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The impact of the healthcare system transformations spurred by the COVID-19 pandemic on stroke and STEMI management: cohorts of patients included in a French regional Cardio-neuro-vascular registry

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ABSTRACT

Objective: To assess the impact of changes in use of care and implementation of hospital reorganizations, spurred by the COVID-19 pandemic (first wave) on acute management times of strokes and ST-segment elevation myocardial infarctions (STEMI).

Design: two cohorts of STEMI and stroke patients included in the Aquitaine Cardio-Neuro-vascular (CNV) registry.

Setting: Six emergency medical services, 30 emergency units, 14 hospitalization units and 11 cathlabs of the Aquitaine region.

Participants: 9,218 patients (6,436 stroke and 2,782 STEMI patients) included in the CNV registry between January 2019 and August 2020.

Method: Hospital reorganizations, retrieved through a scoping review, were collected from heads of hospital departments. Other data were from the CNV registry. The associations between reorganizations, use of care, and care management times were analyzed through multivariate linear regression mixed models. Interaction terms between use of care variables and period (pre, per, post-wave) were introduced.

Main outcome measures: STEMI cohort: first medical contact-to-procedure time; stroke cohort: emergency unit admission-to-imaging time.

Results: Per-wave period management times deteriorated for stroke but maintained for STEMI. Per-wave changes in use of care did not have any impact on STEMI management. No association was found between reorganizations and stroke management times. In the STEMI cohort, the implementation of a systematic testing at admission was associated with an increase of 41% in care management times (exp=1.409, 95%CI [1.075-1.848], p=0.013); the implementation of the global "plan blanc", concentrating resources in emergency activities, was associated with a decrease of 19% in management times (exp=0.801, 95%CI [0.639-1.023], p=0.077).

Conclusions: The pandemic induced no deep altering of emergency pathway structuration. In contrast with stroke patient management that deteriorated, the resilience of the STEMI pathway is interpreted as linked with its stronger structuration. Transversal reorganizations aiming at concentrate resources on emergency care contributed to maintaining quality of care.

STRENGTHS AND LIMITATIONS OF THIS STUDY

- The study was based on two large high quality data cohorts including nearly 10,000 stroke and STEMI patients, managed in a large panel of care structures spread throughout the Aquitaine region, over a period of several months before and after the first wave allowing high historical depth of the data.
- We conducted an original, systematic and exhaustive collection of reorganizations implemented by the involved care structures to cope with the COVID-19 pandemic in the management of stroke and STEMI patients.
- The explanatory analyses present robust results due to the large panel of data collected in the two cohorts (clinical characteristics, socio-geographical factors, acute care management pathway data) that allowed the integration of all the confusion factors identified with the DAG (directed acyclic graph) method.
- The exclusion of patients who did not enter into the health care system prevented us to quantify avoidance of the health care system that is supposed to have been more frequent during the COVID-19 crisis.
- The data collection restricted to the Aquitaine region, less affected by the pandemic during the first wave, questions the geographical generalizability of results regarding the impact of reorganizations focused on emergency units, which were more sensitive to patient influx.

INTRODUCTION

Around the world, governments were responding the COVID-19 pandemic with unprecedented policies affecting societies functioning and healthcare systems, designed to slow the growth rate of the infection.(1–3) France was one of the most affected countries in the early months of the pandemic.(4) From March to May 2020, French authorities implemented a nationwide lockdown and a series of policies to curb the surge of patients requiring critical care. The French health care system was at that time almost entirely devoted to fight against SARS-CoV2.

It is expected that these profound changes have had a negative impact on the delivery of medical and surgical services. Use of care have already been shown to have been modified;(5) all the countries having implemented a policy to prevent the spread of the virus have noticed a huge decrease in the flow of patients entering emergency rooms for reasons other than COVID-19, revealing a tendency to delay or even forego care.(6–9)

Concerns rose about the quality of management of acute conditions other than COVID-19 disease, particularly those of stroke and ST-segment elevation myocardial infarction (STEMI), the both most highly time-sensitive frequent conditions.(10,11) For these two diseases, management pathways have been clearly established for decades, based initially on the patient's use of the emergency medical service (EMS) system in the event of an extreme emergency, followed by relays between emergency structures and specialized technical platforms (cathlabs, stroke units). These care pathways depend on a close collaboration between various professionals both in pre and intra-hospital areas. These pre-defined pathways may have been undermined by the organizational and societal upheavals associated with the COVID-19 pandemic. Indeed, international literature agree that the COVID-19 pandemic has led to a substantial decrease in the rate of stroke and STEMI admissions, reductions in the number of procedures, and longer delays between the onset of the symptoms and hospital treatment; these latest appearing driven predominantly by delays in use of care and transfers.(12)

However, works showed discrepant results on the impact of the COVID-19 pandemic on the intra hospital quality of care of these two diseases.(13–16) We hypothesized that these conflicting results may be due to the organizational environment of each hospital and particularly to the timing and the type of organizations implemented to cope with the COVID-pandemic control. Beyond the application of national directives, each hospital had total autonomy to prioritize its reorganizations, according to local capacities. To date, no study has quantified the effect of the COVID-19 work pattern on the delivery of stroke and STEMI.

