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Impact of the first COVID-19 pandemic peak and lockdown on the interventional management of carotid artery stenosis in France

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ABSTRACT

Objective: The aim of this study was to evaluate the impact of the COVID-19 pandemic on the trends of carotid revascularization (endarterectomy [CEA], transfemoral carotid artery stenting [TFCAS]) for symptomatic and asymptomatic carotid stenosis before, during, and after the end of the first lockdown in 2020 in France.

Methods: Nationwide data were provided by the French National Hospital Discharge database (*Programme de Médicalisation des Systèmes d'Information*). We retrospectively analyzed patients admitted for CEA or TFCAS in all French public and private hospitals during a 9-month period (January-September) in 2017, 2018, 2019, and 2020. Procedures were identified using the French Common Classification of Medical Procedures. Stenoses were considered symptomatic in the presence of stroke and/or transient ischemic attack codes (according to the International Classification of Diseases-Tenth Revision) during the stay, and asymptomatic in the absence of these codes. Hospitalization rates in 2020 were compared with the rates in the same period in the 3 previous years.

Results: Between January and September 2020, 12,546 patients were hospitalized for carotid artery surgery (CEA and TFCAS) in France. Compared with the 3 previous years, there was a decrease in hospitalization rates for asymptomatic (−68.9%) and symptomatic (−12.6%) CEA procedures in April, starting at the pandemic peak concomitant with the first national lockdown. This decrease was significant for asymptomatic CEA ($P < .001$). After the lockdown, while CEA for asymptomatic stenosis returned to usual activity, CEA for symptomatic stenosis presented a significant rebound, up 18.52% in August compared with previous years. Lockdown also had consequences on TFCAS procedures, with fewer interventions for both asymptomatic (−60.53%) and symptomatic stenosis (−16.67%) in April.

Conclusions: This study demonstrates a severe decrease for all interventions during the first peak of the COVID-19 pandemic in France. However, the trends in the postlockdown period were different for the various procedures. These data can be used to anticipate future decisions and organization for cardiovascular care. (J Vasc Surg 2022;75:1670-8.)

Keywords: Coronavirus disease 2019; Pandemic peak; Carotid artery stenosis; Carotid endarterectomy; Carotid artery stenting; Lockdown

Since the beginning of the COVID-19 pandemic, there have been huge changes in medical and surgical care, particularly during the first lockdown in 2020. In practice, the lockdown was required to prevent viral transmission and to maintain the ability of health care centers to manage COVID-19 and non-COVID-19 emergencies.[1] Several reports have underlined a decrease in the rate of hospital admissions for medical emergencies such as myocardial infarction[2-5] or stroke,[6,7] but the impact of the lockdown on the management of peripheral vascular diseases such as carotid stenosis still needs to be assessed. Carotid stenosis is considered to be responsible for 10% to 15% of ischemic strokes (IS).[8] These strokes may be prevented by carotid endarterectomy (CEA) or transfemoral carotid artery stenting (TFCAS). In current guidelines, CEA for symptomatic stenosis must be

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performed within 14 days after symptom onset to decrease the risk of recurrent strokes and transient ischemic attacks (TIA), for which the risk in this period is up to 25%.[9-11] Assessing the repercussions of the COVID-19 pandemic on carotid revascularization, while differentiating CEA/TFCAS for asymptomatic and for symptomatic plaques, may help the national health care system to deal with such crises in the future.

The aim of this study was to evaluate the impact of the COVID-19 pandemic on the volume of CEA and TFCAS for symptomatic and asymptomatic carotid stenosis, observed before and during the first lockdown in 2020 in France. This analysis used complete nationwide administrative data from all primary and comprehensive hospitals, and compared the data from 2020 with the same time period in the 3 previous years. The second objective was to evaluate the volume of interventions for carotid stenosis in the 4 months after lockdown and to compare clinical characteristics between CEA and TFCAS patients.

ARTICLE HIGHLIGHTS

- **Type of Research:** Retrospective cohort study of the French National Hospital Discharge database (Programme de Médicalisation des Systèmes d'Information)
- **Key Findings:** A 58% decrease in symptomatic and asymptomatic carotid stenosis surgeries was observed during the COVID-19 pandemic in France in April 2020 versus April 2017-2019, followed by a recovery toward prior levels, except for symptomatic carotid stenosis surgeries, for which there was a significant rebound exceeding the volume in prior years.
- **Take Home Message:** Hospitalizations and surgical interventions for symptomatic and asymptomatic carotid stenosis decreased during the peak of the COVID-19 pandemic, with no rebound after the first lockdown, except for symptomatic carotid stenosis interventions.

METHODS

The nationwide data of this retrospective cohort study were provided by the French National Hospital Discharge database (*Programme de Médicalisation des Systèmes d'Information*, PMSI). This process was approved by the National Committee for Data Protection. Although confidential, PMSI data are available for researchers who meet specific criteria for access defined by the Agency for Information on Hospital Care (*Agence Technique de l'Information sur l'Hospitalisation*).

