Changes in Neuroendovascular Procedural Volume During the COVID-19 Pandemic: An International Multicenter Study

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ABSTRACT

BACKGROUND AND PURPOSE: **The effect of coronavirus disease 2019 (COVID-19) pandemic on performance of neuroendovascular procedures has not been quantified.**

METHODS: **We performed an audit of performance of neuroendovascular procedures at 18 institutions (seven countries) for two periods; January-April 2019 and 2020, to identify changes in various core procedures. We divided the region where the hospital was located based on the median value of total number of COVID-19 cases per 100,00 population-into high and low prevalent regions.**

RESULTS: **Between 2019 and 2020, there was a reduction in number of cerebral angiograms (30.9% reduction), mechanical thrombectomy (8% reduction), carotid artery stent placement for symptomatic (22.7% reduction) and asymptomatic (43.4% reduction) stenoses, intracranial angioplasty and/or stent placement (45% reduction), and endovascular treatment of unruptured intracranial aneurysms (44.6% reduction) and ruptured (22.9% reduction) and unruptured brain arteriovenous malformations (66.4% reduction). There was an increase in the treatment of ruptured intracranial aneurysms (10% increase) and other neuroendovascular procedures (34.9% increase). There was no relationship between procedural volume change and intuitional location in high or low COVID-19 prevalent regions. The procedural volume reduction was mainly observed in March-April 2020.**

CONCLUSIONS: **We provided an international multicenter view of changes in neuroendovascular practices to better understand the gaps in provision of care and identify individual procedures, which are susceptible to change.**

Keywords: COVID-19, corona virus, neuroendovascular procedures, carotid stent, mechanical thrombectomy.

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Introduction

An estimated 182,485 and 269,383 patients with ischemic stroke and coronavirus disease 2019 (COVID-19) may be diagnosed, assuming that 9,988,254 patients were infected with Covid-19 in the world on June 27, 2020, with an estimated 21-31% of patients required hospitalization.[1] Some procedures, such as mechanical thrombectomy for acute ischemic stroke, carotid angioplasty, and stent placement, were expected to increase with increasing numbers of acute ischemic stroke patients.[1] Paradoxically, there was a decrease in the early phase of the pandemic in some centers.[2] Certain elective procedures are likely to decrease[3] due to declining hospital visits. A 32-60% decrease between March 1 and 29, compared against pre-COVID-19 volumes, was reported in an analysis of more than 500 hospitals in the United States of America (USA).[4] One of the research priorities identified by an international panel[1] was changes in aspects of care for patients with cerebrovascular diseases during the COVID-19 pandemic to better understand the unmet needs and guide resource allocation.

Methods

The study was performed as a collaborative effort between 11 institutions from the USA and 7 international institutions (from

