Global impact of the COVID-19 pandemic on subarachnoid haemorrhage hospitalisations, aneurysm treatment and in-hospital mortality: 1-year follow-up

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Original research

Global impact of the COVID-19 pandemic on subarachnoid haemorrhage hospitalisations, aneurysm treatment and in-hospital mortality: 1-year follow-up

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ABSTRACT

Background Prior studies indicated a decrease in the incidences of aneurysmal subarachnoid haemorrhage (aSAH) during the early stages of the COVID-19 pandemic. We evaluated differences in the incidence, severity of aSAH presentation, and ruptured aneurysm treatment modality during the first year of the COVID-19 pandemic compared with the preceding year.

Methods We conducted a cross-sectional study including 49 countries and 187 centres. We recorded volumes for COVID-19 hospitalisations, aSAH hospitalisations, Hunt-Hess grade, coiling, clipping and aSAH in-hospital mortality. Diagnoses were identified by International Classification of Diseases, 10th Revision, codes or stroke databases from January 2019 to May 2021.

Results Over the study period, there were 16 247 aSAH admissions, 344 491 COVID-19 admissions, 8300 ruptured aneurysm coiling and 4240 ruptured aneurysm clipping procedures. Declines were observed in aSAH admissions (−6.4% (95% CI −7.0% to −5.8%), p=0.0001) during the first year of the pandemic compared with the prior year, most pronounced in high-volume SAH and high-volume COVID-19 hospitals. There was a trend towards a decline in mild and moderate presentations of subarachnoid haemorrhage (SAH) (mild: −5% (95% CI −5.9% to −4.3%), p=0.06; moderate: −8.3% (95% CI −10.2% to −6.7%), p=0.06) but no difference in higher SAH severity. The ruptured aneurysm clipping rate remained unchanged (30.7% vs 31.2%, p=0.58), whereas ruptured aneurysm coiling increased (53.97% vs 56.5%, p=0.009). There was no difference in aSAH in-hospital mortality rate (19.1% vs 20.1%, p=0.12).

Conclusion During the first year of the pandemic, there was a decrease in aSAH admissions volume, driven by a decrease in mild to moderate presentation of aSAH. There was an increase in the ruptured aneurysm coiling rate but neither change in the ruptured aneurysm clipping rate nor change in aSAH in-hospital mortality.

Trial registration number NCT04934020.

WHAT IS ALREADY KNOWN ON THIS TOPIC

⇒ A decline in non-traumatic subarachnoid haemorrhage (SAH), aneurysmal subarachnoid haemorrhage (aSAH) hospitalisations and ruptured aneurysm coiling has been reported during the first wave of the pandemic. A relative increase in ruptured aneurysm coiling was noted in low-coiling volume hospitals of 41.1% despite a decrease in SAH admissions in this tertile.

WHAT THIS STUDY ADDS

⇒ At the 1-year follow-up, we confirm a continued decline in aSAH admissions (−6.4% (95% CI −7.0% to −5.8%)) compared with the prior year, mostly driven by a decline in the mild and moderate presentation of aSAH, but no difference noted in patients with higher severity of aSAH. Another new finding is an increase in the ruptured aneurysm coiling rate but neither change in ruptured aneurysm clipping rate nor change in aSAH in-hospital mortality.

HOW THIS STUDY MIGHT AFFECT RESEARCH, PRACTICE OR POLICY

⇒ aSAH findings at 1 year are concordant with a decrease in other emergencies such as ischaemic stroke. A stable aSAH mortality rate may attest to the resilience of hospitals in the care of patients with aSAH during the pandemic.

INTRODUCTION

More than 2 years since the identification of the first case of COVID-19 in December 2019, the global COVID-19 pandemic has resulted in more than 400 million cases and close to 6 million deaths worldwide. As the COVID-19 pandemic has continued throughout the globe, there has been increasing recognition of the systemic effects of infection. In addition to respiratory symptoms, COVID-19 infection disrupts normal coagulation. Aberrations in coagulation may serve as a source for abnormal clotting events such as venous thromboembolism, stroke and abnormal bleeding.

During the first wave of the COVID-19 pandemic, marked declines in patients presenting with acute cerebrovascular conditions were observed,[1–8] including patients with non-traumatic subarachnoid haemorrhage (SAH).[1 9 10] Our initial report demonstrated declines in non-traumatic SAH (−22.5%) and aneurysmal subarachnoid haemorrhage (aSAH) (−24.9%) hospitalisations over the first 3 months of the pandemic as compared with