Hospitalization data. Hospitalization data from January to September 2017 to 2020 were extracted from the French National Discharge database, which collects the medical records of all patients discharged from all public and private hospitals in France. Hospitalizations included possible hospital transfers.

CEA and/or TFCAS were identified using the French Common Classification of Medical Procedures during the hospital stay. Because transcarotid artery revascularization is not yet available in France for the treatment of carotid stenosis, our study only refers to TFCAS.

Cerebrovascular events included IS and TIA. IS and TIA cases were identified according to the International Classification of Diseases-Tenth Revision codes recorded on the discharge abstract: the codes for IS were I63 and I64, and the code for TIA was G45. Stenoses were considered symptomatic in the presence of IS or TIA codes during the stay and asymptomatic in the absence of these codes. A sensitivity analysis was performed in which symptomatic stenosis was defined as the presence of an IS or TIA coded as the primary diagnosis on the first unit of the carotid revascularization intervention stay or coded in previous stays in the 60 days before the stay for carotid revascularization.

COVID-19 was identified using specific codes created by the Agency for Information on Hospital Care for this pandemic. The codes were considered as a primary diagnosis and as associated and secondary diagnoses. This ensured that the four diseases were identified even if another severe disease was the primary diagnosis.

Other variables were extracted: age in four classes (<65, 65-79, 80-84, and ≥85 years), sex, and available cerebrocardiovascular risk factors (hypertension, diabetes mellitus, obesity, atrial fibrillation)), chronic renal failure, coronary artery disease, chronic obstructive pulmonary disease, chronic respiratory failure, and in-hospital death.

Study design. We retrospectively analyzed all patients admitted to primary or comprehensive public and private French hospitals for CEA and/or TFCAS between January 1 and September 30, 2020, and living in metropolitan France. This period included the first peak of the COVID-19 pandemic, the prelockdown period (weeks 1-11), the lockdown from March 17 (week 12) to May 10, 2020 (week 19), and the postlockdown period (weeks 20-40). Hospitalization numbers in 2020 were compared with the mean numbers from the same time periods in 2017 to 2019, month per month. Trends were represented for CEA/TFCAS overall and per type of procedure, for symptomatic and asymptomatic stenosis, and with the trends of all hospitalizations associated with COVID-19 (including CEA/TFCAS or not). Hospitalization trends for all IS or TIA were also reported (including CEA/TFCAS or not).

Clinical characteristics among the patients hospitalized for CEA and TFCAS were compared between two periods: during the lockdown in 2020 (ie, weeks 12-19) and the months of March, April, and May of 2017, 2018, and

2019, for the total population and then for symptomatic and asymptomatic stenosis subgroups.

This retrospective study had no impact on patient care and all data were anonymous. This study was authorized by the French Data Protection Authority on July 3, 2020 (Registration number: DR-2020-250 on 07/03/2020), and therefore was conducted in accordance with the Declaration of Helsinki. Written consent was not needed for this study.

Statistical analysis. Qualitative variables were presented as frequencies (percentages). Quantitative variables were presented as medians and interquartile ranges. The different variables analyzed in the cohort of hospitalized patients were compared using the χ^2 test or the Fisher exact test (for qualitative variables) and the median test (for quantitative variables) according to the two periods (weeks 12-19 in 2020 and March to May of 2017, 2018, and 2019). An interrupted time series analysis was performed to measure changes in hospitalization rates over time for each condition in January to September 2020, divided into the periods before, during, and after the lockdown. This model used weekly hospitalization rates over the study period and included a linear time trend. We thus quantified the impact of the lockdown as changes in the level and slope compared with the preceding period. The change in the number of stays for each disease in 2020 compared with the mean of 2017 to 2019 by month was plotted as smoothed curves using degree two spline functions. The statistical significance threshold was set at less than .05. All analyses were performed using SAS (SAS Institute Inc, Version 9.4, Cary, NC).

RESULTS

Between January and September 2020, 12,546 patients were hospitalized for carotid artery surgery (CEA and TFCAS) in France. This figure was 9.8% lower than the same period in the 3 previous years (2017-2019), during which a mean of 13,912 patients were recorded (Supplementary Table I, online only). In the 2020 national lockdown period (weeks 12-19), the decrease in the number of surgical interventions was parallel to the peak of the pandemic in France (Fig 1). This decrease started during week 9 (3 weeks before the beginning of lockdown) and continued until April, decreasing 58.4% compared with the mean of the previous years. A rebound occurred very quickly in April, and by June there was a complete recovery compared with prior years (Fig 1; Table I).

The same trends were observed in the total CEA group (Fig 2, *A*), and the asymptomatic CEA subgroup, which showed a 68.9% decrease in April 2020 (Fig 2, *C*; Table I). However, in the symptomatic CEA subgroup, there was a particular trend; after the initial decrease in interventions (–12.5% and -12.94% in March and April, respectively), there was a rapid increase in cases that started during lockdown and that went on to exceed the values of the previous years in the following months (18.5% more interventions in August and 10.03% more in September). After the end of lockdown, from May to September, CEA for symptomatic stenosis remained higher in 2020 compared with the same period in 2017 to 2019 (Fig 2, *B*; Table I).