Table 1. Neuroendovascular Procedures for January-April 2019 and 2020

Study or subgroup	Total number in 2019	Total number in 2020	Change %	Median number in 2019(95% confidence interval)	Median number in 2020(95% confidence interval)	Quantile regression *P*-value
Cerebral angiogram						
Overall	2,917	2,015	–30.9%	27.5(15-41)	17.5(12-30)	.2106
Location according to COVID-19 prevalence						
Low	1,620	935	–42.3%	9(7-42)	9(5-30)	1
High	1,297	1,080	–16.7%	32.5(19-46)	22(17-49)	.291
Institutional location						
USA	1,354	1,163	–14.1%	29.5(19-41)	20(14-35)	.2417
Non-USA	1,563	852	–45.5%	7.5(3-55)	6(2-30)	.946
Mechanical thrombectomy for acute ischemic stroke						
Overall	690	635	–8.0%	7(6-10)	7(6-8)	1
Location according to COVID-19 prevalence						
Low	262	263	.4%	5(3-10)	6(5-8)	.6018
High	428	372	–13.1%	9(7-12)	8(6-11)	.5062
Institutional location						
USA	341	332	–2.6%	7(6-9)	7(6-8)	1
Non-USA	349	303	–13.2%	7.5(3-14)	7.5(4-12)	.8121
Carotid stent placement for symptomatic internal carotid artery stenosis						
Overall	233	180	–22.7%	3(2-3)	2(1-3)	.0814
Location according to COVID-19 prevalence						
Low	136	100	–26.5%	3(1-5)	2(1-3)	.3789
High	97	80	–17.5%	2.5(2-3)	1.5(1-3)	1
Institutional location						
USA	121	120	–.8%	3(2-3)	2(1-4)	.1715
Non-USA	112	60	–46.4%	3(1-5)	.5(0-2)	.0334
Carotid stent placement for asymptomatic internal carotid artery stenosis						
Overall	106	60	–43.4%	0(0-0)	0(0-0)	–
Location according to COVID-19 prevalence						
Low	95	54	–43.2%	1(0-2)	0(0-1)	.0135
High	11	6	–45.5%	0(0-0)	0(0-0)	–
Institutional location						
USA	13	11	–15.4%	0(0-0)	0(0-0)	–
Non-USA	93	49	–47.3%	1.5(0-3)	0(0-1)	.0901
Endovascular treatment of ruptured intracranial aneurysms						
Overall	216	239	10.6%	2(1-3)	2(1-3)	1
Location according to COVID-19 prevalence						
Low	88	112	27.3%	1(0-2)	2(1-3)	.1857
High	128	127	–.8%	3(2-4)	2(1-4)	.3196
Institutional location						
USA	93	98	5.4%	2(1-2)	2(1-2)	1
Non-USA	123	141	14.6%	3.5(1-4)	4(1-7)	1
Endovascular treatment of unruptured intracranial aneurysms						
Overall	444	246	–44.6%	3(2-4)	1(1-3)	.0125
Location according to COVID-19 prevalence						
Low	253	100	–60.5%	2(0-3)	1(0-2)	.2606
High	191	146	–23.6%	4(3-7)	3(1-5)	.5062
Institutional location						
USA	136	98	–27.9%	3(1-4)	1.5(0-3)	.1715
Non-USA	308	148	–51.9%	3.5(2-11)	1(0-7)	.493
Endovascular treatment of ruptured brain arteriovenous malformations						
Overall	48	37	–22.9%	0(0-1)	0(0-0)	1
Location according to COVID-19 prevalence						
Low	26	16	–38.5%	0(0-1)	0(0-0)	–
High	22	21	–4.5%	0(0-1)	0(0-1)	1
Institutional location						
USA	23	20	–13.0%	0(0-1)	0(0-1)	1
Non-USA	25	17	–32.0%	0(0-1)	0(0-0)	1
Endovascular treatment of unruptured brain arteriovenous malformations						
Overall	119	40	–66.4%	0(0-1)	0(0-0)	–
Location according to COVID-19 prevalence						
Low	94	22	–76.6%	.5(0-2)	0(0-0)	–
High	25	18	–28.0%	0(0-1)	0(0-1)	1
Institutional location						
USA	27	13	–51.9%	0(0-1)	0(0-0)	–

(Continued)

Table 1. Continued

Study or subgroup	Total number in 2019	Total number in 2020	Change %	Median number in 2019 (95% confidence interval)	Median number in 2020 (95% confidence interval)	Quantile regression *P*-value
Non-USA	92	27	–70.7%	0(0-3)	0(0-1)	1
Intracranial angioplasty/stent for intracranial stenosis						
Overall	182	99	–45.6%	0(0-1)	0(0-0)	1
Location according to COVID-19 prevalence						
Low	144	63	–56.3%	0(0-1)	0(0-1)	1
High	38	36	–5.3%	0(0-1)	0(0-1)	1
Institutional location						
USA	42	42	.0%	0(0-0)	0(0-1)	1
Non-USA	140	57	–59.3%	0(0-1)	0(0-1)	1
Other neuroendovascular procedures (spinal angiograms, WADA, others)						
Overall	243	328	35.0%	1(0-2)	1.5(0-3)	1
Location according to COVID-19 prevalence						
Low	86	88	2.3%	1(0-2)	0(0-4)	.209
High	157	240	52.9%	0(0-3)	2(1-4)	.0489
Institutional location						
USA	113	143	26.5%	2(0-2)	3(2-4)	.2452
Non-USA	130	185	42.3%	0(0-2)	0(0-0)	1
Other nonendovascular procedures						
Overall	341	320	–6.2%	0(0-0)	0(0-0)	–
Location according to COVID-19 prevalence						
Low	302	277	–8.3%	0(0-6)	0(0-3)	1
High	39	43	10.3%	0(0-0)	0(0-0)	–
Institutional location						
USA	293	294	.3%	0(0-1)	0(0-0)	1
Non-USA	48	26	–45.8%	0(0-0)	0(0-0)	–