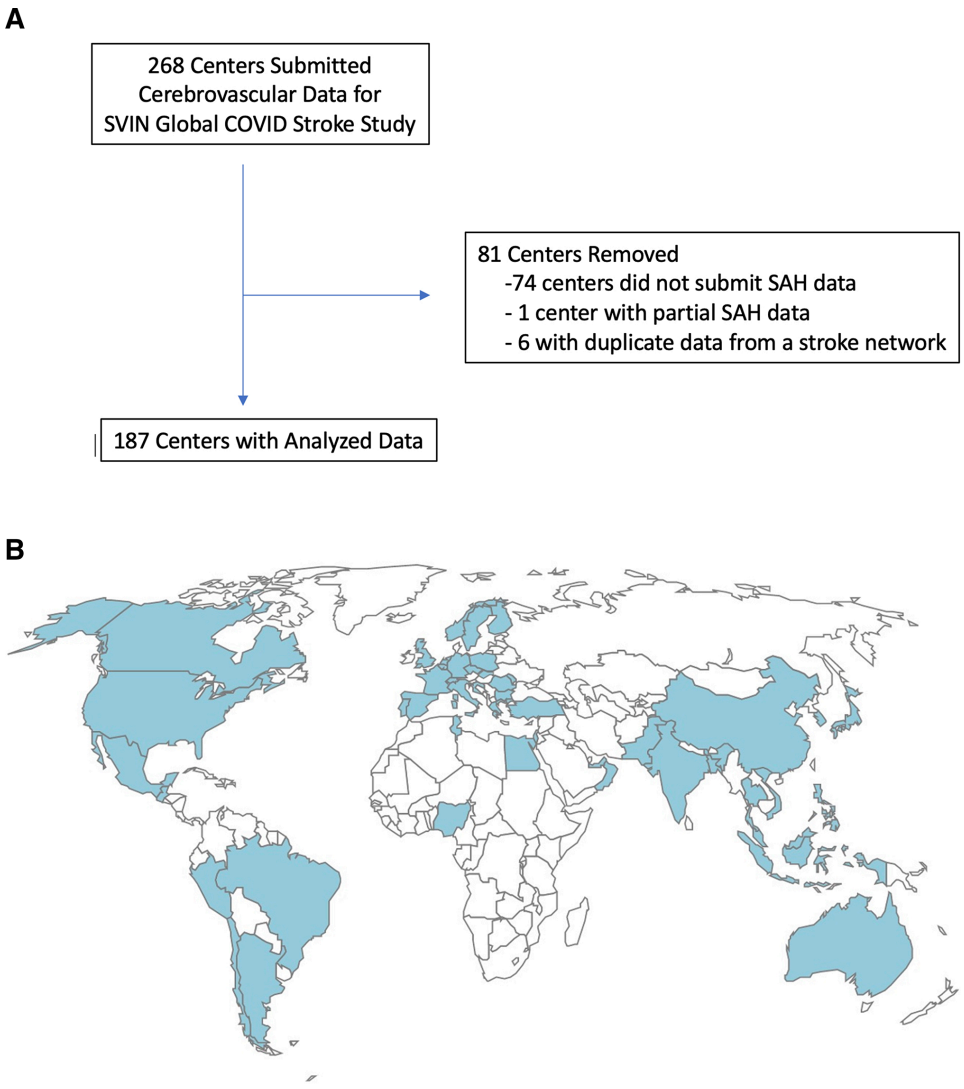

Figure 1 (A) Study flowchart. (B) World map of study countries. SAH, subarachnoid haemorrhage; SVIN, Society of Vascular and Interventional Neurology.

the corresponding 3 months of the prior year. A single-centre study from Lille reported greater disease severity and delayed presentation among patients with aSAH.[11]

Ruptured aneurysm coiling procedures also declined overall, but an increase in coiling procedures at low-volume centres suggested a potential shift in treatment.[1] Higher mortality, longer intensive care unit (ICU) stays and longer hospitalisations[12] have been observed in patients with both SAH and COVID-19 compared with those with SAH alone.[13] The long-term 1-year repercussions of the COVID-19 pandemic on aSAH admission volumes have not been studied, and it is unknown whether the declines during the first wave of the pandemic were related to a change in the severity of disease presentation.

Objectives and prespecified hypothesis

The primary objectives of this study were to evaluate changes in the volume of non-traumatic SAH, aSAH hospitalisations and aSAH in-hospital mortality during the first year of the COVID-19 pandemic (1 January 2020 to 28 February 2021) compared with the preceding year (1 January 2019 to 29 February 2020), adjusted by the beginning month of the pandemic by country. The secondary objectives were to evaluate the severity of aneurysmal aSAH admission presentation, the modality treatment of aSAH and the associations between COVID-19 admission volumes and aSAH volumes over the same period.

Our primary hypothesis was that, similar to the first wave, there would be a decrease in SAH and aSAH hospitalisations between the first year of the COVID-19 pandemic and the preceding year. Our secondary hypothesis was that there could be a shift toward increased use of ruptured aneurysm coiling as we had observed in the first wave of the pandemic.

METHODS

Study design

We conducted a cross-sectional retrospective study evaluating consecutive patients hospitalised with a diagnosis of subarachnoid haemorrhage between 1 January 2019 and 31 May 2021. Primary data collection was conducted between 1 May 2021 and 15 September 2021. A physician or research coordinator verified cases at each site, and follow-up queries to sites by the lead author were completed by 15 January 2022.

This study followed the Strengthening the Reporting of Observational Studies in Epidemiology reporting guideline.

