



Impact of COVID-19 pandemic on acute stroke care: facing an epidemiological paradox with a paradigm shift

Matteo Paolucci^{1,2} · Sara Biguzzi¹ · Francesco Cordici¹ · Enrico Maria Lotti³ · Simonetta Morresi¹ · Michele Romoli^{1,3} · Silvia Strumia⁴ · Rossana Terlizzi¹ · Simone Vidale³ · Maurizio Menarini⁵ · Maria Ruggiero⁶ · Alessandro Valentino⁷ · Marco Longoni^{1,4}

Received: 31 October 2020 / Accepted: 15 November 2020 / Published online: 21 November 2020

© Fondazione Società Italiana di Neurologia 2020

Abstract

Background During the coronavirus disease 2019 (COVID-19) outbreak, a decrease of stroke's hospital admissions and reperfusion therapy has been reported worldwide. This retrospective observational study assessed the volume of stroke cases managed in the Emergency Department (ED) and reperfusion therapies in an Italian stroke network with a high incidence of COVID-19, particularly to evaluate if the in-hospital rerouting and the switch from a drip-and-ship to a mothership model could assure an adequate volume of acute treatments.

Methods We compared data from March 2020 with those from previous years and formulated five PICO questions regarding (1) incidence of stroke cases in the ED; (2) relation between stroke cases and COVID-19; (3) differences in the number of reperfusion therapies, (4) in the call-to-needle and door-to-needle times for intravenous thrombolysis, and (5) in the call-to-groin and door-to-groin times for thrombectomy.

Results We found (1) a 28% decreased of confirmed stroke cases managed in the ED, (2) a negative correlation between stroke cases in ED and COVID-19 progression ($r_s = - .390$, $p = .030$), and (3) a similar number of treatments in March 2020 and March 2019. The adoption of the mothership model (4) did not delay alteplase infusion (median call-to-needle $p = .126$, median door-to-needle $p = .142$) but led to (5) a significant reduction in median call-to-groin ($p = .018$) and door-to-groin times ($p = .010$).

Conclusion The “hospital avoidance” of stroke patients during the “stay-at-home” appeals needs to be considered for future public health campaigns. A prompt reorganization of the stroke network can guarantee optimal performances at times of crisis.

Keywords COVID-19 · SARS-CoV-2 · Stroke incidence · Thrombolysis · Thrombectomy

Abbreviations

SARS-CoV-2 Severe acute respiratory syndrome coronavirus 2
COVID-19 Coronavirus Disease 2019
PICO Patient, intervention/exposure, comparator, outcome

FC Forli-Cesena province
RN Rimini province
ED Emergency Department
IVT Intravenous thrombolysis
EVT Endovascular thrombectomy
CTN Call-to-needle time

✉ Matteo Paolucci
matteo.paolucci@auslromagna.it; matpaolucci@gmail.com;
m.paolucci@unicampus.it

¹ Neurology Unit, “M. Bufalini” hospital, AUSL Romagna, Viale Giovanni Ghirelli, 286, 47521 Cesena, FC, Italy

² Headache and Neurosonology Unit, Campus Bio-Medico University, Rome, Italy

³ Neurology Unit, “Infermi” hospital, AUSL Romagna, Rimini, RN, Italy

⁴ Neurology Unit, “Morgagni-Pierantoni” hospital, AUSL Romagna, Forlì, FC, Italy

⁵ Centrale Operativa 118 Romagna e Emergenza Territoriale della Provincia di Ravenna, AUSL Romagna, Ravenna, Italy

⁶ Neuroradiology Unit, “M. Bufalini” hospital, AUSL Romagna, Cesena, FC, Italy

⁷ Pronto Soccorso e Medicina d’Urgenza, “M. Bufalini” hospital, AUSL Romagna, Cesena, FC, Italy

DTN	Door-to-needle time
CTG	Call-to-groin time
DTG	Door-to groin time

Introduction

Severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) pandemic is deeply affecting health care systems worldwide. This applies tremendously on the management of time-dependent diseases, like stroke. Stroke and coronavirus disease 2019 (COVID-19) share a mutual bond. Stroke and stroke-at-risk population (elders, hypertensives) overlap with the population at higher risk of severe SARS-CoV-2 infection [1–3]. On the other hand, arrhythmic and coagulative complications of SARS-CoV-2 infection may increase the risk and the severity of cerebrovascular diseases [4–6]. However, during the first phase of the pandemic, there have been worldwide observations of decreased rates of stroke patients' hospital admissions, thrombolysis, and thrombectomy [7–10]. Italian stroke opinion leaders confirmed this trend in Italy too (Toni D., on behalf of Italian Stroke Organization, unpublished data, 2020). One of the main identified reasons relies on the falling rate of patients with milder symptoms presenting to healthcare facilities [11, 12]. Increased social isolation, misdiagnosis, or a real reduction in stroke incidence due to behavioral changes are other possible, although not exhaustive, explanations [13]. Apart from the direct and indirect influences on stroke epidemiology, the COVID-19 pandemic forced a complete rearrangement of the territorial and in-hospital healthcare organization, including the neurovascular teams' one. Different solutions have been found depending on each area and hospital characteristics [12, 14].