Egypt, China, Turkey, South Korea, France each, and two from Poland). All investigators who were a part of an internal collaboration developed to form guidelines for management of acute ischemic stroke in patients with COVID-19, were invited to the study.[1,5] Additional centers were added based on referral of original investigators. Each institution provided data for number of practitioners (including fellows), number of cerebral angiograms, mechanical thrombectomy for acute ischemic stroke, carotid stent placement for internal carotid artery (ICA) stenosis separated by symptomatic and asymptomatic ICA stenosis, endovascular treatment of intracranial aneurysms, separated by ruptured and unruptured status, endovascular treatment of brain arteriovenous malformations (BAVMs), separated by ruptured and unruptured status, intracranial angioplasty and/or stent placement, other neuroendovascular (spinal angiogram and WADA) and nonendovascular (vertebroplasty, lumbar puncture, and lumbar catheter placement) procedures. The neuroendovascular procedures were selected as they have been used in previous studies of benchmarking procedural capability.[6–8] The data were provided for each month for a total of 8 months; January-April 2019 and January-April 2020. All sites except two provided data on number of patients who underwent procedures and had either suspected or confirmed COVID-19 at time of procedure.

Statistical Analysis

The analysis was predominantly descriptive. The changes were quantified for each period as percentage change in 2020 using the values from 2019 as denominator. We further estimated the change for January and February in 2020 (early phase) and March and April 2020 (established phase for COVID-19 pandemic). The median number of each procedure per center for the period under study was compared between 2019 and 2020 using quantile regression method. We divided the region where the hospital was located based on the median value of number of COVID-19 cases per 100,00 population on April 30th, 2020 into high and low prevalent regions with values above the median considered as high prevalence and values below as low prevalence. All analysis was performed using SAS studio (Release: 3.8; Enterprise Edition) software.

Results

A total of 9,738 procedures were performed during the two study periods, 5,539 during pre-COVID-19 period in 2019 and 4,199 in 2020. There was a decrease in the total number of practitioners from 759 to 589 in pre-COVID-19 and during COVID-19 periods. The average number of procedures per practitioner decreased from 7.29 to 7.12 in pre-COVID-19 and during COVID-19 periods. Fifty-three patients with confirmed COVID-19 infection and 135 with suspected COVID-19 infection underwent procedures during COVID-19 period. The procedure numbers are presented for each neuroendovascular procedure for each month in Figure 1.

Overall Comparison of Pre-COVID-19 and During COVID-19 Periods

Between 2019 and 2020, there were reductions in cerebral angiograms (30.9%), mechanical thrombectomies (8%), carotid stent placement for symptomatic (22.7%) and asymptomatic (43.4%) ICA stenoses, and intracranial angioplasty and/or stent placements (45%), treatment of unruptured intracranial aneurysms (44.6%) and ruptured (22.9%), and unruptured