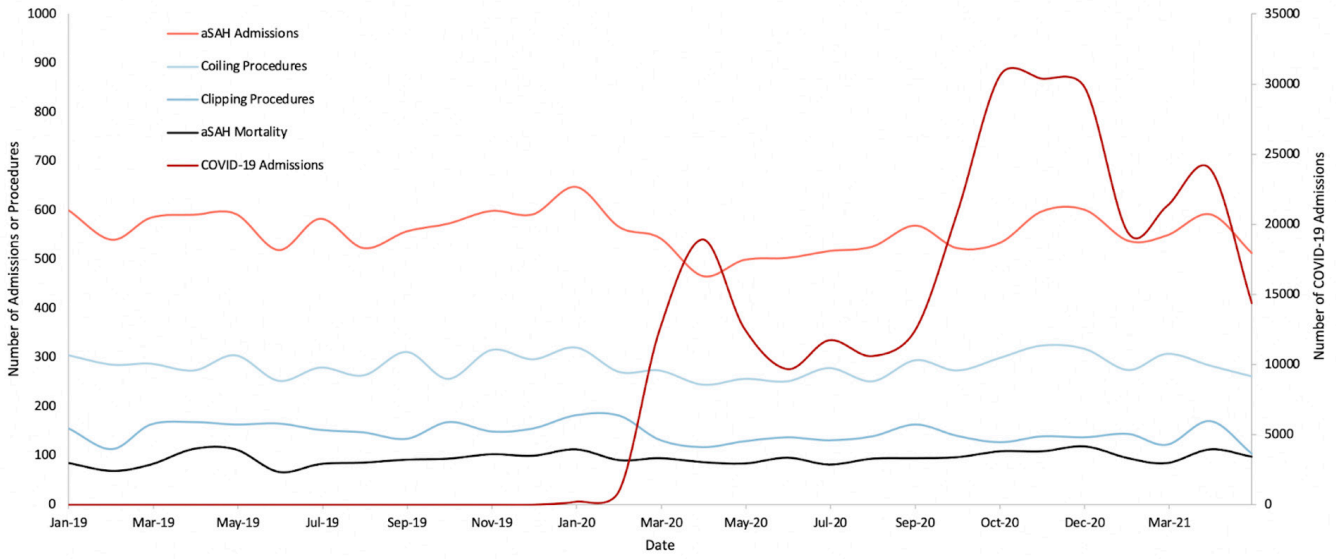

Figure 2 aSAH, coiling, clipping, mortality, COVID-19 admissions. aSAH, aneurysmal subarachnoid haemorrhage.

Setting and participants

Data were collected from collaborators of the Society of Vascular and Interventional Neurology, the Middle East North Africa Stoke and Interventional Neurotherapies Organisation, the Japanese Interventional Neurology Society, the European Stroke Organisation, the Latin America Stroke Group and academic partners.

Of 450 centres invited to participate in this global study of the impact of COVID-19 on cerebrovascular disease (including stroke, cerebral venous thrombosis and subarachnoid haemorrhage), data were received from 268 centres. Of these 268 centres, 74 centres did not submit SAH data and 1 had partial SAH data. There were six centres removed from the Czech Republic to ensure no data duplication because these centres referred patients with SAH to other centres that submitted SAH data in this cohort. This yielded 187 centres for this study cohort (figure 1A,B). The study size was based on the number of submitted cases with complete data for each variable.

The start date of the COVID-19 pandemic in each country was determined as the date of the first reported case. We defined the second wave of the COVID-19 pandemic using two definitions. Our primary definition was a minimum doubling of case volume following a ≥50% decline in case volume from the previous wave's peak. The start date for this occurrence was chosen as the case volume minimum closest to the second wave. Our secondary definition was the primary definition plus a minimum of 2 months between the peak of the first wave and the start of the second wave.[14 15] Centres were divided by low-volume, intermediate-volume and high-volume strata by mean monthly volume tertiles for COVID-19 hospitalisation submitted data (<26.33 vs >26.33 to 126.53 vs >126.53).

Study variables and outcome measures

We collected data on monthly aSAH, non-traumatic SAH hospitalisation volume, aSAH in-hospital mortality, ruptured aneurysm treatment modality with coiling or clipping, and COVID-19 hospitalisation volume. Non-traumatic SAH hospitalisation included patients with aSAH, perimesencephalic SAH or spontaneous convexal SAH. aSAH included patients who presented with ruptured aneurysm. Centres were divided by low-volume, intermediate-volume and high-volume centres by mean monthly volume tertiles for aSAH hospitalisation submitted data prior to the pandemic (<1.54 vs >1.54 to 3.33 vs >3.33).

For patients with aSAH, we categorised aSAH severity according to the Hunt and Hess (HH) scale: grade 1 or 2 as mild severity, grade 3 as moderate severity, and grade 4 or 5 as severe. Mortality data were obtained for aSAH admissions and were defined as a patient with aSAH who died in-hospital or was being transitioned to hospice care.

SAH data were obtained by a prospectively maintained aneurysm database or by International Classification of Diseases, 10th Revision (ICD-10) codes: I60 (non-traumatic SAH), I60.0 (non-traumatic SAH from carotid siphon and bifurcation), I60.1 (non-traumatic SAH from middle cerebral artery), I60.2 (non-traumatic SAH from anterior communicating artery), I60.3 (non-traumatic SAH from posterior communicating artery), I60.4 (non-traumatic SAH from basilar artery), I60.5 (non-traumatic SAH from vertebral artery), I60.6 (non-traumatic SAH from other intracranial arteries), I60.7 (non-traumatic SAH from intracranial artery, unspecified) I60.8 (other non-traumatic SAH) and I60.9 (non-traumatic SAH unspecified).