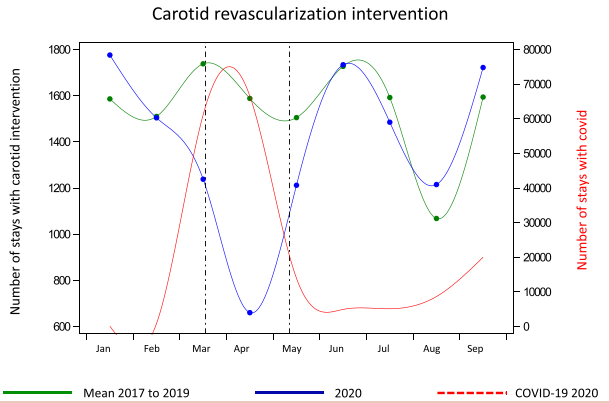

Fig 1. All carotid revascularization interventions in France in 2020 and in 2017-2019, and pandemic peak/number of hospitalizations.

Using interrupted time series for 2020, we observed a significant decrease in the level of CEA overall and for asymptomatic stenosis during lockdown compared with the period before lockdown, and there was a significant increase after lockdown compared with during lockdown ($P < .001$ for all) (Supplementary Fig, online only). For CEA for symptomatic stenosis, we observed a significant decreasing slope after lockdown ($P = .043$).

Similar trends emerged for all TFCAS procedures and for those performed for asymptomatic stenosis. In total, a mean of 903 TFCAS procedures were performed between 2017 and 2019, compared with 858 in 2020, totaling a decrease of 4.8% (Table I). There was a decrease in the volume of surgical interventions starting before lockdown in both the asymptomatic and symptomatic groups, followed by a fast recovery to usual activity levels during lockdown, and an increased number of procedures after lockdown when compared with previous years (Fig 3, *B* and *C*). The number of TFCAS for symptomatic stenosis was higher in 2020 than in 2017 to 2019 (Table I).

Using interrupted time series for 2020, we observed a significant decreasing slope for TFCAS for all patients and for asymptomatic stenosis before lockdown ($P = .030$ and .024, respectively), and a significant increase after lockdown compared with during ($P = .0094$ and .015, respectively) (Supplementary Fig, online only).

Hospitalizations for IS or TIA decreased during the lockdown and then returned to the usual numbers after the lockdown (Supplementary Table II, online only). The sensitivity analysis on the definition of symptomatic stenosis led to similar results.

Table I. Variation between monthly hospitalizations for carotid endarterectomy (*CEA*) and transfemoral carotid artery stenting (*TFCAS*) in France from January to September 2017 to 2019 (mean) and 2020

Period	All variations (%)	Symptomatic stenosis Variation (%)	Asymptomatic stenosis Variation (%)
All carotid procedures (CEA and TFCAS)			
January	+10.67	+1.50	+12.38
February	−−0.40	−0.74	−0.32
March	**−28.77**	**−12.50**	**−32.06**
April	**−58.44**	**−12.94**	**−68.41**
May	**−19.47**	**+8.82**	**−26.04**
June	+0.40	+6.77	−0.90
July	−6.72	+1.69	−8.61
August	+12.10	+18.52	+10.02
September	+7.43	+10.03	+6.91
Total	−9.8	+0.65	−14.22
CEA			
January	+10.46	−1.24	+12.51
February	−1.62	−0.82	−1.71
March	**−28.16**	**−10.37**	**−31.71**
April	**−58.98**	**−12.60**	**−68.90**
May	**−18.03**	**+9.76**	**−24.56**
June	−0.25	+7.47	−1.78
July	−6.39	+1.48	−8.15
August	+9.03	+18.25	+6.16
September	+7.52	+8.78	+7.35
Total	−10.12	+2.58	−12.78
TFCAS			
January	+14.75	+25.93	+11.56
February	+15.18	+4	+19.54
March	**−37.5**	**−24.62**	**−37.65**
April	**−50.50**	**−16.67**	**−60.53**
May	**−38.61**	**−5**	**−46.91**
June	+8.53	0	+11
July	−11.43	+4	−16.05
August	+43.93	+21.74	+50
September	+6.19	+22.22	+1.16
Total	−4.88	+2.83	−6.78

Boldface entries indicate the months concerned by the first lockdown in France.

The clinical characteristics of patients treated with CEA and TFCAS are presented in Tables II and III, respectively. In-hospital death was similar in both groups. During the study period, 5 patients in the asymptomatic CEA group underwent surgery while suffering from COVID-19 (0.6%) compared with 12 patients in the symptomatic group (2.8%). Only one patient with COVID-19, who had symptomatic stenosis, underwent stenting treatment. In the TFCAS subgroups, there were no significant differences in age, sex, hypertension, diabetes, obesity, atrial fibrillation, chronic renal failure, coronary artery disease, chronic obstructive pulmonary disease, or chronic respiratory failure. In 2020, there were more men in the CEA group overall (74.4% vs 71.5%; $P = .031$), less hypertension in the asymptomatic subgroup (54.7% vs 59.5%; $P = .0061$), and more diabetes in the symptomatic subgroup (31.5% vs 26.4%; $P = .028$). No significant differences were observed for the other available variables.