Table 2. Neuroendovascular Procedures for January and February 2019 and 2020

Study or subgroup	Total number in 2019	Total number in 2020	Change %	Median number in 2019(95% confidence interval)	Median number in 2020(95% confidence interval)	Quantile regression *P*-value
Cerebral angiogram						
Overall	1,332	1,226	–8.6%	24(13-41)	21(15-45)	.9128
Location according to COVID-19 prevalence						
Low	690	539	–21.9%	9(3-45)	14(2-44)	.8139
High	642	687	7.0%	29.5(14-46)	37(17-53)	.7888
Institutional location						
USA	625	723	15.7%	29.5(14-42)	30(17-49)	.8227
Non-USA	707	503	–28.9%	7.5(2-103)	7(2-82)	.9729
Mechanical thrombectomy for acute ischemic stroke						
Overall	310	313	1.0%	7(5-10)	6.5(6-10)	.5686
Location according to COVID-19 prevalence						
Low	103	127	23.3%	4(2-10)	7(4-12)	.4321
High	207	186	–10.1%	8(7-13)	6.5(5-12)	.7105
Institutional location						
USA	163	162	–.6%	7(5-11)	6(5-10)	.571
Non-USA	147	151	2.7%	6.5(1-20)	11(4-13)	.5273
Carotid stent placement for symptomatic internal carotid artery stenosis						
Overall	110	106	–3.6%	2(1-4)	2.5(1.4)	1
Location according to COVID-19 prevalence						
Low	66	58	–12.1%	3(0-5)	2.5(0-5)	1
High	44	48	9.1%	2(1-3)	2.5(0-5)	1
Institutional location						
USA	51	71	39.2%	2(1-4)	3(1-5)	.3573
Non-USA	59	35	–40.7%	3.5(1-5)	0(0-6)	.0965
Carotid stent placement for asymptomatic internal carotid artery stenosis						
Overall	49	32	–34.7%	0(0-1)	0(0-0)	1
Location according to COVID-19 prevalence						
Low	44	29	–34.1%	1(0-2)	1.5(0-1)	1
High	5	3	–40.0%	0(0-0)	0(0-0)	–
Institutional location						
USA	5	7	40.0%	0(0-0)	0(0-1)	1
Non-USA	44	25	–43.2%	1.5(0-4)	0(0-2)	.3246
Endovascular treatment of ruptured intracranial aneurysms						
Overall	102	124	21.6%	2(1-3)	2(1-4)	1
Location according to COVID-19 prevalence						
Low	39	55	41.0%	1(0-3)	2(1-4)	.3158
High	63	69	9.5%	3(1-4)	2.5(1-7)	.485
Institutional location						
USA	41	49	19.5%	1.5(1-3)	2(1-3)	1
Non-USA	61	75	23.0%	4(0-9)	4.5(1-11)	.7413
Endovascular treatment of unruptured intracranial aneurysms						
Overall	167	154	–7.8%	3(2-4)	2(1-4)	.2606
Location according to COVID-19 prevalence						
Low	74	64	–13.5%	1.5(0-3)	1(0-3)	1
High	93	90	–3.2%	4(2-8)	3.5(2-7)	1
Institutional location						
USA	59	59	.0%	2(1-4)	2(1-4)	1
Non-USA	108	95	–12.0%	3.5(1-13)	2(0-13)	1
Endovascular treatment of ruptured brain arteriovenous malformations						
Overall	25	27	8.0%	0(0-1)	0(0-1)	1
Location according to COVID-19 prevalence						
Low	14	14	.0%	.5(0-1)	0(0-1)	1
High	11	13	18.2%	0(0-1)	1(0-1)	.002
Institutional location						
USA	10	12	20.0%	0(0-1)	0(0-1)	1
Non-USA	15	15	.0%	0(0-2)	0(0-2)	1
Endovascular treatment of unruptured brain arteriovenous malformations						
Overall	43	31	–27.9%	0(0-1)	0(0-1)	1
Location according to COVID-19 prevalence						
Low	33	17	–48.5%	.5(0-2)	0(0-1)	1
High	10	14	40.0%	0(0-1)	.5(0-1)	1
Institutional location						
USA	11	11	.0%	0(0-1)	0(0-1)	1

(Continued)

Table 2. Continued

Study or subgroup	Total number in 2019	Total number in 2020	Change %	Median number in 2019 (95% confidence interval)	Median number in 2020 (95% confidence interval)	Quantile regression *P*-value
Non-USA	32	20	–37.5%	0(0-4)	0(0-3)	1
Intracranial angioplasty/stent for intracranial stenosis						
Overall	67	51	–23.9%	0(0-1)	0(0-1)	1
Location according to COVID-19 prevalence						
Low	52	29	–44.2%	0(0-1)	0(0-1)	1
High	15	22	46.7%	0(0-2)	0(0-1)	1
Institutional location						
USA	14	23	64.3%	0(0-1)	0(0-1)	1
Non-USA	53	28	–47.2%	1(0-2)	0(0-2)	.1245
Other neuroendovascular procedures (spinal angiograms, WADA, others)						
Overall	99	162	63.6%	.5(0-2)	1(0-4)	1
Location according to COVID-19 prevalence						
Low	29	46	58.6%	1.5(0-2)	0(0-5)	.4891
High	70	116	65.7%	0(0-4)	1.5(0-7)	.635
Institutional location						
USA	43	79	83.7%	2(0-2)	2.5(1-7)	1
Non-USA	56	83	48.2%	0(0-8)	0(0-9)	1
Other nonendovascular procedures						
Overall	153	204	33.3%	0(0-1)	0(0-0)	1
Location according to COVID-19 prevalence						
Low	133	170	27.8%	0(0-7)	0(0-11)	1
High	20	34	70.0%	0(0-1)	0(0-1)	1
Institutional location						
USA	138	190	37.7%	0(0-8)	0(0-13)	1
Cerebral angiogram	15	14	–6.7%	0(0-1)	0(0-0)	–