We operate in a stroke network in the Romagna region, central Italy, covering two provinces, one of them deeply affected by the COVID-19 pandemic. During March 2020, to better cope with hospitals occupation, the stroke network shifted from an integral drip-and-ship model (primary transport of suspected stroke patients to a Primary Stroke Centers [PSC or “spoke”] capable of administering intravenous thrombolysis, followed by secondary transport to a Comprehensive Stroke Center [CSC or “hub”] to access endovascular treatment) to a partial one, having introduced mothership (direct transport of all suspected stroke patients to the hub) for one of the two provinces (Fig. 1). Hub's and spokes' in-hospitals routes for stroke patients have been rearranged too. To evaluate changes in incidence and management of suspected stroke cases during the COVID-19 pandemic in this stroke network, we performed a retrospective analysis on stroke referrals and

acute treatments comparing data from March 2020 with whom of March 2019.

Material and methods

Anonymized data have been made publicly available at Harvard Dataverse and can be accessed at <https://doi.org/10.7910/DVN/EVHWSB>.

We designed a retrospective observational multicenter study, addressing five PICO (patient, intervention/exposure, comparator, outcome) questions regarding influences of the COVID-19 pandemic on suspected stroke epidemiology and stroke treatments. The study was conducted in a vast stroke network comprehending two provinces in Emilia-Romagna region, in central Italy (Fig. 1). Two major cities constitute the province of Forli-Cesena (FC), Forli and Cesena, which numbered a resident population of 394,627 as on the 1st of January 2019 [15]. The province of Rimini (RN) has a resident population of 339,017. Health care system in the two provinces depends on the same public healthcare company, named as “Azienda Unità Sanitaria Locale della Romagna” (AUSL Romagna). The stroke network is based on a hub-spoke model. The “M. Bufalini” hospital in Cesena is the hub of the network; until March 2020, it was the primary stroke center for Cesena territory and received patients from the main hospitals of Forli (“Morgagni-Pierantoni” hospital) and Rimini (“Infermi” hospital) in a drip-and-ship model to perform endovascular treatments.

As far as the COVID-19 pandemic spread out in Italy, Rimini province was one of the most hit. On the 7th of March 2020, it was declared “red zone,” 2 days before the beginning of national lockdown. The Rimini “Infermi” hospital was converted to a COVID-19 sole hospital. Hence, all the RN province-suspected strokes were rerouted to Cesena “M. Bufalini” hospital, converting the model to a mothership one (Fig. 1).

At the “M. Bufalini” hospital, the Emergency Department (ED) planned a double separated route, one committed to COVID-19-suspected patients (based on anamnesis of contacts, fever or cough) and one for COVID-19-negative patients. Both routes had a dedicated CT scan. For COVID-19-negative patients, a CT scan outside ED was used, extending the internal transporting time. To handle a greater number of neurological referrals, the Neurology service opened a neurological fast track outside the ED, with a four-bed intensive outpatient clinic.

To address the study questions, we compared data from March 2020 with March 2019. Preliminarily, we also compared data from March 2019 with March 2018 to exclude potential bias.

As this is an observational study, the Institution Review Board has been notified as requested by the Italian law.