DISCUSSION

This nationwide population-based study revealed a deep drop in activity for overall carotid procedures

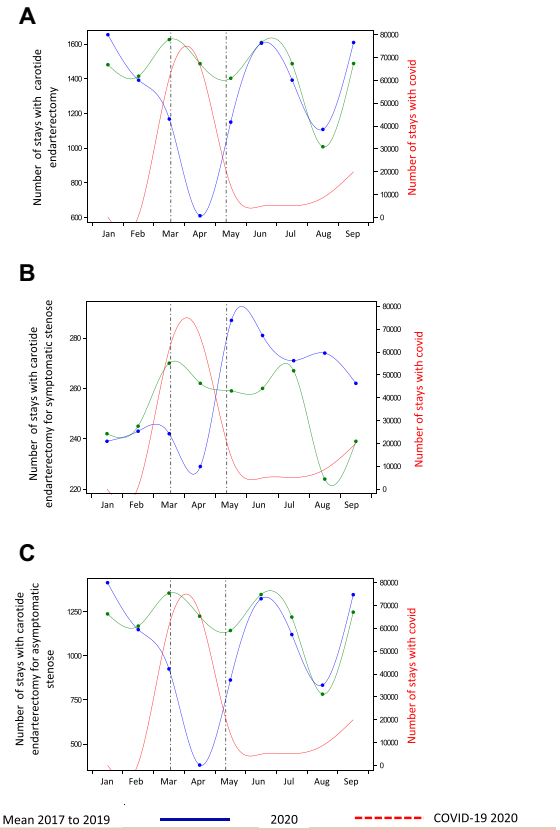

Fig 2. Monthly comparison of hospitalizations for carotid endarterectomy in 2020 compared with January to September 2017-2019. **A,** Carotid endarterectomy (CEA). **B,** CEA for symptomatic stenoses. **C,** CEA for asymptomatic stenoses.

(CEA + TFCAS) parallel with the peak of the first wave of the COVID-19 pandemic, which was not compensated for after lockdown. In the analyses focused on patients undergoing CEA, asymptomatic procedures showed the same trend. However, for symptomatic stenosis, the CEA numbers dropped around the peak of the first wave, but afterward we observed a rebound exceeding the usual activity in prior years. Moreover, patients who had a postponed CEA did not undergo TFCAS instead.

Earlier reports have described the local[12] or nationwide[13] effects of COVID-19 and the lockdown in the vascular field. There are currently few available data to analyze how the pandemic has influenced carotid revascularization,[3,13,14] and large ongoing international studies, such as the COvid-19 Vascular sERvice (COVER) Study and the Vascular Surgery COVID-19 Collaborative (VASCC), are currently working on an assessment of the impact of the COVID-19 pandemic on vascular procedures.[15,16] Nevertheless, several authors have emphasized the urgent need to quantify the pandemic's effects on surgical interventions and the practices of surgical teams.[15-17]

During the peak of the first wave, we observed a sharp decrease in CEA procedures for asymptomatic stenosis. This decrease has also been described in other studies, with decreases in usual activity ranging up to 90%.[13] In France, this decrease in activity may have several explanations. CEA may have been postponed following the national public health strategy in the organization of the medical and surgical neurocardiovascular networks and owing to a shift in hospital priority toward medical and surgical COVID-19 emergencies. Some patients may have experienced a deterioration in preoperative health status and a higher mortality rate before the intervention, because carotid stenosis is most often diagnosed in elderly populations susceptible to severe infection and with a high risk of mortality.[18,19] Asymptomatic patients may have been afraid of exposure to COVID-19 in the hospital, and public messages to stay at home to avoid COVID-19 contamination and to avoid overburdening the health care system may also have played a role in keeping patients at home. However, despite this clear decrease in cases, the overall number may seem high for an elective procedure during a pandemic. No national restrictions were imposed, and interventional strategies may have varied between centers, which may explain the remaining elective CEA activity in asymptomatic patients.