(66.4%) BAVMs. There were increases in endovascular treatment of ruptured intracranial aneurysms (10%) and other neuroendovascular procedures (34.9%). The slight increase in endovascular treatment of ruptured intracranial aneurysms was more prominent in low COVID-19 prevalent regions and non-USA institutions (Table 1).

Comparison of Pre-COVID-19 and During COVID-19 Periods (January-February)

There was a minor reduction in the number of cerebral angiograms more prominent in low COVID-19 prevalent regions and non-USA institution (Table 2). There was no change in mechanical thrombectomy and carotid stent placement for symptomatic ICA stenosis. Carotid stent placement for symptomatic ICA stenosis increased in USA but decreased in non-USA centers. There was a reduction in carotid stent placement for asymptomatic ICA stenosis and intracranial angioplasty and/or stent placement and no change in endovascular treatment of unruptured intracranial aneurysms and ruptured and unruptured BAVMs. There was a slight increase in endovascular treatment of ruptured intracranial aneurysms, other neuroendovascular procedures, and nonendovascular procedures.

Comparison of Pre-COVID-19 and During COVID-19 Periods (March-April)

There were reductions of cerebral angiograms, mechanical thrombectomy, and carotid stent placement for symptomatic and asymptomatic ICA stenosis (Table 3). There were reductions in endovascular treatment of unruptured intracranial aneurysms, ruptured and unruptured BAVMs, and intracranial angioplasty and/or stent placement. There was no change in the treatment of ruptured intracranial aneurysms and slight increase in low COVID-19 prevalent regions.

Comparison of January and February (Early Phase) and March and April (Established Phase) in 2020

There were reductions in cerebral angiograms (55.4%) carotid artery stent placement for symptomatic (30.2%) and asymptomatic (12.5%) stenoses, intracranial angioplasty and/or stent placement (45%), and endovascular treatment of unruptured intracranial aneurysms (40.3%) and ruptured (63.9%) and unruptured (71.0%) BAVMs, and endovascular treatment of ruptured intracranial aneurysms (7.3%). There was a minor increase in mechanical thrombectomy (2.9%).

Discussion

Comparisons of procedures between January to April 2019 and 2020 demonstrated a reduction in almost all neuroendovascular procedures, except the treatment of ruptured intracranial aneurysms in 2020 compared with 2019. In January and February, there was some heterogeneity in changes in various neuroendovascular procedures. In March and April, there was a reduction in almost all neuroendovascular procedures except the treatment of ruptured intracranial aneurysms in 2020 compared with 2019. There was no clear relationship between location of hospital (high or low COVID-19 prevalent regions) and changes in procedures.

One surprising finding was the reduction in mechanical thrombectomy for acute ischemic stroke and carotid stent place-

Table 3. Neuroendovascular Procedures for 2019 and 2020 (March-April)