Since 2012, the Aquitaine region (South Western France, 3 million inhabitants) has implemented a regional registry of cardio-neuro-vascular pathologies called "CNV Registry" allowing to analyzing the care pathway of STEMI and stroke patients managed in the Aquitaine hospitals, providing a unique opportunity to study the differences in care management in the region and their evolution over time.(17) Our main objective was to assess the impact of changes in use of care and health reorganizations implementation, spurred by the first wave of the COVID-19 pandemic on care management times of STEMI and stroke patients hospitalized in the Aquitaine region. We also sought to analyze use of care as well as the quality of care provided to these patients during the COVID-19 pandemic.

METHODS

Study design and population

This study was based on two exhaustive retrospective cohorts of stroke and STEMI patients. We performed an ad hoc collection of the reorganizations implemented by health care structures in the Aquitaine region during the first wave of the COVID-19 pandemic.

The two cohorts were constituted of all adult patients, living in metropolitan France, with recent stroke or STEMI, admitted to a care structure involved in the CNV registry between January 1st 2019 and August 31 2020.(17) The STEMI cohort included recent STEMI patients less than 24h from symptoms onset. The stroke cohort included recent ischemic or haemorrhagic stroke patients diagnosed by brain imaging with validation by a neurovascular physician. The CNV registry has been approved by the French authority on data protection and met regulatory requirements for patient information (file 2216283).

Data collection

Stroke and STEMI cohorts

Data is collected from each care structure managing patients throughout his pathway:

1) in EMS, data previously entered in electronic care records (ECR) are extracted from the hospital information system (HIS),

2) in emergency units (EU), data are entered prospectively by physicians in a dedicated paper or ECR then extracted from the HIS or collected retrospectively by clinical research assistants (CRA),

3) in cathlabs or in stroke hospitalization units, data are entered prospectively by physicians in ECR then extracted from the HIS.

Data of the two cohorts are consolidated by CRA and incorporated, after a first homogenisation process, into one data warehouse allowing the reconstructing of the whole patient STEMI or stroke management pathway.

The CNV registry collects information on:

1) patient socio-demographic characteristics: age, gender, place of residence,

2) patient clinical characteristics: medical history, cardio-vascular risk factors, stroke clinical severity (modified Rankin Scale –mRS- and National Institute of Health Stroke Score –NIHSS) and stroke type (ischaemic/haemorrhagic),

3) use of care (table 1): call to Emergency Dispatch Organization (EDO), first medical contact (FMC), symptoms-to-care time,

4) acute care management quality (table 1): times between key management steps (stroke: EU admission-to-imaging time; STEMI: FMC-to-procedure time), pre hospital and hospital pathway type, mode of transport to EU, orientation to specialized technical platforms (stroke unit or cathlab), treatment (stroke: first imaging type, intravenous thrombolysis (IVT) in ischemic stroke, mechanical thrombectomy in ischemic stroke; STEMI: fibrinolysis, percutaneous coronary intervention - PCI, coronary angiography alone),

5) structural characteristics of care: care during on-call activity, EDO activity during care, administrative status of the taking care hospital, FMC-to-cathlab distance, and specifically for the stroke cohort, availability of Magnetic Resonance Imaging (MRI) 24 hours a day, presence of stroke unit, presence of interventional neuroradiology unit.

Place of residence allowed the determination of three geographical indexes: urbanicity, deprivation index (Fdep15), potential accessibility indicator to general practitioners (APL MG 2018) (table 1), and distances between residence and care structures.(18–20)

Table 1. Definition of use of care variables, acute care management quality variables and geographical indexes

Variables	Definition
Use of care	
Call to EDO	Patient call to EDO after the onset of symptoms
FMC	First medical team to take care of the patient: - in the stroke cohort, two categories of FMC: 1) ALS in case of call to, 2) EU in case of no call to EDO; - in the STEMI cohort, three categories of FMC: 1) ALS, 2) EU with cathlab, 3) EU without cathlab.
Symptoms-to-care time	Delay in minutes between symptoms onset and start of management by the healthcare system, either call to EDO or EU admission in case of no call to EDO
Acute care management quality	
EU admission-to-imaging time	Delay in minutes between EU admission and start of the first imaging (MRI or CT scan)
FMC-to-procedure time	Delay in minutes between FMC and the start of the treatment procedure (coronary angiography or PCI)
IVT in ischemic stroke	Two variables: 1) IVT in all ischemic stroke patients, 2) IVT in "IVT alert" patients *ie.* patients with symptoms-to-EU admission time less than 4 hours.
Geographical indexes	
Urbanicity	Urban defined as commune or group of communes with a continuous built-up area with at least 2,000 inhabitants
FDep15	Validated social level index calculated from four variables attributed to each commune: median household income, proportion of baccalaureate, proportion of workers in the active population and unemployment rate
APL MG 2018	Index calculated from the supply of general practitioners, the demand for care and the distance between the place of residence and the supply of care

ALS= advanced life support; APL MG 2018=potential accessibility indicator to general practitioners, CT=computerized tomography scan; EDO=emergency dispatch offices; EU=emergency unit; FDep15=deprivation index; FMC=first medical contact; IVT=intravenous thrombolysis; MRI=magnetic resonance imaging; PCI=Percutaneous Coronary Intervention; STEMI=segment elevation myocardial infarction.
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Reorganizations implemented in the health care structures