In symptomatic stenosis, the same decrease in CEA rates was observed in the month after the peak of the first wave. In France, we observed an initial phase of decline in the symptomatic population for several potential reasons, such as hospital adjustments to the pandemic (same as for asymptomatic stenosis) and limits on the number of procedures in some centers, as described in other countries,[20] contrasting with the increase observed by Pini et al in Italy.[14] Moreover, CEA for symptomatic stenosis is performed for a minor stroke or TIA; a recent study demonstrated a decrease in stroke- or TIA-related hospitalization during the same period in France,[6] suggesting that patients with minor symptoms made fewer visits to emergency units and stroke centers, perhaps resulting in an initial decrease in the number of procedures performed. Another explanation may be the decrease in air pollution, which is a trigger for the inflammatory reaction of vascular plaques.[2,6] Finally, social isolation,[6] patients dying at home, and misdiagnosis in emergency rooms are other factors that may be involved. The COVID-19 pandemic may also have led some institutions to implement radical changes in practice,[13,20,21] and some interventions for symptomatic stenosis may have been delayed owing to organizational issues. In the subgroup of patients with symptomatic stenosis eligible for CEA, newly available data suggest that dual antiplatelet therapy should be introduced for patients with a recent TIA or minor stroke who cannot

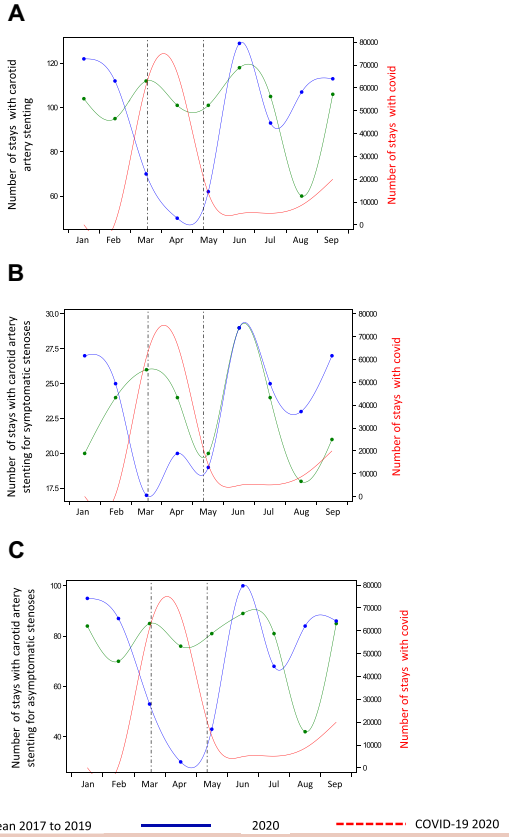

Fig 3. Monthly comparison of hospitalizations for carotid artery stenting in 2020 compared with January to September 2017-2019. **A,** Carotid artery stenting (CAS). **B,** CAS for symptomatic stenoses. **C,** CAS for asymptomatic stenoses.

be treated surgically[20,22] to achieve maximum benefit and avoid recurrence.

In the postlockdown period, there was no visible compensation for the decrease in CEA performed in asymptomatic patients. It is possible that frail patients and those infected with COVID-19 were operated on at a later stage, possibly beyond the study period. Nevertheless, these data suggest that many patients with asymptomatic stenosis did not receive an early intervention in the weeks after the lockdown. In contrast, elective TFCAS interventions were maintained during the immediate postlockdown period. Afterward, we observed a decrease in TFCAS interventions during the summer, but the number was still higher than in previous years. For some patients, as suggested previously, TFCAS may have been offered instead of CEA so that local anesthesia could be used rather than cervical blockade or general anesthesia, which may have been unavailable.

An important finding of this work is the increase in the volume of symptomatic CEA procedures observed after lockdown. It is well-known that the risk of recurrent stroke is highest in the first 15 days after the index event. To limit the devastating effect of postponed CEA in symptomatic patients, vascular surgery units may have implemented early measures to compensate for procedures that had been postponed. This effort may have been supported by adaptive strategies in the organization of medical and surgical neurocardiovascular networks, reinforcement from general practitioners, and improvements in public health education resulting from national campaigns focused on stroke and TIA over the last 10 years. Concerning TFCAS interventions in this particular pandemic period, one might have expected TFCAS to be preferred to over CEA if the intervention could not be postponed, for example, in patients with symptomatic stenosis. As mentioned elsewhere in this article, TFCAS can be performed under local anesthesia, without the need for an anesthesiologist and with a shorter hospital stay. Indeed, the latest European guidelines advise practitioners to consider carotid artery stenting as an alternative to CEA for some particular subgroups of patients at high risk for CEA, particularly for symptomatic stenosis.[23] The COVID-19 pandemic might have increased the number of patients considered to be at high risk for CEA and, therefore, increased the number of TFCAS interventions, as previously described.[21,24] This was not confirmed herein, because the number of cases of TFCAS did not compensate for the CEAs that were not performed.