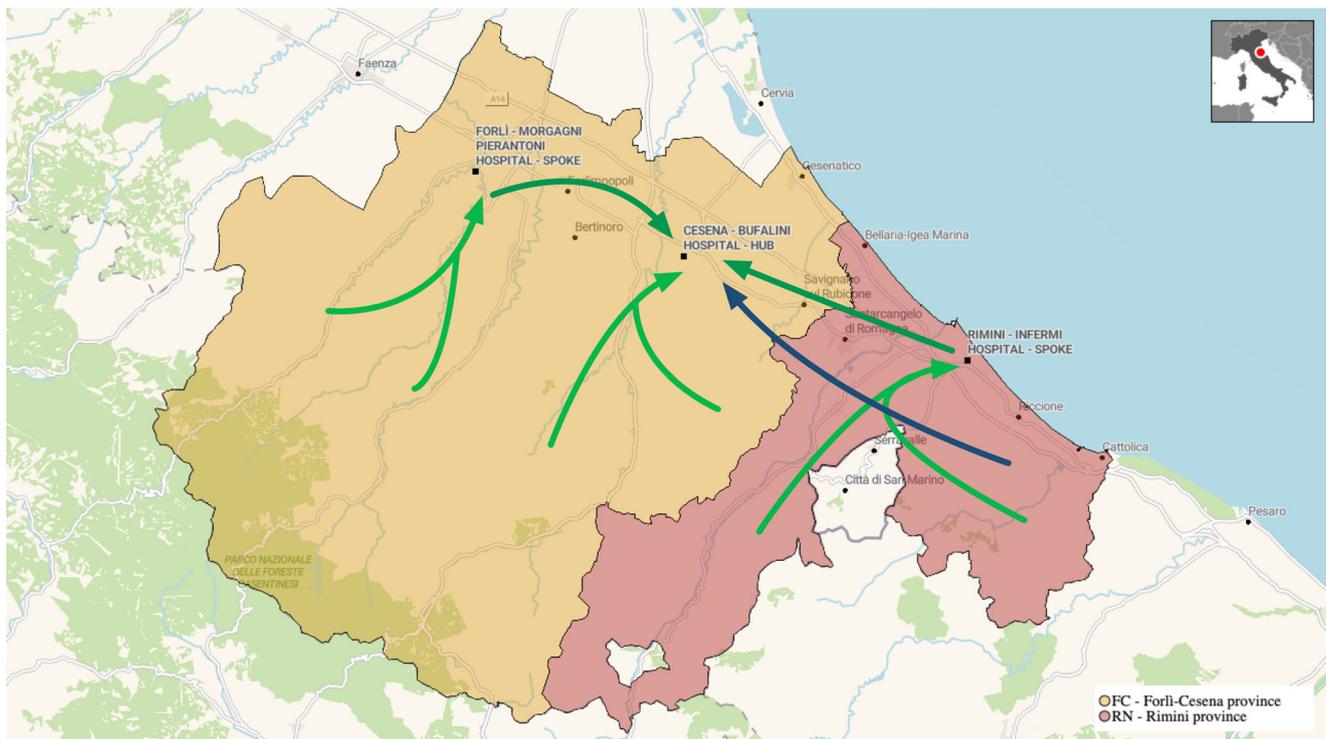


Fig. 1. Forlì-Cesena (FC—yellow) and Rimini (RN—red) provinces. “Morgagni-Pierantoni” hospital in Forlì and “Infermi” hospital in Rimini are the main Primary Stroke Centers (spokes) of the network; “M. Bufalini” hospital in Cesena is the Comprehensive Stroke Center

(hub) of the stroke network. Green arrows: drip-and-ship model (light green arrows: primary transport to the spokes; dark green arrows: secondary transport to the hub). Blue arrows: mothership model (direct transportation to the hub), applied in the province of Rimini

The detailed description and methods of the 5 PICO questions can be found in the [Supplementary information](#).

PICO question 1: is the number of suspected and confirmed strokes managed in ED decreased in March 2020 compared with March 2019 in the provinces of FC and RN?

We obtained the number of suspected and confirmed stroke cases managed in the ED in the 2 months. We then calculated the incidence of suspected and confirmed stroke managed in the ED for each month based on mean resident population in the two provinces. To evaluate a reduction in the incidence of suspected and confirmed stroke managed in the ED, we calculated incidence rate ratio (IRR) between observed incidence in the two intervals.

PICO question 2: is there a correlation between COVID-19 pandemic progression and the number of suspected stroke cases managed in the ED in March 2020 in the provinces of FC and RN?

We run a Spearman’s rank-order correlation to assess the relationship between daily new COVID-19 cases and daily new suspected stroke cases managed in ED in the two provinces in March 2020.

PICO question 3: has a reduction of acute stroke treatment (intravenous thrombolysis, IVT; endovascular thrombectomy, EVT) occurred in the two provinces in March 2020 compared with March 2019?

We wondered if the rearrangement of the emergency system (both on the territory and in the ED) could affect the volume of the performed acute stroke treatments. We then compared the absolute number of IVT, EVT, and combined treatments between the two time periods in the two provinces (individually and as a whole). To observe differences in the clinical characteristics of the treated patients (severity on the NIHSS score and age of presentation), we adopted the Student *t* test and Mann-Whitney *U* test.

PICO question 4: is the COVID-19 pandemic in March 2020 influencing the call-to-needle (CTN) and door-to-needle (DTN) times of IVT in stroke patients in FC province, compared with March 2019?

We wanted to address the possibility that COVID-19 could slow the out-hospital and in-hospital acute care of stroke patients. We then compared the median call-to-needle and door-to-needle times in March 2020 and 2019 with an independent-samples Mann-Whitney *U* test. We narrowed the analysis to the sole FC province because a drip-and-ship model remained constant between the years only in this territory.

PICO question 5: is the mothership model adopted in March 2020 for patients of RN province advantageous over the previous drip-and-ship model in terms of treatment time?