A scoping review was conducted in compliance with the PRISMA recommendations (21) to retrieve the structural reorganizations implemented in care structures to deal with the first wave of the COVID-19 pandemic in the acute management of stroke and STEMI (supplementary material 1).(22) The retrieved reorganizations were classified according to care structure concerned: in EMS ("increase in the telephone reception capacities", "restriction of helicopter transport for COVID patients"), in EU ("systematic COVID testing", "separate COVID/no-COVID patients pathway", "decrease in no-COVID patients management and admission capacities", "Plan blanc" - global emergency plan to face a sudden increase of activity), in stroke or STEMI hospitalization units ("coronary angiography room dedicated to COVID patients in cathlabs", "deprogramming of non-urgent procedures or hospitalizations", "decrease in bed capacity for no-COVID patients", "specific access to imaging for COVID patients"). The retrieved reorganizations were compiled in a questionnaire addressed to the care structure heads who were asked to indicate, for each reorganization identified, whether it had been implemented and, if so, its dates of implementation and of termination.

Care management times

The primary endpoints were: for the STEMI cohort, FMC-to-procedure time and for the stroke cohort, EU admission-to-imaging time.

Statistical analyses

Analyses were performed separately for each cohort. Three periods were defined according to the dates of implementation and termination of national policies against COVID-19 pandemic spread: pre-wave (from January 1, 2019 to February 9, 2020), per-wave (from February 10 to May 10, 2020), and post-wave (from May 11 to August 31, 2020).

Use of care and acute care management quality variables were compared between the three periods (Khi2 test or Fisher exact test for qualitative variables, Kruskal-Wallis test for quantitative variables – p corrected by False Discovery Rate - FDR- to take into account the multiplicity of tests).

The associations between reorganizations (STEMI: 9 variables; stroke: 5 variables), use of care (STEMI: 2 variables; stroke: 2 variables), and care management times (introduced as continuous variables after logarithmic transformation) were analyzed through a multivariate linear regression mixed model (two random effects on hospital and health territory). Interaction terms between the use of care variables and the period (pre, per, post-wave) were introduced. The confounding variables were identified through a directed acyclic graph (DAG) (supplementary material 2).

The relationships between reorganizations or use of care and care management times were quantified (β) by the contrast method (statistical significance reached if P-value less than 0.05) then the exponentials of the betas (exp (β)), their 95% confidence intervals and percentage change (1 - exp (β)) were calculated.

For the stroke cohort, a sensitivity analysis was carried out by adding the variable symptoms-to-care time in the model. This variable was not introduced in principal analysis because it presented more than 20% missing data. Statistical analysis were conducted using SAS 9.4.

Patient and Public Involvement statement

As members of the CNV registry scientific boards, association of patient representatives were involved in the conception of the study, implementation and dissemination; they validated data collection and analysis, results diffusion. Dissemination of results involved information delivered on the CNV registry website, to the scientific boards and to care structure physicians.

This study is reported in accordance with the STROBE guideline and is registered with ClinicalTrials.gov NCT04979208.

RESULTS

Description of the study sample (supplementary material 3)

Study sample included 9,218 patients in a stable monthly rhythm along the study period. A total of 6,436 stroke patients (5,669-88.1% with ischemic stroke and 767 with haemorrhagic stroke) were managed in 5 EMS, 14 EU, and 14 hospitalization units (7 stroke units); 2,782 STEMI patients were managed in 6 EMS, 30 EU, and 11 cathlabs. The analysis of the demographic characteristics of the study sample highlights lower median age in the stroke cohort during the per and post-wave periods (77 and 76 years vs. 79 years). The only notable clinical feature to point out in both cohorts was lower frequency of severe strokes in the per and post-waves (respectively, 56.2% and 57.3% of stroke patients with NIHSS<7) than in the pre-wave period (52.8% of stroke patients with NIHSS<7).

Reorganizations implemented in care structures (figure 1)

First reorganizations have been implemented from early February 2020, then spread in a few weeks; in the midst of the per-wave period, 83% of EMS, 90% of EU, 93% of stroke hospitalization units, and 64% of cathlabs had implemented at least one reorganization. The two most frequently implemented reorganizations were “increase in the telephone reception capacities” (implemented in all EMS) and “separate COVID/no-COVID patient’s pathway in EU” (implemented by 93% of EU - n=13 for stroke cohort, n=28 for STEMI cohort). Half of the EU have implemented the “Plan blanc”. Most frequent reorganizations implemented during the per-wave period were maintained in the post-wave period.

Comparison of use of care and acute care management quality between the pre, per, and post-wave periods (tables 2, 3)

Use of care

In both cohorts, no statistically difference in use of care was observed between periods. Only trends could be observed to: a higher proportion of calls to EDO during the per-wave period compared to the pre and post-wave periods (stroke cohort: 65.5% vs 61.5% and 64.1%, STEMI cohort: 81.8% vs 77.4% and 78.1%), longer median times from symptoms onset to call to EDO during the per-wave period compared to the pre and post-wave periods (stroke cohort: 139 minutes vs. 121 minutes and 125 minutes, STEMI cohort: 84 minutes vs. 76 minutes and 75 minutes), and specifically in the STEMI cohort, a higher proportion of patients with ALS (Advanced Life Support) transport during the per-wave period compared to the pre and post-wave periods (60.7% vs. 57.2% and 55.4%).