For clinical features, it is interesting to observe that patients with symptomatic carotid stenosis treated by CEA presented the classical vascular profile, including more males and more patients with diabetes, similar to the stroke population.[6]

The consequences of a postponed CEA or TFCAS for a population at risk of stroke with carotid stenosis might be serious, particularly in the symptomatic population, for whom the risk of recurrent stroke is higher in the first 15 days, potentially explaining the observed increase in interventions. For asymptomatic patients, recently updated data have shown a decrease in the spontaneous stroke risk of approximately 1% per year after improvements in medical treatments,[25] suggesting that these patients could be managed adequately without a carotid revascularization procedure. Although this issue remains to be clarified with ongoing trials, patients whose procedures are postponed should benefit from optimal medical treatment and be followed carefully. The low rate of complications in asymptomatic patients makes the effects of delayed procedures difficult to assess. For both symptomatic and asymptomatic stenosis, prospective stroke registries could be used to assess the consequences of postponing a carotid revascularization procedure. A detailed analysis of patient medical records will also be essential to measure the impact of the national lockdown over a longer period of time and the medical complications arising as a result. Regardless, it is important for vascular surgeons and stroke center teams to work closely together to improve patient screening and to provide CEA or TFCAS for symptomatic

Table II. Comparison of patient characteristics among carotid endarterectomy (CEA) groups between week 12 (mid-March) and week 19 (mid-May) 2020 as compared with March-April and May 2017-2019

	Total			Asymptomatic			Symptomatic		
	2017-2019[a]	2020 (Week 12-19)	*P* Value	2017-2019[a]	2020 (Week 12-19)	*P* Value	2017-2019[a]	2020 (Week 12-19)	*P* Value
No.	13,551	1271		11,177	839		2374	432	
Male sex	9689 (71.5)	945 (74.4)	**.031**	7996 (71.5)	620 (73.9)	.14	1693 (71.3)	325 (75.2)	.096
Median age, ears	72.0 [13.0]	73.0 [13.0]	.11	72.0 [13.0]	72.0 [13.0]	.59	73.0 [16.0]	74.0 [14.0]	.38
Hypertension	8260 (61.0)	745 (58.6)	.10	6654 (59.5)	459 (54.7)	**.0061**	1606 (67.7)	286 (66.2)	.56
Diabetes	3471 (25.6)	330 (26.0)	.79	2845 (25.5)	194 (23.1)	.13	626 (26.4)	136 (31.5)	**.028**
Obesity	1250 (9.2)	135 (10.6)	.10	987 (8.8)	74 (8.8)	.99	263 (11.1)	61 (14.1)	.069
Atrial fibrillation	1284 (9.5)	127 (10.0)	.55	946 (8.5)	66 (7.9)	.55	338 (14.2)	61 (14.1)	.95
Chronic renal failure	745 (5.5)	68 (5.4)	.83	604 (5.4)	37 (4.4)	.22	141 (5.9)	31 (7.2)	.32
Coronary disease	3198 (23.6)	282 (22.2)	.26	2706 (24.2)	193 (23.0)	.43	492 (20.7)	89 (20.6)	.95
COPD	969 (7.2)	89 (7.0)	.84	836 (7.5)	58 (6.9)	.55	133 (5.6)	31 (7.2)	.20
CRF	126 (0.9)	14 (1.1)	.55	100 (0.9)	7 (0.8)	.86	26 (1.1)	7 (1.6)	.35
COVID-19	0 (0.0)	17 (1.3)	NA	0 (0.0)	5 (0.6)	NA	0 (0.0)	12 (2.8)	NA
In-hospital death	117 (0.9)	9 (0.7)	.56	41 (0.4)	2 (0.2)	.77	76 (3.2)	7 (1.6)	.074

COPD, Chronic obstructive pulmonary disease; *CRF*, chronic respiratory failure; *NA*, not applicable.
The *P* value is for the χ^2 test or Fisher's exact test (for qualitative variables) or the median test (for age). Values are number (%) or median [interquartile range]. Boldface entries indicate statistical significance.
[a]For the following month: March-April and May 2017-2019.

Table III. Comparison of patient characteristics among transfemoral carotid artery stenting (TFCAS) groups between week 12 (mid-March) and week 19 (mid-May) 2020 as compared with March-April and May 2017-2019

	Total			Asymptomatic			Symptomatic		
	2017-2019[a]	2020 (Week 12-19)	*P* Value	2017-2019[a]	2020 (Week 12-19)	*P* Value	2017-2019[a]	2020 (Week 12-19)	*P* Value
No.	944	82		729	52		215	30	
Male sex	655 (69.4)	57 (69.5)	.98	504 (69.1)	34 (65.4)	.57	151 (70.2)	7 (23.3)	.47
Median age, years	71.0 [14.0]	69.5 [15.0]	.071	71.0 [14.0]	70.0 [16.0]	.31	70.0 [18.0]	65.5 [15.0]	.30
Hypertension	513 (54.3)	37 (45.1)	.11	383 (52.5)	24 (46.2)	.37	130 (60.5)	13 (43.3)	.075
Diabetes	204 (21.6)	15 (18.3)	.48	157 (21.5)	8 (15.4)	.29	47 (21.9)	7 (23.3)	.86
Obesity	185 (19.6)	14 (17.1)	.58	153 (21.0)	10 (19.2)	.76	32 (14.9)	4 (13.3)	1
Atrial fibrillation	99 (10.5)	4 (4.9)	.11	57 (7.8)	2 (3.9)	.42	42 (19.5)	2 (6.7)	.085
Chronic Renal Failure	62 (6.6)	6 (7.3)	.79	48 (6.6)	1 (1.9)	.24	14 (6.5)	5 (16.7)	.066
Coronary disease	262 (27.8)	15 (18.3)	.064	218 (29.9)	11 (21.2)	.18	44 (20.5)	4 (13.3)	.36
COPD	61 (6.5)	4 (4.9)	.57	52 (7.1)	3 (5.8)	1	9 (4.2)	1 (3.3)	1
CRF	17 (1.8)	1 (1.2)	1	14 (1.9)	0 (0.0)	.62	3 (1.4)	1 (3.3)	.41
COVID-19	0 (0.0)	1 (1.2)	NA	0 (0.0)	0 (0.0)	NA	0 (0.0)	1 (3.3)	NA
In-hospital death	24 (2.5)	4 (4.9)	.27	3 (0.4)	0 (0.0)	1	21 (9.8)	4 (13.3)	.52