Since the 13th of March 2020, all the suspected strokes in RN province were directly rerouted to “M. Bufalini” hospital

Table 1 Suspected and confirmed stroke cases in ED in March 2019 and March 2020

	FC			RN			Total					
	ED stroke-code ^b			Final stroke diagnosis ^c			ED stroke-code ^b			Final stroke diagnosis ^c		
	Resident population	Absolute number	Incidence (/100,000)	Resident population	Absolute number	Incidence (/100,000)	Resident population	Absolute number	Incidence (/100,000)	Resident population	Absolute number	Incidence (/100,000)
March 2019	394475	145	36.76	339259	115	33.90	733734	260	35.44	733734	194	26.44
March 2020 ^a	394609	118	29.90	340125	102	29.99	734734	220	29.94	734734	139	18.92
% variation		-19%			-11%			-15%			-28%	
Incidence rate ratio		1.23 (95% CI 0.96–1.58)			1.13 (95% CI 0.86–1.48)			1.60 (95% CI 1.11–2.30)			1.18 (95% CI 0.99–1.42)	

^a Resident population based on Nov 2019^b Allocated in each province by place of stroke onset^c Allocated in each province by place of hospital admission

in Cesena. We selected centralized patients from RN province that have undergone EVT (\pm IVT) between the 13th and 31st of March 2020. We compared their median call-to-needle, door-to-needle, call-to-groin, and door-to-groin times with those of EVTs (\pm IVT) of patients from Rimini of March 2019 and of the period 1–12 March 2020 with a one-way ANOVA.

Statistical analysis was made with SPSS v. 25, STATA v. 12, GraphPad Prism v.8.

Results

Comparisons between March 2018 and March 2019

The preliminary comparison of stroke referrals incidence and acute treatments in March 2018 and March 2019 showed no significant differences. In the whole stroke network, we found 256 suspected stroke cases managed in the ED in March 2018 and 260 in March 2019 (IRR 0.99, 95% CI 0.83–1.18) (Suppl. Table 1). Confirmed stroke cases discharged from the ED were 184 in March 2018 and 194 in March 2019 (IRR 0.95, 95% CI 0.77–1.17). Volume of reperfusion therapies was similar: 34 patients were treated in March 2018 (22 IVT, 3 EVT, 9 combined treatments), while 32 in March 2019 (22 IVT, 4 EVT, 6 combined treatments) (Fig. 3).

PICO 1

Overall, we found a 15% decreased of suspected strokes managed in ED in March 2020 compared with March 2019 (Table 1; suppl. Fig. 2), in line with a 14% decrease of 118's "neurological symptom-code" activations (details on the volume of 118 calls can be found in [Supplementary information](#)). The IRR of suspected strokes managed in ED presented a non-significant reduction in March 2020 compared with March 2019 in the provinces of FC and RN, considered both individually and as a whole. Nevertheless, in the whole stroke network, there was a statistically significant reduction of confirmed stroke diagnosis from March 2019 to March 2020 (28% decrease, IRR 1.40, 95% CI 1.12–1.75). The comparison of the incidence confirmed stroke cases between March 2018 and March 2020 validates the results from the 2019 to 2020 analysis. The IRR of 2018–2020 is a significant value of 1.33 (95% CI 1.06–1.66; -25% of cases). The single-province analysis of confirmed stroke diagnosis of March 2020, due to allocation modality based on discharge forms, needs to be evaluated in the light of the shift to the mothership model, so that the considerable decrease in RN province is compensated by FC province.

Interestingly, we observed a huge difference in the number of patients assisted by ambulances and not transported to hospitals due to refusal or at-home management, since it