Table 2. Comparison of use of care and acute care management quality characteristics between the pre, per, post-wave periods - Stroke cohort (N=6,436)

	Global (N=6,436)		Pre-wave (N=4,140)		Per-wave (N=1,080)		Post-wave (N=1,216)		p-value corrected (FDR)	
	n	(%)	n	(%)	n	(%)	n	(%)		
Use of care										
Call to EDO	6,430		4,135		1,079		1,216		0.083	*
No	2,399	(37.3)	1,590	(38.5)	372	(34.5)	437	(35.9)		
Yes	4,031	(62.7)	2,545	(61.5)	707	(65.5)	779	(64.1)		
Missing values	*6*		*5*		*1*		*0*			
FMC	6,436		4,140		1,080		1,216		0.332	*
EU	6,278	(97.5)	4,040	(97.6)	1,059	(98.1)	1,179	(9.0)		
ALS	158	(2.5)	100	(2.4)	21	(1.9)	37	(3.0)		
Symptoms-to-care time (min)	3,157		1,991		556		610		0.232	**
Median [IQR]	126	[38;401]	121	[38;384]	139	[46;488]	125	[38;392]		
Missing values	*3,279*		*2,149*		*524*		*606*			
Acute care management quality										
EU admission-to-imaging time (min)	4,819		3,014		889		916		0.332	**
Median [IQR]	86	[47;194]	83	[45;201]	91	[51;175]	88	[52;191]		
Missing values	*1,617*		*1,126*		*191*		*300*			
Pre-hospital pathway type	6,430		4,135		1,079		1,216		0.040	*
Optimal pathway: call to EDO/ALS transport/EU	3,719	(57.8)	2,368	(57.3)	642	(59.5)	709	(58.3)		
Call to EDO/non-ALS transport/EU	312	(4.9)	177	(4.3)	65	(6.0)	70	(5.8)		
EU direct entry	2,399	(37.3)	1,590	(38.5)	372	(34.5)	437	(35.9)		
Missing values	*6*		*5*		*1*		*0*			
Mode of transport to the EU	6,436		4,140		1,080		1,216		0.812	*
Personal transport	732	(11.4)	475	(11.5)	117	(10.8)	140	(11.5)		
Non-ALS transport	4,495	(69.8)	2,902	(70.1)	758	(70.2)	835	(68.7)		
ALS transport	222	(3.4)	149	(3.6)	34	(3.1)	39	(3.2)		
Unknown	987	(15.3)	614	(14.8)	171	(15.8)	202	(16.6)		
Transfer to a stroke unit	6,436		4,140		1,080		1,216		0.923	*
No	752	(11.7)	484	(11.7)	123	(11.4)	145	(11.9)		
Yes	5,684	(88.3)	3,656	(88.3)	957	(88.6)	1,071	(88.1)		
First imaging type	6,041		3,870		1,019		1,152		0.332	***
MRI	3,782	(62.6)	2,395	(61.9)	650	(63.8)	737	(64.0)		
CT scan	2,245	(37.2)	1,463	(37.8)	369	(36.2)	413	(35.9)		
None	14	(0.2)	12	(0.3)	0	(0.0)	2	(0.2)		
Missing values	*395*		*270*		*61*		*64*			
IVT (all ischemic strokes)	5,660		3,616		938		1,106		0.011	*
No	4,635	(81.9)	2,913	(80.6)	801	(85.4)	921	(83.3)		
Yes	1,025	(18.1)	703	(19.4)	137	(14.6)	185	(16.7)		
Missing values	*9*		*1*		*3*		*5*			
Exclusion	*767*		*523*		*139*		*105*			
IVT in 'Thrombolysis alert' patients (ischemic stroke)	1,758		1,100		310		348		0.011	*
No	1,060	(60.3)	634	(57.6)	213	(68.7)	213	(61.2)		
Yes	698	(39.7)	466	(42.4)	97	(31.3)	135	(38.8)		
Missing values	*2*		*1*		*0*		*1*			
Exclusion	*4,676*		*3,039*		*770*		*867*			
Mechanical thrombectomy (all ischemic stroke)	5,620		3,585		938		1,097		0.332	*
No	4,998	(88.9)	3,170	(88.4)	842	(89.8)	986	(89.9)		
Yes	622	(11.1)	415	(11.6)	96	(10.2)	111	(10.1)		
Missing values	*49*		*32*		*3*		*14*			
Exclusion	*767*		*523*		*139*		*105*			

Test realized=Khi2 test (*), Kruskal-Wallis test (**), Fisher exact test (***); ALS= advanced life support; CT scan=computerized tomography scan; EDO=emergency dispatch offices; EU=emergency unit; FDR=correction of p-value by False Discovery Rate method; FMC=first medical contact; IVT=intravenous thrombolysis; MRI=magnetic resonance imaging.