COVID-19 hospitalisation was defined as a patient admitted using ICD-10 code UO7.1 (COVID-19, virus identified), including those without a neurological diagnosis.

Standard protocol approvals, registrations and patient consents

This was an investigator-initiated study. There were no protected health information data collected in this study.

Bias

Data collection was completed more than 3 months after the final date of patient inclusion to ensure complete data capture including mortality events. Data verification was conducted by the lead author (TNN) on receipt of site data and centres with incomplete data were excluded from the subgroup analysis in which the data were missing. Centres contributing data within a stroke network were instructed to include transferred patients at the site of initial evaluation only. COVID-19 waves were evaluated based on publicly available data and the actual dates may not have been captured, especially early

Table 1 (A) aSAH admissions overall and monthly volumes before and during the COVID-19 pandemic. (B) SAH admissions by severity: overall and monthly volumes before and during the COVID-19 pandemic

(A)		Overall volume				Monthly volume*			
	N	Before COVID-19†	During COVID-19‡	Change % (95% CI)	P value	N	Before COVID-19 Adjusted mean (SE)	During COVID-19	P value
Overall	165	6912	6471	−6.4 (−7.0 to −5.8)	0.0001	172	3.84 (0.75)	3.62 (0.74)	0.03
Hospital aSAH volume§									
Low	56	422	471	11.6 (8.9 to 15.0)	0.101	57	0.56 (0.09)	0.64 (0.11)	0.142
Int.	53	1460	1472	0.82 (0.47 to 1.4)	0.825	56	2.28 (0.12)	2.28 (0.15)	0.977
High	56	5030	4528	−10.0 (−10.8 to −9.2)	<0.0001	59	8.14 (1.41)	7.42 (1.39)	0.008
Hospital aSAH volume stratified by hospital COVID-19 volume¶									
Low	49	1788	1833	2.5 (1.9 to 3.4)	0.455	52	2.94 (1.02)	3.0 (1.03)	0.657
Int.	46	1456	1368	−6.0 (−7.4 to −4.9)	0.098	46	2.19 (0.73)	2.03 (0.68)	0.19
High	47	2275	2074	−8.8 (−10.1 to −7.7)	0.002	49	3.77 (1.18)	3.40 (1.15)	0.137

(B)		Overall volume				Monthly volume*			
	N	Before COVID-19†	During COVID-19‡	Change % (95% CI)	P value	N	Before COVID-19 Adjusted mean (SE)	During COVID-19	P value
Mild	125	2698	2562	−5.0 (−5.9 to −4.3)	0.061	125	1.92 (0.37)	1.83 (0.36)	0.205
Mod.	125	981	900	−8.3 (−10.2 to −6.7)	0.062	125	0.60 (0.09)	0.55 (0.09)	0.204
Severe	125	1508	1490	−1.2 (−1.9 to −0.75)	0.742	125	0.87 (0.16)	0.86 (0.17)	0.78

Table 1b: Mild, moderate and severe cases were defined as Hunt-Hess grades 1–2, 3 and 4–5, respectively. 125 hospitals submitted complete data 12-month prepandemic and pandemic data on grades.
*The monthly volume analysis is adjusted for the date of peak COVID-19 volume for each country, the start date of the second wave and the continent.
†Number of admissions during 12 months before COVID-19 pandemic.
‡Number of admissions during 12 months of COVID-19 pandemic;.
§P value: low versus int. ≤0.0001; low versus high=N/A; int. versus high=N/A.
¶P value: low versus int.=N/A, low versus high=N/A, int. versus high=0.002.
aSAH, aneurysmal subarachnoid haemorrhage; int., intermediate; mod., moderate; N/A, not applicable; n, number of hospitals; SAH, subarachnoid haemorrhage.

in the pandemic and in nations where testing was not widely available. In nations with extremes of COVID-19 incidence, pandemic waves were obscured and not well captured by our definitions for the second wave of the pandemic.

Statistical analysis

We compared percentage change in the absolute number of aSAH admissions, non-traumatic SAH admissions, the severity of aSAH, endovascular coiling, aneurysm clipping, and aSAH mortality before and during the COVID-19 pandemic. The 95% CIs for percentage change were calculated using the Wilson procedure without correction for continuity. The differences in admissions across the two periods were assessed for significance using the Poisson means test. The analysis was repeated within categories of hospital aSAH volume (low, intermediate or high) and hospital COVID-19 volume (low, intermediate or high). The relative percentage decrease in volume between different categories (eg, low vs intermediate hospital volume) was tested using the z-test of proportion.