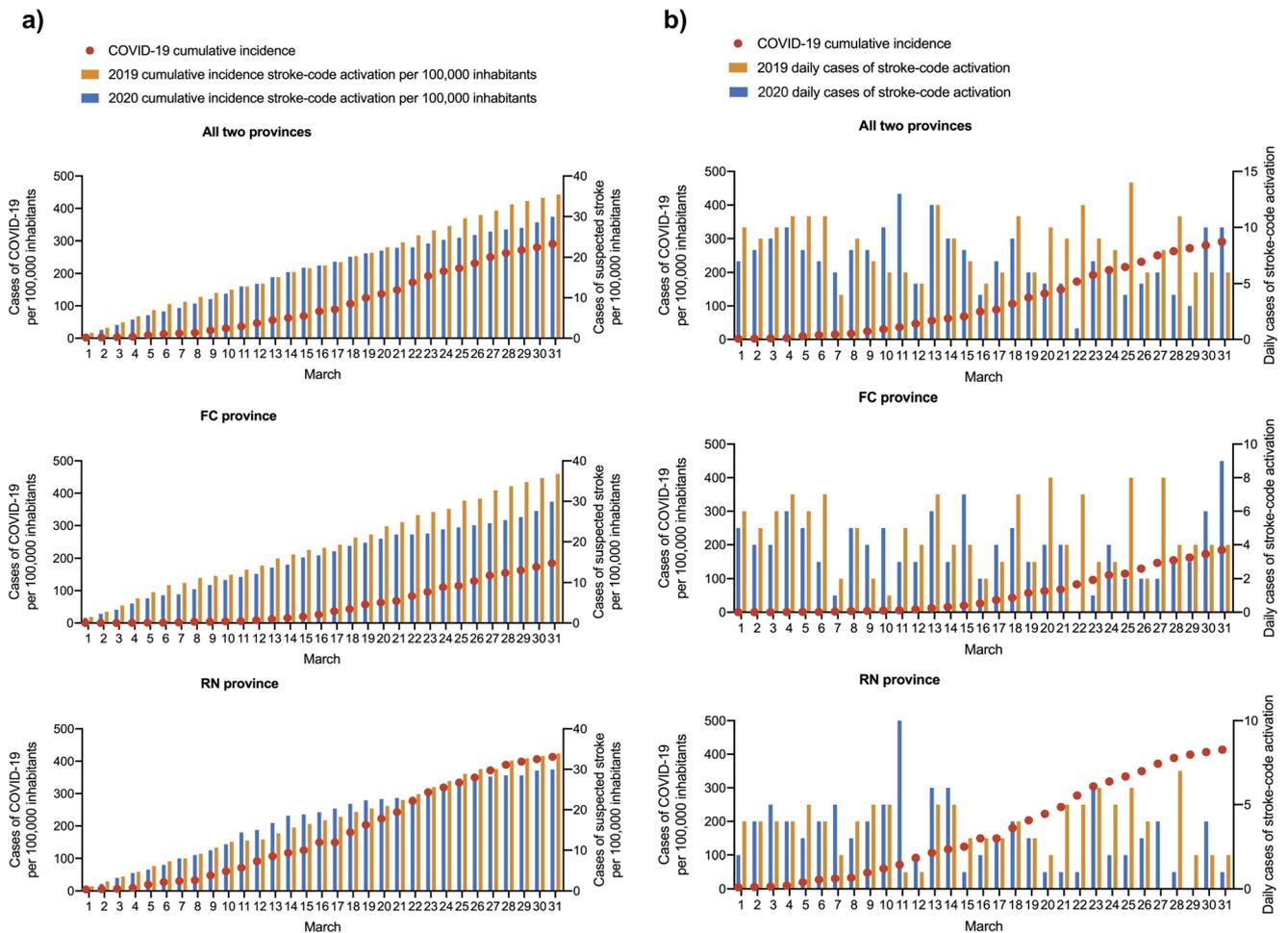


Fig. 2. **a** Cumulative incidence of suspected stroke cases during March 2020 (blue) and March 2019 (orange) and cumulative incidence of COVID-19 cases in March 2020 (red dots). **b** Daily cases of suspected stroke cases during March 2020 (blue) and March 2019 (orange) and cumulative incidence of COVID-19 cases in March 2020 (red dots)

Fig. 3 Volumes of reperfusion therapies in March 2018, 2019, and 2020 in the stroke network

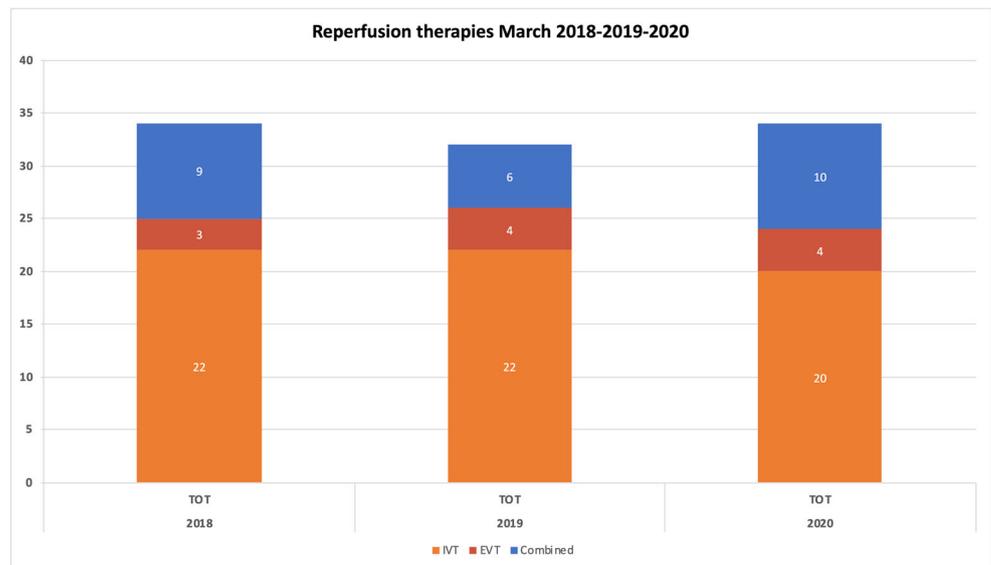


Table 2 Performances of intravenous thrombolysis in FC province in March 2019 and March 2020. Noteworthy, in March 2020

	IVT no.	EVT no.	Combined treatment no.	Median call-to-needle time (min)	Median door-to-needle time (min)
March 2019	11	2	4	108.5 (IQR 34)	69 (IQR 41)
March 2020 ^a	10	2	3	96 (IQR 23)	49 (IQR 37)
<i>p</i>				.126	.142

^a Three IVT, one EVT, and five combined treatments were carried out in Cesena but were excluded because they were transported from RN province due to the switch to a mothership model

increased from 15% (113/760) of total “neurological symptom-code” activations in March 2019 to 31% (203/655) in March 2020.