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Table 3. Comparison of use of care and acute care management quality characteristics between the pre, per, post-wave periods - STEMI cohort (N=2,782)

	Global (N=2,782)		Pre-wave (N=1,868)		Per-wave (N=407)		Post-wave (N=507)		p-value corrected (FDR)	
	n	(%)	n	(%)	n	(%)	n	(%)		
Use of care										
Call to EDO	2,782		1,868		407		507		0.704	*
No	607	(21.8)	422	(22.6)	74	(18.2)	111	(21.9)		
Yes	2,175	(78.2)	1,446	(77.4)	333	(81.8)	396	(78.1)		
FMC	2,782		1,868		407		507		0.704	*
ALS	1,597	(57.4)	1,069	(57.2)	247	(60.7)	281	(55.4)		
EU with cathlab	458	(16.5)	321	(17.2)	51	(12.5)	86	(17.0)		
EU without cathlab	727	(26.1)	478	(25.6)	109	(26.8)	140	(27.6)		
Symptoms-to-care time (min)	2,360		1,581		349		430		0.799	**
Median [IQR]	77	[30;206]	76	[30;212]	84	[31;202]	75	[30;178]		
Missing values	*422*		*287*		*58*		*77*			
Acute care management quality										
FMC-to-procedure time (min)	2,364		1,577		353		434		0.799	**
Median [IQR]	99	[71;157]	100	[71;158]	95	[69;152]	102	[71;153]		
Missing values	*418*		*291*		*54*		*73*			
Pathway type	2,742		1,841		400		501		0.799	*
Optimal pathway: call to EDO/ALS transport/direct referral to cathlab	1,557	(56.8)	1,042	(56.6)	240	(60.0)	275	(54.9)		
Call to EDO/EU/direct referral to cathlab	550	(20.1)	356	(19.3)	82	(20.5)	112	(22.4)		
No call to EDO/EU/direct referral to cathlab	591	(21.6)	412	(22.4)	72	(18.0)	107	(21.4)		
Call to EDO/EU/no direct referral to cathlab	28	(1.0)	20	(1.1)	4	(1.0)	4	(0.8)		
No call to EDO/EU/no direct referral to cathlab	16	(0.6)	11	(0.6)	2	(0.5)	3	(0.6)		
Missing values	*40*		*27*		*7*		*6*			
Mode of transport to the first hospital	2,782		1,868		407		507		0.722	*
Personal transport	444	(16.0)	311	(16.6)	55	(13.5)	78	(15.4)		
Non-ALS transport	558	(20.1)	372	(19.9)	77	(18.9)	109	(21.5)		
ALS transport (road)	1,523	(54.7)	1,010	(54.1)	243	(59.7)	270	(53.3)		
ALS transport (helicopter)	123	(4.4)	84	(4.5)	11	(2.7)	28	(5.5)		
Unknown	134	(4.8)	91	(4.9)	21	(5.2)	22	(4.3)		
Direct referral to cathlab	2,782		1,868		407		507		0.799	*
No	84	(3.0)	58	(3.1)	13	(3.2)	13	(2.6)		
Yes	2,698	(97.0)	1,810	(96.9)	394	(96.8)	494	(97.4)		
Fibrinolysis	2,560		1,724		366		470		0.799	*
No	2,428	(94.8)	1,633	(94.7)	345	(94.3)	450	(95.7)		
Yes	132	(5.2)	91	(5.3)	21	(5.7)	20	(4.3)		
Missing values	*222*		*144*		*41*		*37*			
PCI	2,364		1,577		353		434		0.799	*
No	330	(14.0)	211	(13.4)	50	(14.2)	69	(15.9)		
Yes	2,034	(86.0)	1,366	(86.6)	303	(85.8)	365	(84.1)		
Missing values	*418*		*291*		*54*		*73*			
Fibrinolysis or PCI	2,359		1,576		349		434		0.704	*
No	292	(12.4)	190	(12.1)	38	(10.9)	64	(14.7)		
Yes	2,067	(87.6)	1,386	(87.9)	311	(89.1)	370	(85.3)		
Missing values	*423*		*292*		*58*		*73*			

Test realized=Khi2 test (*), Kruskal-Wallis test (**), Fisher exact test (***); ALS= advanced life support; EDO=emergency dispatch offices; EU=emergency unit; FDR=correction of p-value by False Discovery Rate method; FMC=first medical contact; PCI=Percutaneous Coronary Intervention.
Created by the authors

Care management quality

Stroke cohort

Median EU admission-to-imaging time tended to increase along the three periods, from 83 minutes to 91 minutes and to 88 minutes (p=0.332). Proportion of IVT decreased during the per-wave compared to the pre and post-wave periods (all ischemic strokes: 14.6% vs. 19.4% and 16.7%, p=0.011; IVT alert patients: 31.3% vs. 42.4% and 38.8%, p=0.011). The proportion of patients with an optimal pathway (call to EDO/ALS transport/EU) was higher during the per-wave period (59.5%) compared to the pre (57.3%) and post-wave periods (58.3%, p=0.040).

STEMI cohort

Two main trends were observed to: 1) decreasing median FMC-to-procedure time during the per-wave period (95 minutes) compared to the pre (100 minutes) and post-wave (102 minutes) periods and 2) higher proportion of patients managed through the optimal pathway (call to EDO/ALS transport/direct referral to cathlab) during the per-wave period (60.0%) compared to the pre (56.6%) and post-wave periods (54.9%, p=0.799).

