analysis, Writing – review & editing. **Shuiquan Yang:** Writing – original draft, Conceptualization, Writing – review & editing.

Acknowledgments

The authors thank all coordinators for data collection.

References

1. Marler J, Tilley B, Lu M, et al. Early stroke treatment associated with better outcome: the NINDS rt-PA stroke study. Neurology 2000;55:1649-1655.
2. Hacke W, Kaste M, Bluhmki E, et al. Thrombolysis with alteplase 3 to 4.5 hours after acute ischemic stroke. N Engl J Med 2008;359:1317-1329.
3. Lees KR, Bluhmki E, von Kummer R, et al. Time to treatment with intravenous alteplase and outcome in stroke: an updated pooled analysis of ECASS, Atlantis, NINDS, and EPITHET trials. Lancet 2010;375:1695-1703.
4. Saver JL. Time is brain-quantified. Stroke 2006;37(1):263-266.
5. Meretoja A, Weir L, Ugalde M, et al. Helsinki model cut stroke thrombolysis delays to 25 minutes in Melbourne in only 4 months. Neurology 2013;81:1071-1076.
6. Casaubon LK, Boulanger JM, Blacquiere D, et al. Canadian stroke best practice recommendations: hyperacute stroke care guidelines, update 2015. Int J Stroke 2015;10 (6):924-940.
7. Fonarow GC, Smith EE, Saver JL, et al. Timeliness of tissue-type plasminogen activator therapy in acute ischemic stroke. Circulation 2011;123:750-758.
8. Chao BH, Yan F, Hua Y, et al. Stroke prevention and control system in China: CSPPC-stroke program. Int J Stroke 2021;16(3):265-272.
9. Kamal N, Smith EE, Jeerakathil T, et al. Thrombolysis: improving door-to-needle times for ischemic stroke treatment - a narrative review. Int J Stroke 2018;13(3):268-276.
10. Nguyen T, Nogueira R, Jovin T. 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(8).
11. Nogueira R, Qureshi M, Abdalkader M, et al. Global impact of COVID-19 on stroke care and IV thrombolysis. Neurology 2021;96(23):e2824-e2838.
12. Nguyen T, Haussen D, Qureshi M, et al. Decline in subarachnoid haemorrhage volumes associated with the first wave of the COVID-19 pandemic. Stroke Vasc Neurol 2021. svn-2020-000695. https://doi.org/10.1136/svn-2020-000695. Online ahead of print.
13. Nogueira R, Abdalkader M, Qureshi M, et al. Global impact of COVID-19 on stroke care. Int J Stroke 2021;16 (5):573-584.
14. Zhao J, Li H, Kung D, et al. Impact of the COVID-19 epidemic on stroke care and potential solutions. Stroke 2020;51(7):1996-2001.
15. Kristoffersen ES, Jahr SH, Thommesson B, et al. Effect of COVID-19 pandemic on stroke admission rates in a Norwegian population. Acta Neurol Scand 2020;142(6):632-636.

16. Zhou Y, Hong C, Chang J, et al. Intravenous thrombolysis for acute ischaemic stroke during COVID-19 pandemic in Wuhan, China: a multicentre, retrospective cohort study. J Neurol Neurosurg Psychiatry 2021;92 (2):226-228.
17. Jillella DV, Nahab F, Nguyen TN, et al. Delays in thrombolysis during COVID-19 are associated with worse neurological outcomes: the society of vascular and interventional neurology multicenter collaboration. J Neurol 2021:1-6. Online ahead of print.