Table 2 aSAH admissions overall and monthly volumes per continent before and during the COVID-19 pandemic

	Overall volume					Monthly volume*			
	N	n1	n2	Change % (95% CI)	P value	N	Immediately before Adjusted mean (SE)	During COVID-19	P value
Overall	165	6912	6471	−6.4 (−7.0 to −5.8)	**0.0001**	172	3.84 (0.75)	3.62 (0.74)	**0.030**
Europe	59	2056	1944	−5.4 (−6.5 to −4.6)	0.077	62	2.90 (0.33)	2.74 (0.36)	0.290
North America	48	1856	1849	−0.38 (−0.78 to −0.18)	0.908	48	3.22 (0.51)	3.21 (0.46)	0.908
Asia	45	2340	2178	−6.9 (−8.0 to −6.0)	**0.016**	48	4.28 (0.81)	4.03 (0.72)	0.270
South America	8	435	291	−33.1 (−37.7 to −28.8)	**<0.0001**	9	4.84 (2.09)	3.28 (1.36)	0.121
Africa	4	146	146	0.0 (0 to 2.6)	1.0	4	3.04 (0.23)	3.04 (0.23)	1.0
Oceania	1	79	63	−20.3 (−30.4 to −12.9)	0.180	1	–	–	–

*The monthly volume analysis for each continent is adjusted for the date of peak COVID-19 volume for each country and the start date of the second wave. The overall monthly volume analysis is also adjusted for the continent.
.aSAH, aneurysmal subarachnoid haemorrhage; n1, number of admissions during 12 months before the COVID-19 pandemic; n2, number of admissions during 12 months of COVID-19 pandemic; n, number of hospitals; SAH, subarachnoid haemorrhage.

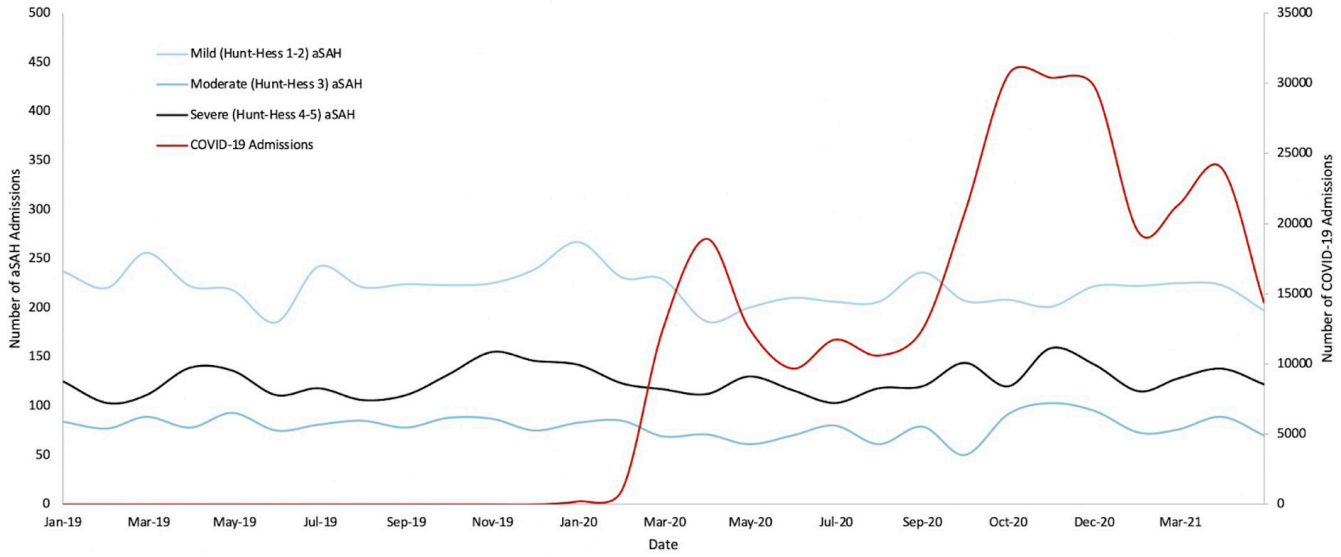

Figure 3 Hunt-Hess grade presentation and COVID-19 admissions.

In addition to absolute volume analysis, we also compared average monthly volumes (admissions/month) for the periods mentioned previously. The data were analysed in a mixed design using a repeated-measures analysis of variance (PROC MIXED analysis in SAS) accounting for the paired data structure and potential covariates. The unstructured matrix was the best fit and was used for the analyses. The monthly hospital volume analysis was adjusted for the date of peak COVID-19 volume for each country, the start date of the second wave and the continent. Estimated marginal means were calculated using the LSMEANS statement in PROC MIXED. The monthly volume analysis was stratified by aSAH and COVID-19 volume like the overall volume analysis.

Finally, we compared aSAH in-hospital mortality rate (aSAH mortality/aSAH admissions) before and during the COVID-19 pandemic using the χ^2 test. The difference in in-hospital mortality in patients with aSAH with or without concomitant COVID-19 was also tested using the χ^2 test. All data were analysed using SAS V.9.4, and the significance level was set at a p value of <0.05. No adjustments were made for multiple hypothesis testing.

Data availability

Data are available on reasonable request from the corresponding author.

RESULTS

Over the study period from January 1, 2019, to May 31, 2021, there were 20 680 non-traumatic SAH admissions and 344,491 COVID-19 admissions among participating centres. Of these, there were 16,247 aSAH admissions. There were 8300 endovascular coiling procedures and 4240 aneurysmal clipping procedures over the study period (figure 2).