Association between use of care, reorganizations, and care management times (figure 2, supplementary material 4)

Stroke cohort model (4,603 patients)

The final model showed no statistically significant association between reorganizations and EU admission-to-imaging time. FMC by ALS transport was associated with a global statistically significant decrease of 27% of the EU admission-to-imaging time (expβ=0.726, 95%CI [0.548-0.961], p=0.034), without any interaction with the COVID period (p=0.807). The association between call to EDO and EU admission-to-imaging time, not statistically significant (expβ=0.939, 95%CI [0.793-1.112], p=0.360) on the whole study period, differed according to the COVID period (significant interaction with the Covid period p=0.039): call to EDO was associated with an increase of 8% in admission-to-imaging time during the post-wave period, compared to the pre and per-wave periods. The sensitivity analysis conducted on 2,458 patients confirmed the absence of any association between reorganizations or use of care changes along the COVID period and care management times.

STEMI cohort model (1,843 patients)

COVID systematic testing was associated with an increase of 41% (expβ=1.409, 95%CI [1.075-1.848], p=0.013) of the FMC-to-procedure time. The implementation of the "plan blanc" was associated with a decrease of 19% (expβ=0.801, 95%CI [0.639-1.023], p=0.077) of the FMC-to-procedure time. Compared with FMC "EU without cathlab », FMC "ALS transport pathway" was globally associated with a decrease of 66% (expβ=0.344, 95%CI [0.266-0.445], p<0.001) of the FMC-to-procedure time and FMC "EU with cathlab" associated with a decrease of 20% (expβ=0.804, 95%CI [0.674-0.958], p<0.001) of this time. The interaction with the COVID period was not significant (p=0.492). Finally, each 10-minute delay of the symptoms-to-care time affects the FMC-to-procedure with an increase of 0.36% (expβ=1.004, 95%CI [1.002-1.005], p<0.001), with no effect of the COVID period (p=0.206).

DISCUSSION

Main Results

Our study adds a better understanding of the global impact of the societal changes and the health system transformation, spurred by the first wave of the COVID-19 health crisis, on use of care and acute management of stroke and STEMI patients.

Most hospitals of the Aquitaine region have adapted their organization from the beginning of the per-wave period to cope with the COVID-pandemic control and most of the implemented reorganizations were maintained several months after the end of the national lockdown. Globally, the stroke management times tended to deteriorate during the pandemic, but this deterioration did not seem to be directly related to the reorganizations implemented. In contrast, STEMI patients' quality of care was maintained during the first wave of the COVID-19 pandemic; the reorganization "plan blanc" consisting in concentrate resources in emergency activities contributed to this improvement. Systematic COVID-19 screening implementation at admission was associated with an increase in STEMI patient time management. In both STEMI and stroke cohorts, a tendency to more frequent calls to EDO and to longer times to health care system call was observed during the first wave of the pandemic compared with the per and post-wave period.

Results interpretation

The contrasting results in the management times evolution during the per crisis period, observed in cardio and neurovascular sectors, may find explanation in the different structuring and performance of these two networks in France. The STEMI network is indeed structured in a dedicated pathway, organized and implemented since decades in France. On the contrary, the stroke network is of younger implementation and is not fully structured in a dedicated way. Many works have highlighted the value of highly structured patient centred clinical pathway on quality of care of whether chronic or acute conditions with predictable trajectories.(23–27) Moreover, all the guidelines on stroke and STEMI patients management and national stroke and STEMI improvement programs recommend the implementation of structured pathways including close collaboration between health care professionals, patient orientation to specialized technical platforms (cathlabs, stroke units) and to the EMS system.(28,29)

Even if the resilience to the COVID-19 crisis was contrasted between these two pathways, our results are in favour of the absence of a deep and global altering of these emergency pathways structuration during the pandemic. Indeed, call to EDO by STEMI patients and orientation to optimal pathway using ALS was associated with a decrease of stroke and STEMI management times. This fundamental root of the management organization of these two highly time-sensitive pathologies was not disrupted during the crisis.

The "plan blanc", implemented in the whole acute pathway to create an organizational environment favorable to the quality of care of COVID patients, helped to improve the one of STEMI patients by decreasing management times. In the stroke cohort, this organization tended to decrease management times without reaching statistical significance. These different results may be explained by different primary endpoints in the two cohorts; in the STEMI cohort, the FMC-to-procedure time that took into account the coordination of care between the multiple actors involved in pre-hospital and in-hospital care was spread enough to allow an effect showing; in the stroke cohort, the EU admission-to-imaging time, that focused on the short stage of the very beginning of intra-hospital care, involving too few different actors to reveal any effect. In a concordant way, most organizations implemented more specifically in EU or in hospitalization units have had little effect on STEMI and stroke care management times.

Only the reorganization "systematic COVID-19 testing in EU" increased STEMI management times. This deleterious effect was marked in patients arriving late after symptom onset. In these patients, whose symptoms were often less typical and may include respiratory signs suggestive of COVID, management could have been delayed up to the screening results delivery. STEMI patients arriving at a very early stage were managed as conditions requiring extreme emergency management before screening. This organization was not integrated in the stroke cohort model but similar results to those of the STEMI cohort were found in the only hospital of the stroke cohort having implemented it.