Study or subgroup	Total number in 2019	Total number in 2020	Change %	Median number in 2019(95% confidence interval)	Median number in 2020(95% confidence interval)	Quantile regression *P*-value
Cerebral angiogram						
Overall	1,585	789	–50.2%	27.5(15-49)	12(6-30)	.1184
Location according to COVID-19 prevalence						
Low	930	396	–57.4%	11.5(2-50)	6.5(1-39)	.9431
High	655	393	–40.0%	38(18-51)	20(7-34)	.1387
Institutional location						
USA	729	440	–39.6%	31.5(18-49)	13.5(7-35)	.133
Non-USA	856	349	–59.2%	7.5(2-69)	4(1-43)	.9129
Mechanical thrombectomy for acute ischemic stroke						
Overall	380	322	–15.3%	8(6-12)	7(5-10)	1
Location according to COVID-19 prevalence						
Low	159	136	–14.5%	5.5(2-14)	5.5(4-8)	.7408
High	221	186	–15.8%	9.5(6-14)	8.5(7-13)	1
Institutional location						
USA	178	170	–4.5%	7(5-12)	7(5-11)	1
Non-USA	202	152	–24.8%	11.5(2-30)	6.5(3-24)	.6183
Carotid stent placement for symptomatic internal carotid artery stenosis						
Overall	123	74	–39.8%	3(2-4)	1.5(1-2)	.2606
Location according to COVID-19 prevalence						
Low	70	42	–40.0%	3(0-4)	2(1-3)	.485
High	53	32	–39.6%	3(2-4)	1(0-3)	.0496
Institutional location						
USA	70	49	–30.0%	3(2-5)	2(1-4)	.4156
Non-USA	53	25	–52.8%	2.5(1-6)	1(0-3)	.5092
Carotid stent placement for asymptomatic internal carotid artery stenosis						
Overall	57	28	–50.9%	0(0-1)	0(0-0)	–
Location according to COVID-19 prevalence						
Low	51	25	–51.0%	1(0-2)	0(0-1)	.1167
High	6	3	–50.0%	0(0-0)	0(0-0)	–
Institutional location						
USA	8	4	–50.0%	0(0-0)	0(0-0)	–
Non-USA	49	24	–51.0%	1.5(0-4)	0(0-1)	.2862
Endovascular treatment of ruptured intracranial aneurysms						
Overall	114	115	.9%	2(1-4)	2(1-4)	1
Location according to COVID-19 prevalence						
Low	49	57	16.3%	1(0-4)	2(1-4)	.4321
High	65	58	–10.8%	2.5(2-5)	2(1-5)	1
Institutional location						
USA	52	49	–5.8%	2(1-4)	2(1-3)	1
Non-USA	62	66	6.5%	3(1-9)	3.5(0-10)	.7413
Endovascular treatment of unruptured intracranial aneurysms						
Overall	277	92	–66.8%	3(2-5)	.5(0-3)	.0809
Location according to COVID-19 prevalence						
Low	179	36	–79.9%	2.5(0-4)	1(0-3)	.3887
High	98	56	–42.9%	4.5(1-8)	0(0-6)	.0999
Institutional location						
USA	77	39	–49.4%	3(1-5)	0(0-3)	.0078
Non-USA	200	53	–73.5%	4(0-16)	1(0-9)	.6288
Endovascular treatment of ruptured BAVMs						
Overall	23	10	–56.5%	0(0-1)	0(0-0)	–
Location according to COVID-19 prevalence						
Low	12	2	–83.3%	0(0-1)	0(0-0)	–
High	11	8	–27.3%	.5(0-1)	0(0-1)	1
Institutional location						
USA	13	8	–38.5%	.5(0-1)	0(0-1)	1
Non-USA	10	2	–80.0%	0(0-2)	0(0-0)	–
Endovascular treatment of unruptured BAVMs						
Overall	76	9	–88.2%	0(0-2)	0(0-0)	–
Location according to COVID-19 prevalence						
Low	61	5	–91.8%	.5(0-2)	0(0-0)	–
High	15	4	–73.3%	0(0-2)	0(0-0)	–
Institutional location						
USA	16	2	–87.5%	0(0-1)	0(0-0)	–

(Continued)