PICO 2

To better outline the impact of the COVID-19 pandemic progression on stroke epidemiology, we compared cumulative incidences and new daily cases of stroke and COVID-19.

In March 2020, 2120 new cases of COVID-19 have been diagnosed in the territory of the two provinces. At the 31st of March 2020, the total number of cases of COVID-19 was 730 in FC and 1407 in RN. At the same date, the incidence of COVID-19 was 291/100,000 inhabitants in the whole territory, with an important difference between the provinces: 185/100,000 in FC and 414/100,000 in RN.

Figure 2a shows the cumulative incidence of COVID-19 in March 2020 and the cumulative incidence of cases of suspected stroke managed in ED in March 2020 and March 2019 in both the provinces. Despite the progression of COVID-19 pandemic, the cumulative incidence of suspected stroke cases managed in the ED in March 2020 maintained the same slope, reduced but similar in shape compared with the one of 2019.

As better outlined in Fig. 2b, the monthly distribution of the number of daily cases of suspected stroke managed in ED in March 2020 was similar to the one on March 2019 in the first part of the month; as the pandemic proceeded, a decrease in

suspected stroke cases in ED occurred especially in RN province, where the incidence of COVID-19 increased mostly.

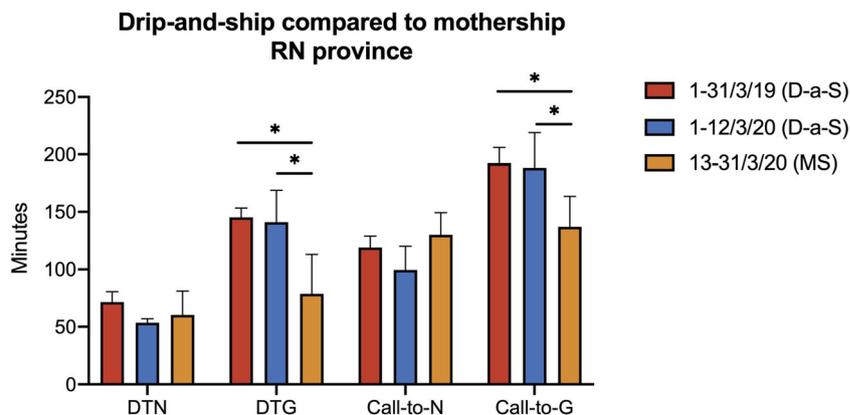
There was a statistically significant negative correlation between COVID-19 progression (cumulative incidence) and daily new cases of suspected stroke managed in ED, $r_s = -.390$, $p = .030$. When considered individually, FC province didn't show the aforementioned correlation ($r_s = -.220$, $p = .234$), while RN province confirmed the negative correlation ($r_s = -.434$, $p = .015$).

PICO 3

We did not observe a reduction in the absolute number of acute stroke treatments (IVT and EVT) between March 2020 compared with March 2019 or March 2018 in the whole network (Fig. 3; details on single-province volume are depicted in suppl. Fig. 3), nor differences in basal NIHSS score or age of treated patients of 2020 compared with 2019 (respectively, 7 vs 6.5, $p = .379$ and 71 vs 70, $p = .852$).

In March 2020, the absolute number of treatments remained unchanged (32 in 2019 vs 34 in 2020), despite a reduction of stroke patients. Indeed, the 16.5% of confirmed strokes in March 2019 received a reperfusion therapy, whereas in March 2020, this percentage increased to 24.5%. From the analysis of the characteristics of treated patients, we could not conclude that treated patients were elderly or had a more severe stroke at baseline.

Fig. 4 Door-to-needle (DTN), call-to-needle (CTN), door-to-groin (DTG), and call-to-groin times in RN provinces. Red and blue bars represent drip-and-ship (D-a-S) treatments in, respectively, March 2019 and the first part of March 2020; yellow bars represent mothership (MS) treatments in March 2020.



PICO 4

In FC province, 15/145 (10%) suspected stroke patients managed in ED in March 2019 and 13/118 (11%) in March 2020 received IVT (alone or combine with EVT) (Table 2).

We did not find any significant difference in out-hospital (call-to-needle) and in-hospital (door-to-needle) time intervals in acute stroke management in March 2020 compared with March 2019 in treated stroke patients from the province of FC. In March 2018, 16 suspected stroke cases were treated with IVT (alone or combined with EVT) in the same province; the Kruskal-Wallis test comparing median of DTN times of 2018, 2019, and 2020 did not show significant differences ($p = .161$).