COPD, Chronic obstructive pulmonary disease; *CRF*, chronic respiratory failure; *NA*, not applicable.
The *P* value is for the χ^2 test or Fisher's exact test (for qualitative variables) or the median test (for age). Values are number (%) or median [interquartile range].
[a]For the following month: March-April and May 2017-2019.

stenosis as quickly as possible. It is also important for vascular teams to closely follow patients with unoperated carotid stenosis who have been screened for CEA and TFCAS.

During a health crisis, there is a need to implement changes in the distribution of medical resources, and it is important to focus on the management of emergencies (such as symptomatic stenosis) and postpone elective

interventions (such as for asymptomatic stenosis). In the future, the experience provided by this first lockdown should allow us to quickly identify the interventions to be postponed and to organize the treatment and follow-up of unoperated asymptomatic patients.

Several limitations must be acknowledged. First, this was study was retrospective and observational in nature. The time between the scheduling of a carotid intervention and its completion is not available in the PMSI, nor is information on whether the procedure was postponed. The definition of symptomatic and asymptomatic groups is debatable, because they were obtained in a national database, combining stroke with TIA and CEA with TFCAS in the same hospitalization. However, a sensitivity analysis where symptomatic stenosis was defined as the presence of an IS or TIA coded as the primary diagnosis on the first unit of the carotid intervention stay or coded in previous stays in 60 days before the carotid intervention stay led to similar results. Moreover, the identification of stroke and TIA in the PMSI by International Classification of Diseases-Tenth Revision codes was validated previously and this method has been used in published studies.[26-28] Second, the results concerning TFCAS must be interpreted with caution because of the low number performed annually in France. Our study includes data for the 4 months after lockdown, but some of the consequences of the lockdown might not occur until later. The decrease in interventions highlights the importance of continuing regular monitoring of patients. Third, this methodology does not fully differentiate between preoperative stroke or TIA and perioperative or postoperative outcomes because the specific dates are not recorded for the occurrence of the condition or interventions during the stay.

The present study has several strengths. Although the collection of administrative data may be hindered by a delay in data collection, we have follow-up data collected through December 2020, reinforcing the reliability of the data collected in the 4 months after lockdown. All French primary and comprehensive public and private hospital data were included, and our data were thus nationally representative. In addition, although it has been well-documented in other countries that carotid stenosis procedures tended to decrease in the years preceding the COVID-19 pandemic,[29-31] our data from the pandemic period in 2020 are compared with the mean from the previous three years (2017-2019), also limiting the possible risk of a seasonal effect.

CONCLUSIONS

In this nationwide study, we report a 58% decrease in carotid revascularization procedures during the first lockdown in France, which was mostly owing to a decrease in procedures in asymptomatic patients. For symptomatic carotid stenosis interventions, we observed a rebound exceeding the volume in prior years. These data are of major interest for the scientific community, because they can help to anticipate future challenges and needs in cardiovascular care, particularly in patients requiring carotid revascularization.

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AUTHOR CONTRIBUTIONS

Conception and design: VC, YB, MG, ES, CQ
Analysis and interpretation: ASM, AB, CB, CQ
Data collection: EB, ASM, CQ
Writing the article: VC, ASM
Critical revision of the article: VC, EB, ASM, AB, CB, YB, MG, ES, CQ
Final approval of the article: VC, EB, ASM, AB, CB, YB, MG, ES, CQ
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Overall responsibility: CQ