Table 3. Continued

Study or subgroup	Total number in 2019	Total number in 2020	Change %	Median number in 2019 (95% confidence interval)	Median number in 2020 (95% confidence interval)	Quantile regression *P*-value
Non-USA	60	7	–88.3%	.5(0-4)	0(0-1)	1
Intracranial angioplasty/stent for intracranial stenosis						
Overall	115	48	–58.3%	0(0-1)	0(0-1)	1
Location according to COVID-19 prevalence						
Low	92	34	–63.0%	0(0-1)	0(0-1)	1
High	23	14	–39.1%	0(0-2)	0(0-1)	1
Institutional location						
USA	28	19	–32.1%	0(0-2)	0(0-1)	1
Non-USA	87	29	–66.7%	0(0-2)	0(0-1)	1
Other neuroendovascular procedures (spinal angiograms, WADA, others)						
Overall	144	166	15.3%	1(0-3)	2(0-4)	.3789
Location according to COVID-19 prevalence						
Low	57	42	–26.3%	1(0-5)	0(0-4)	.4764
High	87	124	42.5%	0(0-6)	2.5(1-5)	.288
Institutional location						
USA	70	64	–8.6%	1.5(0-5)	3(1-4)	.4694
Non-USA	74	102	37.8%	.5(0-7)	0(0-9)	1
Other nonendovascular procedures						
Overall	188	116	–38.3%	0(0-1)	0(0-0)	–
Location according to COVID-19 prevalence						
Low	169	107	–36.7%	0(0-14)	0(0-6)	1
High	19	9	–52.6%	0(0-1)	0(0-0)	–
Institutional location						
USA	155	104	–32.9%	0(0-6)	0(0-1)	1
Non-USA	33	12	–63.6%	0(0-4)	0(0-0)	-

ment for symptomatic ICA stenosis, given that COVID-19 leads to an increased risk of ischemic stroke.[1] Another analysis from 32 centers in French administrative regions reported a 21% reduction in mechanical thrombectomy volumes during the epidemic period.[2] This may be due to less patients seeking medical attention, and challenges in preforming mechanical thrombectomy and carotid stent placement with implementation of screening protocols to reduce the risk of transmission to medical professionals.[1] A reduction in mechanical thrombectomy may increase the rate of death and disability among acute ischemic stroke patients.[9,10] A reduction and/or delay in performance of carotid stent placement for symptomatic ICA stenosis may increase the risk of recurrent ischemic stroke among eligible patients.[11,12] There was no change in endovascular treatment of ruptured intracranial aneurysms and possibly aneurysmal subarachnoid hemorrhage (aSAH). In contrast, a previous study in France had noted that the number of admissions for aSAH had decreased with institution of social distancing measures.[13] There may be preferential use of endovascular treatment[14] if a larger segment of patients with aSAH are presenting in a delayed manner similar to that observed in acute ischemic stroke patients.[1]

The large reduction in elective procedures, such as carotid stent placement for asymptomatic ICA stenosis and endovascular treatment of unruptured intracranial aneurysms and BAVMs, was expected.[1] Several local and regional authorities had issued mandates to defer all elective procedures.[3] A survey reported that more than 27% of patients in the United States had an elective surgery, appointment, or procedure delayed or cancelled due to the COVID-19 pandemic.[4] Many patients may also avoid elective procedures due to loss of employment and medical insurance.[15] We also noted an unexpected decrease in total number of practitioners from 759 to 589 in pre-COVID-19 and during COVID-19 periods, respectively. The exact reasons for this decrease are not known. Possible reasons could be exclusion of practitioners who may be at high risk for acquiring COVID-19 and/or reallocation to other hospitals or services to meet increasing demands due to COVID-19. We acknowledge that a reduction in number of practitioners may have influenced the number of neuroendovascular procedures performed. However, there was also a reduction in the number of procedures per practitioner during the COVID-19 pandemic.

There are certain limitations that must be considered prior to the interpretation of our study. The data were derived from large stroke institution from various geographical settings with their own COVID-19 related restrictions and timelines of implementation, which may have introduced heterogeneity within observed results. While such data provide a broader perspective of neuroendovascular practice changes, in-depth analysis of eligible patients and procedures performed was not possible and therefore, we are unable to comment upon any changes in patient demographics or clinical characteristics among those undergoing procedures during the COVID-19 pandemic. We used a sampling period of 2 months post epidemic and previous year data from same months as reference as has been used in previous studies.[16–19] Some studies have used even a shorter period of 2 weeks to study changes in acute stroke admissions and mechanical thrombectomy procedures to study the effect of COVID-19 pandemic.[2,20] However, the pandemic has been prolonged beyond initial projections with dynamic changes in regional prevalence of COVID-19. Such dynamic changes pose challenges in defining in regions where hospitals were located as high prevalence and low prevalence. Many of the regions would have been reclassified particularly in the resurgence of