1-year aSAH admissions

There were 6912 patients with aSAH admissions 1 year prior to the pandemic compared with 6471 during the pandemic, representing a 6.4% decrease (95% CI −7.0% to –5.8%, p=0.0001; table 1A) with continental variation (table 2). Monthly aSAH also declined from a mean of 3.8 (SE 0.75) to 3.6 (SE 0.74) patients per month, per centre. The decline in aSAH was most pronounced in high-volume aSAH hospitals (−10% (95% CI –10.8% to –9.2%), p<0.0001) and high-volume COVID-19 hospitals (−8.8% (95% CI –10.1% to –7.7%), p=0.002). Non-traumatic SAH admissions also exhibited decline over the same time period (overall: −4.1% (95% CI –4.6% to –3.7%), p=0.006; monthly mean 5.3 (SE 0.89) to 5.0 (SE 0.89), p=0.003; online supplemental table S1). Similar to aSAH, the declines were most marked in high non-traumatic SAH volume and high-volume COVID-19 centres (online supplemental table S1).

Severity of aSAH presentation

There were 125 hospitals that submitted complete data on aSAH severity on presentation using the HH grading scale. There was a trend towards a decline in mild and moderate presentations of aSAH (mild: −5% (95% CI −5.9% to –4.3%), p=0.06; moderate: −8.3% (95% CI –10.2% to –6.7%), p=0.06) but no difference noted in patients with higher severity of aSAH (table 1B and figure 3).

Ruptured aneurysm coiling

Overall, there were no changes in endovascular coiling of ruptured aneurysms before and during the pandemic. In subgroup analysis, hospitals with low aSAH volume prepandemic exhibited an increase in coiling procedures for ruptured aneurysms (26.2% (95% CI 20.4% to 33.1%), p=0.02, n=42 centres; table 3A). No difference in coiling volume was seen across hospitals with low-volume, intermediate-volume or high-volume COVID-19 hospitalisation.

Ruptured aneurysm clipping

Overall, there was a decline in aneurysm clipping procedures for ruptured aneurysms in the 1 year before and during the pandemic (−9.3% (95% CI −10.7% to –8.1%), p=0.004, n=140 centres; table 3B). The decline was most prominent in centres with high aSAH volume prior to the pandemic (−13.6% (95% CI −15.6% to –12.0%), p=0.0002) and with high COVID-19 hospitalisation burden (−22.7% (95% CI −26.5% to –19.3%), p=0.0001)

Table 3 (A) Endovascular coiling admissions overall, monthly volumes before and during the COVID-19 pandemic, and (B) surgical clipping admissions overall and monthly volumes before and during the COVID-19 pandemic

(A)

		Overall volume				Monthly volume*			
				Change			Before COVID-19	During COVID-19	P value
	N	n1	n2	% (95% CI)	P vaue	N	Adjusted mean (SE)		
Overall	152	3464	3374	−2.6 (−3.2 to −2.1)	0.276	166	2.06 (0.44)	2.02 (0.43)	0.518
Hospital endovascular coiling volume stratified by prepandemic aSAH volume††									
Low	42	183	231	26.2 (20.4 to 33.1)	**0.019**	47	0.35 (0.09)	0.45 (0.10)	0.058
Int.	54	842	813	−3.4 (−4.9 to −2.4)	0.476	56	1.28 (0.15)	1.26 (0.15)	0.783
High	50	2240	2135	−4.7 (−5.7 to −3.9)	0.112	55	4.13 (0.82)	3.97 (0.81)	0.269
Hospital endovascular coiling volume stratified by hospital COVID-19 volume‡‡									
Low	45	851	870	2.2 (1.4 to 3.5)	0.647	49	1.44 (0.46)	1.48 (0.45)	0.729
Int.	42	798	828	3.8 (2.7 to 5.3)	0.457	45	1.35 (0.45)	1.41 (0.44)	0.495
High	44	1047	990	−5.4 (−7.0 to −4.2)	0.207	48	2.12 (0.78)	2.0 (0.78)	0.273

(B)

		Overall volume				Monthly volume*			
				Change			Before COVID-19	During COVID-19	P value
	N	n1	n2	% (95% CI)	P value	N	Adjusted mean (SE)		
Overall	140	1848	1676	−9.3 (−10.7 to −8.1)	**0.004**	151	1.29 (0.42)	1.18 (0.43)	0.067
Hospital clipping volume stratified by prepandemic aSAH volume§§									
Low	40	91	101	11.0 (6.1 to 19.1)	0.471	45	0.13 (0.05)	0.14 (0.06)	0.616
Int.	50	350	368	5.1 (3.3 to 8.0)	0.502	51	0.61 (0.11)	0.63 (0.12)	0.826
High	47	1392	1202	−13.6 (−15.6 to −12.0)	**0.0002**	51	2.65 (0.90)	2.32 (0.93)	0.034
Hospital clipping volume stratified by hospital COVID-19 volume ¶¶									
Low	45	650	672	3.4 (2.2 to 5.1)	0.545	47	0.40 (0.68)	0.44 (0.72)	0.655
Int	37	411	387	−5.8 (−8.5 to −4.0)	0.396	41	0.68 (0.46)	0.63 (0.48)	0.308
High	42	519	401	−22.7 (−26.5 to −19.3)	**0.0001**	44	1.16 (0.29)	0.89 (0.23)	0.102

*The monthly volume analysis is adjusted for the date of peak COVID-19 volume for each country, the start date of the second wave, and the continent.
†P value: low versus int.=N/A, low versus high=N/A, int. versus high=0.115.
‡P value: low versus int.=0.056, low versus high=N/A, int. versus high=N/A.
§P value: low versus int.=0.040, low versus high=N/A, int. versus high=N/A.
¶P value: low versus int.=N/A, low versus high=N/A, int. versus high≤0.0001.
aSAH, aneurysmal subarachnoid haemorrhage; int., intermediate; n1, number of admissions during 12 months before COVID-19 pandemic; n2, number of admissions during 12 months of COVID-19 pandemic; N/A, not applicable; n, number of hospitals; SAH, subarachnoid haemorrhage.