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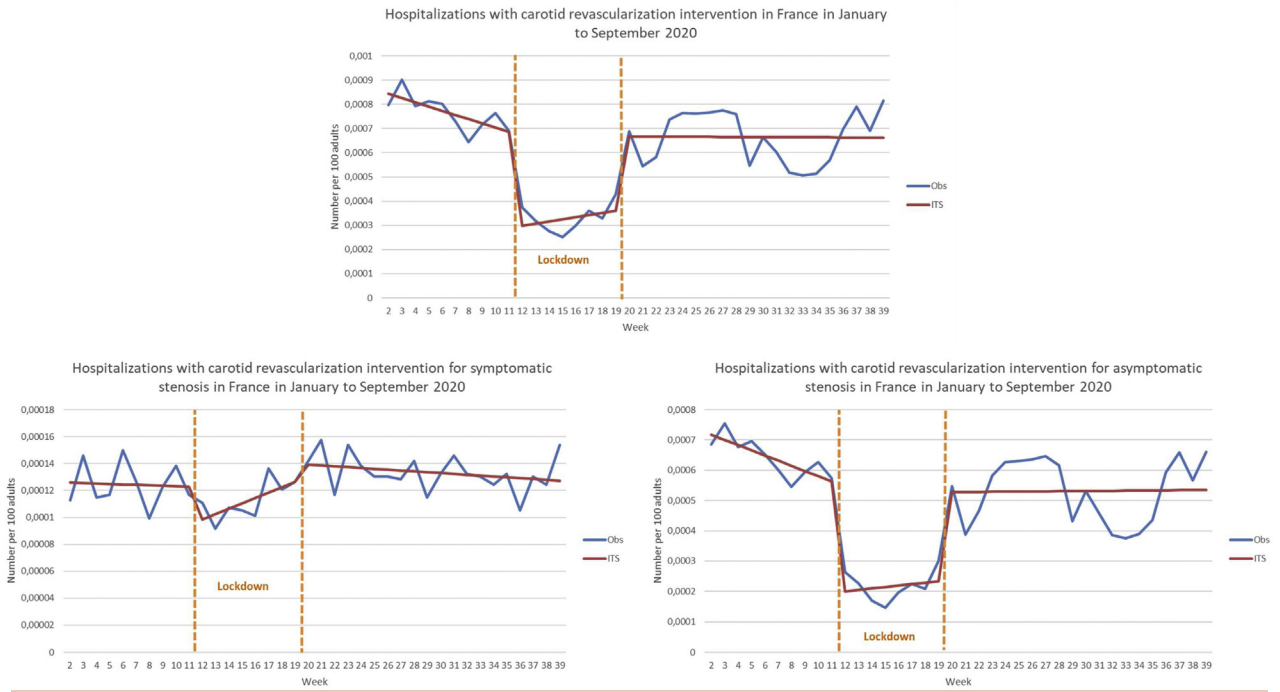
Supplementary Table I (online only). Monthly hospitalizations for carotid endarterectomy (*CEA*) and transfemoral carotid artery stenting (*TFCAS*) in France from January to September 2017 to 2019 (mean) and 2020

	All (a)		Symptomatic stenosis (b)		Asymptomatic stenosis (c)	
Period	2017-2019	2020	2017-2019	2020	2017-2019	2020
All carotid procedures (CEA and TFCAS)						
January	1590	1776	268	266	1321	1510
February	1510	1504	270	268	1240	1236
March	1738	1238	296	259	1441	979
April	1588	660	286	249	1301	411
May	1505	1212	279	306	1225	906
June	1727	1734	289	310	1437	1424
July	1592	1485	291	296	1301	1189
August	1068	1215	242	297	826	918
September	1594	1722	260	289	1334	1433
Total	13,912	12,546	2481	2540	11,426	10,006
CEA						
January	1484	1654	247	239	1237	1415
February	1415	1392	245	243	1169	1149
March	1626	1168	270	242	1356	926
April	1487	610	262	229	1225	381
May	1403	1150	259	287	1144	863
June	1609	1605	260	281	1348	1324
July	1487	1392	267	271	1220	1121
August	1008	1108	224	274	783	834
September	1488	1609	239	262	1248	1347
Total	13,007	11,688	2273	2328	10,730	9360
TFCAS						
January	105	122	21	27	84	95
February	95	112	24	25	70	87
March	112	70	26	17	85	53
April	101	50	24	20	76	30
May	101	62	20	19	81	43
June	118	129	29	29	89	100
July	105	93	24	25	81	68
August	60	107	18	23	42	84
September	106	113	21	27	85	86
Total	903	858	207	212	693	646

Values are means.

Supplementary Table II (online only). French nationwide monthly hospitalization numbers for ischemic stroke (IS) or transient ischemic attack (TIA) from January to September 2017 to 2019 compared with 2020

	Before lockdown		Lockdown		After lockdown					Total
Period	January	February	March	April	May	June	July	August	September	
2017	14,352	13,426	15,561	13,206	14,275	14,245	13,188	13,440	13,360	125,053
2018	14,659	13,321	15,279	14,036	14,168	14,004	13,827	13,099	12,951	125,344
2019	14,876	13,343	14,773	14,013	14,403	13,455	13,655	12,780	13,423	124,721
2017-2019, mean	14,629	13,363	15,204	13,751	14,282	13,901	13,556	13,106	13,244	125,036
2020	14,451	13,580	11,937	11,512	13,173	13,833	13,480	12,797	13,294	118,057



Supplementary Fig (online only). Observed (*Obs*) and predicted (*ITS*) hospitalizations for carotid revascularization intervention for weeks 2 to 39 of 2020 in France, interrupted time series (ITS) analysis with three periods (before, during, after the first lockdown).