PICO 5

From RN province, 4/115 (3.5%) suspected stroke patients in March 2019 and 9/102 (8.3%) in March 2020 received EVT, alone or combined with IVT (Suppl. Fig. 3; 2018 results are presented in [supplementary information](#)). Of these, three patients were treated between 1 and 12 March 2020, while 6 between 13 and 31 March 2020.

No significant differences in median NIHSS ($p = .194$) or age ($p = .946$) were found. While we found no statistically significant differences in DTN and CTN times among time intervals, the DTG and the CTG times were statistically different among the three periods (respectively, $p = .006$ and $p = .013$). Post hoc analysis revealed no significant differences between the two drip-and-ship groups, while there was a decrease from 145 to 79 min in DTG ($p = .010$) and a decrease from 192 to 137 min in call-to-groin times in the mothership group ($p = .018$).

Despite the COVID-19-related troubles affecting the healthcare system, a mothership model guaranteed significant reduced call-to-groin time, without significantly affecting the timing of infusion of alteplase (Fig. 4).

Discussion

In this study, we found a significant 25–28% decrease of confirmed strokes cases managed in ED in March 2020 compared with the same month of previous years, confirming the phenomenon observed by other stroke networks. Overall, the total number of calls to the emergency number for neurological symptoms decreased, while it doubled the number of patients managed at home or that refused to be transported to the hospital, probably because of fear of in-hospital Sars-CoV2 infection. The daily number of suspected strokes in ED in March 2020 negatively correlated with the progression of the COVID-19 pandemic, and this was particularly true for the province of RN where the incidence of the infection was more than double.

This may confirm the “hospital avoidance” phenomenon that has grown as the pandemic spread out. Despite the reduction of confirmed stroke cases, the absolute number of treatments remained similar to the previous years. This corroborates the hypothesis of a more refined selection of suspected stroke, with a reduced seek for helping and hospitalization of patients with transient or non-debilitating neurological symptoms. The consequences of missed evaluation of all these cases have to be addressed in the next future. Undoubtedly, the “stay-at-home” message has been fundamental to COVID-19 restraint. However, the redundant and often passionate politicians and healthcare professionals or other stakeholders’ stay-at-home appeals were not counterbalanced by messages regarding the need to regularly seek assistance for non-COVID-19-related emergencies. Public campaign to increase awareness on stroke risk may be needed, even more than before.

Regarding the response of our stroke network, the results obtained by our model shift are encouraging. Screening and triaging COVID-19–suspected patients at the entrance of ED and adopting two parallel intra-hospital routes for suspected or not suspected patients permitted to manage stroke patients in safety without affecting the effectiveness of the neurovascular team. Not only was the absolute number of treatments slightly higher than the previous year but we also obtained a decrease in DTN time, despite not statistically significant. Importantly, as the province of RN switched to the mothership model, we obtained a significant reduction in CTG time with respect to the previous year, without significantly delaying the alteplase infusion, indicating that in our stroke network, a mothership model can be advantageous. Our results corroborate with real-world data the strength of the recommendations given by stroke experts [7].

This study has some limitations. Limiting the analysis to the month of March, this study only considered the first weeks of national lockdown, which lasted until mid-May. The evaluation of efficiency of the mothership model has been conducted on limited data since it was adopted in just one of the provinces. Moreover, we could not obtain data about the onset time of all stroke cases, limiting the evaluation of delays in the onset-to-call interval. Indeed, the call-to-needle/groin time does not account for the patient or bystander delay, which is of special interest during this pandemic as the patient may be more reluctant to contact medical services.

There are several lessons to be learned from the COVID-19 pandemic; as a stroke team, we need to be flexible and prepared for a quick reorganization of our services, not only in the in-hospital settings. We need to know our territory, adapt our models, and participate in the awareness of our population.

Supplementary Information The online version contains supplementary material available at <https://doi.org/10.1007/s10072-020-04914-4>.

Data availability Anonymized data have been made publicly available at Harvard Dataverse and can be accessed at <https://doi.org/10.7910/DVN/EVHWSB>.

Compliance with ethical standards

Conflicts of interest None.

Ethics approval As this is an observational study, the Institution Review Board has been notified as requested by the Italian law and approved the study.