Rate of ruptured aneurysm coiling or clipping

There were 132 centres that reported complete data on aSAH admissions, coiling and clipping in the 1 year before and during the pandemic. In this cohort, while the number of aneurysm clipping declined numerically, the rate of aneurysm clipping of the total aSAH admissions remained unchanged in the previous 1 year compared with during the pandemic (30.7% (1724/5616) vs 31.2% (1624/5205), p=0.58), whereas the rate of aneurysm coiling increased (53.97% (3031/5616) vs 56.5% (2940/5205), p=0.009).

SAH mortality

In patients with aSAH, there was no difference in the in-hospital or short-term mortality rate in the 1 year prepandemic compared with the first year of the pandemic (19.1% (1129/5918) vs 20.1% (1181/5654), p=0.12). In subgroup analysis, compared with the prepandemic year, there was an increase in aSAH mortality during the pandemic year in hospitals with higher tertile aSAH volume (17.3% (725/4191) vs 19.9% (771/3870), p=0.003) and high COVID-19 hospitalisation burden (21.9% (445/2035) vs 26.0% (495/1907), p=0.003) (table 4). Low-volume and medium-volume aSAH hospitals demonstrated no change in mortality during or prepandemic (table 4).

COVID-19 and aSAH

There were 42 centres that submitted data on the concomitant presence of COVID-19 and aSAH, which was present in 2.3% (60/2651) of patients with aSAH and 0.07% (60/85 506) of COVID-19 admissions over the first year of the COVID-19 pandemic (table 5).

DISCUSSION

In this multinational, cross-sectional study, we observed a 6.4% decrease in aSAH admissions during the first year of the COVID-19 pandemic compared with the 1-year period prior to the pandemic. The decrease in aSAH admissions was most profound in the tertile of high-volume aSAH hospitals and high-volume COVID-19 hospitals, whereas a non-significant numerical increase in aSAH volume was seen in low-volume aSAH and low-volume COVID-19 hospitals, respectively. We therefore concede with the possibility that aSAH rates may not have changed, and that patients were shifted to being treated

Table 4 SAH in-hospital mortality rate 1 year previously compared with 1 year during the COVID-19 pandemic

		Overall volume			
	N	aSAH admissions	Mortality	Mortality rate (%)	P value
Overall					
Before COVID	144	5918	1129	19.08	0.12
During COVID		5654	1181	20.89	
Hospital aSAH volume: low					
Before COVID	46	325	94	28.92	0.936
During COVID		377	108	28.65	
Hospital aSAH volume: medium					
Before COVID	51	1402	310	22.11	0.678
During COVID		1407	302	21.46	
Hospital aSAH volume: high					
Before COVID	47	4191	725	17.30	**0.003**
During COVID		3870	771	19.90	
Centre COVID-19 volume: low					
Before COVID	47	1772	293	16.53	0.872
During COVID		1812	296	16.34	
Centre COVID-19 volume: intermediate					
Before COVID	42	1421	296	20.83	0.116
During COVID		1334	311	23.31	
Centre COVID-19 volume: high					
Before COVID	41	2035	445	21.87	**0.003**
During COVID		1907	495	25.96	

The periods before and during COVID-19 pandemic were defined as 12 months before and during the COVID-19 pandemic, respectively.
aSAH, aneurysmal subarachnoid haemorrhage; n, number of hospitals; SAH, subarachnoid haemorrhage.

at lower-volume COVID-19 hospitals if high-volume hospitals were overwhelmed with COVID-19 hospitalisations. A similar overall 4.1% decrease in non-traumatic SAH admission was also observed. There was a decline of 9.3% in the number of aneurysm clipping procedures for ruptured aneurysms performed but no difference in the number of endovascular coiling procedures. Moreover, the decline in ruptured aneurysm clipping was proportional to the decline in aSAH admission as the rate of aneurysm clipping was unchanged between the two epochs, whereas the rate of endovascular coiling per aSAH admission increased, suggesting a shift in treatment toward coiling.

Over the same time period, there was a trend toward a decline in presentation of both mild and moderate aSAHs, similar to reported decreases in the mild presentation of ischaemic stroke.[16] There was no change in the in-hospital or short-term mortality rate between the year prior to and during the pandemic, attesting to the emergency preparedness[17] and resilience of hospitals in the care of patients with aSAH in the face of a global pandemic. However, the in-hospital or short-term mortality rate increased at high-COVID-19 volume and high-aSAH volume centres. To our knowledge, this is the first report to examine the effect of the COVID-19 pandemic on aSAH admissions, the severity of aSAH presentation, coiling and clipping volumes, in-hospital aSAH mortality over the 1 year of the COVID-19 pandemic compared with the previous year, across a large multinational cohort.