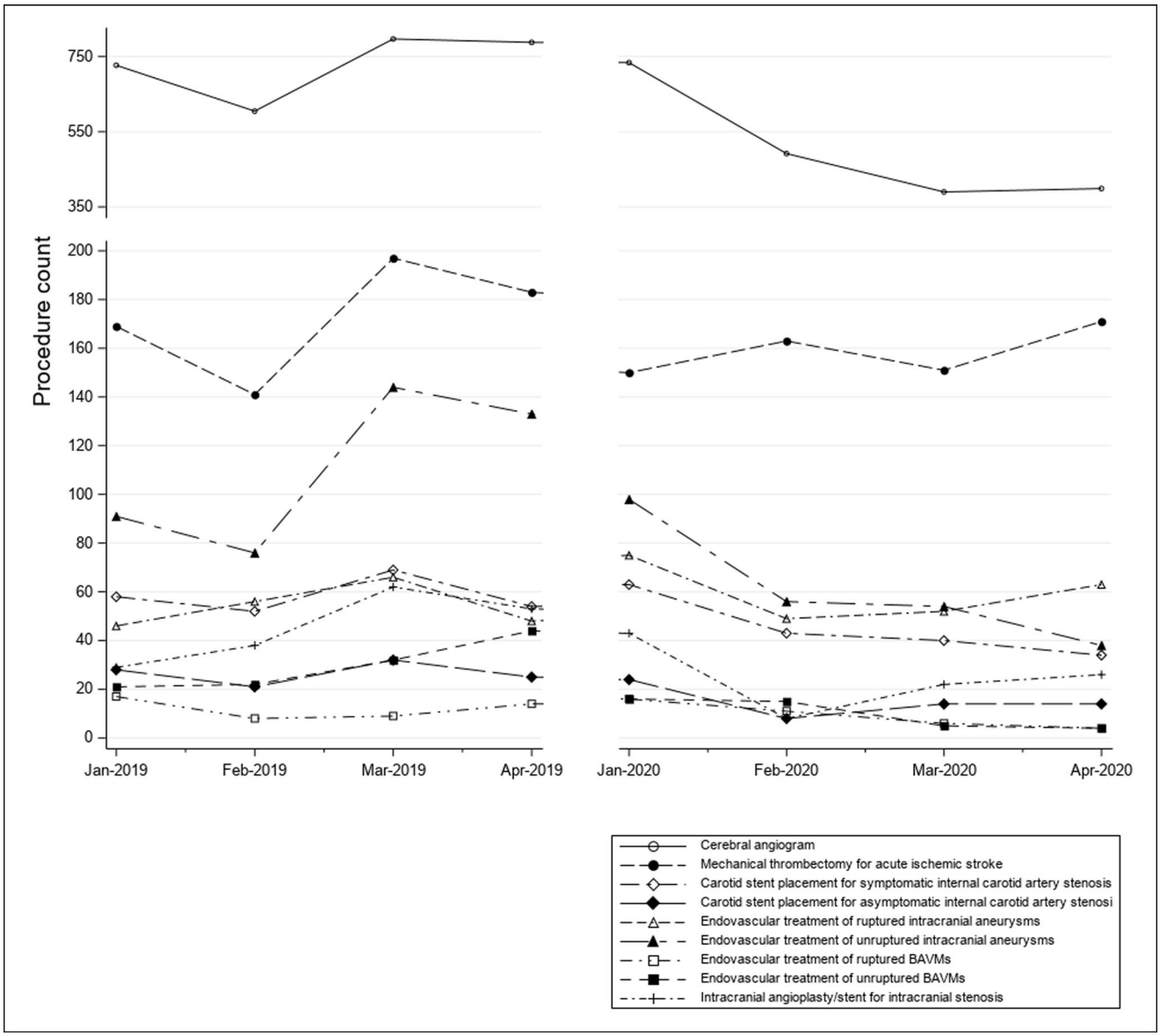

Fig 1. Procedure numbers are presented for each neuroendovascular procedure for each month.

COVID-19 in months that followed. These changes were not anticipated when the study was first designed.

We provided an international multicenter view of changes in neuroendovascular practices to better understand the gaps in provision of care to address the previously unmet needs of the ongoing COVID-19 pandemic. Any gaps in the provision of care during COVID-19 pandemic must be identified in future analyses to avoid increasing the rate of unfavorable outcomes among patients with ischemic stroke and transient ischemic attack.

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