Comparison with the literature

Our results showing tendency to an increase in the times taken by stroke and STEMI patients to contact the health care system during the COVID pandemic are consistent with the literature, both internationally and in France.(6,13,30) Elsewhere, by calling the EDO more frequently, patients followed the national recommendations, which were widely publicised in the French media at the time of the health crisis. The literature presents mixed results on the impact of the COVID-19 pandemic on the quality of stroke and STEMI management.(13–16) Our data help to validate the hypothesis that these discordant results could be explained by the various policies implemented and to the heterogeneity of the hospital organizations. To our knowledge, no study has analyzed at regional level the impact of reorganizations implemented by hospitals to deal with the health care crisis in the management of stroke and STEMI patients. Only a few studies can be retrieved consisting in feedbacks on reorganizations implemented at a local level.(11,31,32)

Strength and weaknesses

Our study is based on the analysis of two high quality databases including a large number of stroke and STEMI patients managed in a large panel of care structures in the Aquitaine region. The broad geographical scope of patient inclusion, ensuring a wide range of clinical and management characteristics and the historical depth of the data constitutes a major strength of the study.

We conducted an original systematic and exhaustive collection of the reorganizations implemented by hospitals to cope with the COVID-19 pandemic in the management of stroke and STEMI patients. This survey was conducted at the beginning of 2021 and asked professionals about organizations set up between March and August 2020. Through a series of reminders, we obtained all the questionnaires completed in full. However, we cannot exclude errors in the answers given, particularly concerning the dates on which organizations were implemented or terminated, due to memory bias. For reasons of feasibility, it was not possible to interview several different people for the same questionnaire and to cross-check the answers.

The explanatory analyses present robust results, based on models of good performance, including appropriate confusion variables identified by the DAG method. The large panel of data collected allowed the integration of a large variety of confusion factors, including clinical characteristics, socio-geographical factors, and acute care management pathway data. In the stroke cohort, the symptoms-to-FMC time containing a lot of missing data (20%), we have taken the decision to exclude this variable from the main model to favor the power of our analysis. The absence of a systematic mechanism identified to explain these missing data did not allow us to take them into account through multiple imputations. A sensitivity analysis carried out by including this variable as an explanatory variable did not change our main results and confirmed their robustness.

Our primary endpoints were the care management times which are major prognostic issues in the management of stroke and STEMI, and sensitive to intra-hospital organizational changes. They were used as continuous variables, to optimize the power of the study. Use of an end-point expressed as a proportion of patients managed within the recommended time frame would have been interesting as it would have had strong operational implications. For statistical reasons, it was not possible to do this (only 3.3% of patients with a first imaging within 20 minutes, recommended target time).

Our sample was representative of stroke and STEMI patients managed at hospital. However, patients who did not enter into the health care system, because either they have died before or they did not benefit from hospital care, were not included. These inclusion criteria prevented us to quantify this phenomenon of avoidance of the health care system that is supposed to have been more frequent during the COVID-19 crisis and may have generated selection bias.

The geographical data perimeter was limited to the Aquitaine region, which have been one of the regions least affected by the pandemic during the first wave.(6) We hypothesis that some reorganizations such as "decrease in no-COVID patients management and admission capacities in EU" that have had no impact on STEMI and stroke patient management times in our study, would have had negative effects on the management of no-COVID conditions in regions with saturated EU. Indeed, the impact of these EU focused reorganizations may be more sensitive to patient influx. Moreover, there is every reason to believe that the impact of global and structural reorganizations such as "Plan blanc" should be the same in any place, whatever the spread of the outbreak. As use of care have been shown not to vary according to the strength of the pandemic's spread, our results on this topic are thought not to be specific of our region.(33) All the same, it would be interesting to conduct the same study in another region of France or another country, more affected by the pandemic to test the external validity of our results.

Finally, the question of the generalizability of our results to other conditions than stroke and STEMI is posed. Stroke and STEMI constitutes two models of conditions managed in emergency within a defined pathway. We think our results may be extend to other similar conditions requiring urgent management in a coordinated pathway, such as respiratory distress or life-threatening bleeding.

Perspectives

This is the first of a three-step project on the impact of the COVID-19 pandemic on stroke and STEMI patient management. Two other questions are arising concerning: 1) the clinical and social health inequalities in stroke and STEMI patient management, induced or reinforced by the Covid-19 crisis. 2) the impact of the COVID-19 pandemic on the stroke and STEMI patient long term mortality and morbidity.

Conclusions

Our study results are in favour of the absence of a deep and global altering of emergency pathways structuration during the pandemic with however a deterioration of stroke patient management. The resilience of the STEMI pathway was interpreted as linked with its stronger structuration. Our results seem also to show that transversal reorganizations aiming at concentrate resources on the whole emergency care network, such as "plan blanc", contributed to maintaining quality of care of stroke and STEMI, the two most-frequent conditions requiring emergency management. These results can be extended to other time-sensitive conditions that require coordination of all EMS and benefit from a defined pathway.

- **Data sharing statement**

Deidentified participant data will be available upon reasonable request. Proposals may be submitted to the corresponding author. Data requestors will need to sign a data access agreement

- **Ethics statements**

Patient consent for publication

Not applicable.