Informed consent None

References

- Wang B, Li R, Lu Z, Huang Y (2020) Does comorbidity increase the risk of patients with COVID-19: evidence from meta-analysis. *Aging (Albany NY)* 12(7):6049–6057. <https://doi.org/10.18632/aging.103000>
- Aggarwal G, Lippi G, Michael Henry B (2020) Cerebrovascular disease is associated with an increased disease severity in patients with Coronavirus Disease 2019 (COVID-19): a pooled analysis of published literature. *Int J Stroke*:1747493020921664. doi:<https://doi.org/10.1177/1747493020921664>
- Qin C, Zhou L, Hu Z, Yang S, Zhang S, Chen M, Yu H, Tian DS, Wang W (2020) Clinical characteristics and outcomes of COVID-19 patients with a history of stroke in Wuhan, China. *Stroke: STROKEAHA*120030365. doi:<https://doi.org/10.1161/STROKEAHA.120.030365>
- Larson AS, Savastano L, Kadirvel R, Kallmes DF, Hassan AE, Brinjikji W (2020) COVID-19 and the cerebro-cardiovascular systems: what do we know so far?. *J Am Heart Assoc*:e016793. doi:<https://doi.org/10.1161/JAHA.120.016793>
- Yaghi S, Ishida K, Torres J, Mac Grory B, Raz E, Humbert K, Henninger N, Trivedi T, Lillemo K, Alam S, Sanger M, Kim S, Scher E, Dehkharghani S, Wachs M, Tanweer O, Volpicelli F, Bosworth B, Lord A, Frontera J (2020) SARS2-CoV-2 and stroke in a New York Healthcare System. *Stroke:STROKEAHA*120030335. doi:<https://doi.org/10.1161/STROKEAHA.120.030335>
- Tsivgoulis G, Katsanos AH, Ormello R, Sacco S (2020) Ischemic stroke epidemiology during the COVID-19 pandemic: navigating uncharted waters with changing tides. *Stroke:STROKEAHA*120030791. doi:<https://doi.org/10.1161/STROKEAHA.120.030791>
- Zhao J, Li H, Kung D, Fisher M, Shen Y, Liu R (2020) Impact of the COVID-19 epidemic on stroke care and potential solutions. *Stroke:STROKEAHA*120030225. doi:<https://doi.org/10.1161/STROKEAHA.120.030225>
- Rudilosso S, Laredo C, Vera V, Vargas M, Renu A, Llull L, Obach V, Amaro S, Urta X, Torres F, Jimenez-Fabrega FX, Chamorro A (2020) Acute stroke care is at risk in the era of COVID-19: experience at a comprehensive stroke center in Barcelona. *Stroke: STROKEAHA*120030329. doi:<https://doi.org/10.1161/STROKEAHA.120.030329>
- Montaner J, Barragan-Prieto A, Perez-Sanchez S, Escudero-Martinez I, Moniche F, Sanchez-Miura JA, Ruiz-Bayo L, Gonzalez A (2020) Break in the stroke chain of survival due to COVID-19. *Stroke:STROKEAHA*120030106. doi:<https://doi.org/10.1161/STROKEAHA.120.030106>
- Kerleroux B, Fabacher T, Bricout N, Moise M, Testud B, Vingadassalom S, Ifergan H, Janot K, Consoli A, Ben Hassen W, Shotar E, Ognard J, Charbonnier G, L'Allinec V, Guedon A, Bolognini F, Marnat G, Forestier G, Rouchaud A, Pop R, Raynaud N, Zhu F, Cortese J, Chalumeau V, Berge J, Escalard S, Boulouis G, List of C (2020) Mechanical thrombectomy for acute ischemic stroke amid the COVID-19 outbreak: decreased activity, and increased care delays. *Stroke:STROKEAHA*120030373. doi:<https://doi.org/10.1161/STROKEAHA.120.030373>
- Siegler JE, Heslin ME, Thau L, Smith A, Jovin TG (2020) Falling stroke rates during COVID-19 pandemic at a Comprehensive Stroke Center: cover title: falling stroke rates during COVID-19. *J Stroke Cerebrovasc Dis*:104953. doi:<https://doi.org/10.1016/j.jstrokecerebrovasdis.2020.104953>
- Naccarato M, Scali I, Olivo S, Ajcevic M, Buoite Stella A, Furlanis G, Lugnan C, Caruso P, Peratoner A, Cominotto F, Manganotti P (2020) Has COVID-19 played an unexpected “stroke” on the chain of survival? *J Neurol Sci* 414:116889. <https://doi.org/10.1016/j.jns.2020.116889>
- Aguiar de Sousa D, Sandset EC, Elkind MSV (2020) The curious case of the missing strokes during the COVID-19 pandemic. *Stroke: STROKEAHA*120030792. doi:10.1161/STROKEAHA.120.030792
- Baracchini C, Pieroni A, Viaro F, Cianci V, Cattelan AM, Tiberio I, Munari M, Causin F (2020) Acute stroke management pathway during coronavirus-19 pandemic. *Neurol Sci* 41(5):1003–1005. <https://doi.org/10.1007/s10072-020-04375-9>
- ISTAT - Istituto Nazionale di Statistica (2020) Popolazione residente al 1° gennaio - Emilia-Romagna. <http://dati.istat.it/Index.aspx?QueryId=18964>. Accessed 01/05/20 2020

Publisher's note Springer Nature remains neutral with regard to jurisdictional claims in published maps and institutional affiliations.