The mortality of patients with both COVID-19 and SAH has been reported to be more than four times greater compared with patients with SAH alone, likely attributed to concomitant comorbidities.[13] Both prior to and during the pandemic, aSAH mortality was inversely related to centre aSAH volume tertile and directly related to centre COVID-19 volume tertile. During the pandemic, mortality rates were unchanged at low-volume and moderate-volume centres and were increased at high-volume centres for both aSAH (from 17.3% to 19.9%) and COVID-19 (from 21.9% to 26.0%). This increased mortality was observed in conjunction with a decrease in aSAH volume of 10.0% at high-aSAH volume centres and 8.8% at high-COVID-19 volume centres.

The decline in aSAH and non-traumatic SAH observed in this study mirrors the decreases in SAH volumes that have been previously reported [1 9 10 18] during the first wave of the pandemic, whereas other centres have reported no change in aSAH volumes.[19] The observed decrease of 6.4% in overall aSAH volume in our study was driven by a decreased presentation of mild and moderate aSAHs, at 5.0% and 8.3%, respectively. As expected, no change in the presentation of severe aSAH was observed. Patients with symptoms of mild or moderate aSAH may have been less likely to present to a hospital due to the perceived danger of medical facilities during the COVID-19 pandemic. Rebleeding and neurological deterioration rates within the first 24 hours of aSAH are high, estimated between 4% and 13.6% and 35%, respectively.[20–22] This would likely result in patients with initially mild or moderate aSAH progressing to severe aSAH and presenting to a hospital. However, no increase in severe aSAH was observed, suggesting that lack of patient presentation does not sufficiently explain the decline seen in mild and moderate aSAHs. Late recurrence of treated aSAH is estimated to occur in 0.2%–0.3% annualised risk in treated patients, 22 times higher than matched controls.[23 24] The rate of recurrent bleeding in untreated patients with aSAH may be higher.

Among 140 centres reporting surgical clipping, there was a decline of 9.3% in the number of aneurysm clipping procedures for ruptured aneurysms performed but no difference in the number of coiling procedures among 152 reporting centres.

Table 5 Rates of concomitant COVID-19 and aSAH admissions

	N	COVID-19 and aSAH	aSAH overall	COVID-19 overall	Fraction of aSAH % (95% CI)	Fraction of COVID-19 % (95% CI)
Overall	42	60	2651	85 506	2.3 (1.8 to 2.9)	0.07 (0.05 to 0.09)
Europe	11	19	459	18 764	4.1 (2.7 to 6.4)	0.10 (0.06 to 0.16)
North America	19	36	862	45 952	4.2 (3.0 to 5.7)	0.08 (0.06 to 0.11)
Asia	8	0	1117	5983	0 (0 to 0.3)	0.00 (0.00 to 0.08)
South America	3	1	113	7676	0.9 (0.2 to 4.8)	0.01 (0.00 to 0.07)
Africa	1	4	100	7101	4.0 (1.6 to 9.8)	0.06 (0.02 to 0.15)
Oceania	0	–	–	–	–	

aSAH, aneurysmal subarachnoid haemorrhage; n, number of hospitals; SAH, subarachnoid haemorrhage.

Aneurysm clipping procedures declined most in centres with high aSAH volume prior to the pandemic and in centres with high COVID-19 hospitalisation burden. Meanwhile, at centres with low aSAH volume prepandemic, there was an increase of 26.2% in coiling procedures for ruptured aneurysms. These observed changes of relatively more endovascular coiling were also observed during the first wave of the pandemic[1] and may be related to a shift to mitigate risks of perioperative infection to the patient and/or provider with less invasive endovascular techniques to secure the aneurysm. Another explanation of this shift to endovascular coiling may be related to conservation of hospital resources amidst a pandemic, whereby reduced hospital length of stay has been reported in patients with ruptured aneurysms who are coiled compared with those who are clipped.[25]

Study limitations

While there were many centres in our study, the limitation is that data capture in our study may not have been complete without a comprehensive national database to account for regional differences in SAH care. We did not capture information on out-of-hospital death to account for potential rebleeding that may occur with a decline in mild to moderate SAH.

However, as several of our findings in this study, such as decrease in aSAH admissions or relative increase in coiling of ruptured aneurysms, were reproduced from the first wave of the pandemic, this may confirm the reproducibility and generalisability of our initial findings at the 1-year mark of the pandemic. Without granular data on patients presenting with aSAH, we could not identify confounding factors that might have explained higher in-hospital aSAH mortality during the pandemic in the hospitals with higher COVID-19 burden.

CONCLUSIONS

In conclusion, there was a decline in non-traumatic SAH and aSAH admissions during the first year of the COVID-19 pandemic. This decline was likely driven by an observed trend in the decline of patients presenting with mild to moderate aSAH. Overall, there was no significant difference in aSAH in-hospital mortality between the pandemic and prepandemic years, except in subgroup analysis of higher aSAH mortality in hospitals with the highest COVID-19 burden, attesting to resilience in the care of patients with aSAH amidst the pandemic. There was a decline in aneurysm clipping for ruptured aneurysms proportional to the decline in aSAH admissions during the first year of the pandemic and an increase in the coiling rate of ruptured aneurysms, suggesting a shift towards endovascular technique during the pandemic.

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