According to French authority on data protection "Commission Nationale Informatique et Libertés", in the category of studies not involving humans based on secondary use of health data, the CNV registry met regulatory requirements for patient information and do not require a patient consent form.

Ethics approval

The CNV registry has been approved by the French authority on data protection (file 2216283).

- **Authors' contributions**

Conceiving, design and coordination of the study: FSG, EL, SD, FS
Literature search: FSG, EL, FF, MB, QL
Data collection: EL, FS, MB, QL
Data analysis: SD, SMH
Data interpretation: FSG, EL, SD, FS, FF, LC, PC, FR, IS, CP
Writing: FSG, EL, SD, FF, LC, PC, FR, IS, CP

- **Competing interests statement**

The authors declare that they have no competing interests with this study.

- **Funding statement**

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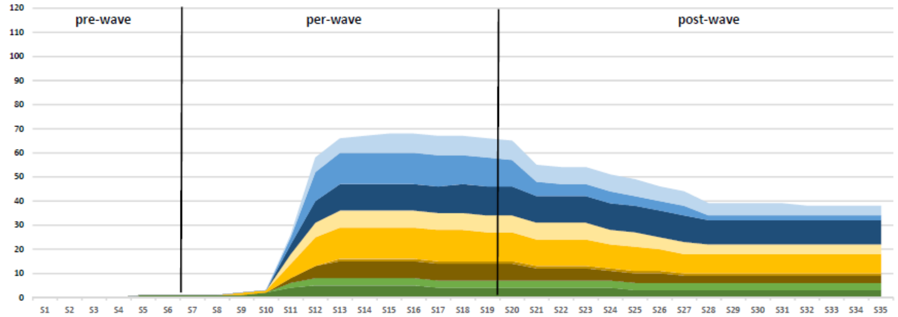
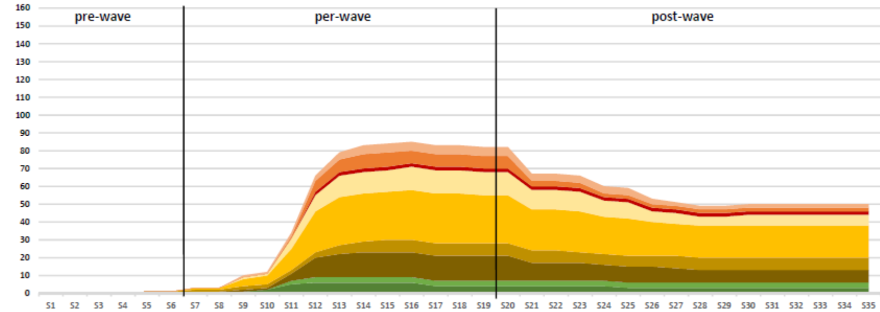
Stroke cohort



Reorganization categories*	pre-wave min	(%)	max	(%)	per-wave min	(%)	max	(%)	post-wave min	(%)	max	(%)
EMS (N=5)												
Increase in the telephone reception capacities	0	(0.0)	1	(20.0)	1	(20.0)	5	(100.0)	3	(60.0)	4	(80.0)
Restriction of helicopter transport for Covid patients	0	(0.0)	0	(0.0)	0	(0.0)	3	(60.0)	3	(60.0)	3	(60.0)
Emergency unit (N=14)												
"Plan blanc"	0	(0.0)	0	(0.0)	0	(0.0)	7	(50.0)	3	(21.4)	7	(50.0)
Systematic Covid testing	0	(0.0)	0	(0.0)	0	(0.0)	1	(7.1)	1	(7.1)	1	(7.1)
Separate Covid/no-Covid patients pathway	0	(0.0)	0	(0.0)	0	(0.0)	13	(92.9)	8	(57.1)	12	(85.7)
Decrease in no-Covid patients management and admission capacities	0	(0.0)	0	(0.0)	0	(0.0)	7	(50.0)	4	(28.6)	7	(50.0)
Hospitalisation unit (N=14)												
Specific access to imaging for Covid patients	0	(0.0)	0	(0.0)	0	(0.0)	12	(85.7)	10	(71.4)	12	(85.7)
Deprogramming of non-urgent procedures or hospitalizations	0	(0.0)	0	(0.0)	0	(0.0)	13	(92.9)	2	(14.3)	11	(78.6)
Decrease in bed capacity for no-Covid patients	0	(0.0)	0	(0.0)	0	(0.0)	8	(57.1)	4	(28.6)	8	(57.1)

* minimal and maximal number of structures having implemented each reorganisation among the three periods - (%) : percentage calculated on total number of structures concerned

STEMI cohort



Reorganization categories*	pre-wave min	(%)	max	(%)	per-wave min	(%)	max	(%)	post-wave min	(%)	max	(%)
EMS (N=6)												
Increase in the telephone reception capacities	0	(0.0)	1	(16.7)	1	(16.7)	6	(100.0)	3	(50.0)	4	(66.7)
Restriction of helicopter transport for Covid patients	0	(0.0)	0	(0.0)	0	(0.0)	3	(50.0)	3	(50.0)	3	(50.0)
Emergency unit (n=30)												
"Plan blanc"	0	(0.0)	0	(0.0)	0	(0.0)	14	(46.7)	7	(23.3)	14	(46.7)
Systematic Covid testing	0	(0.0)	0	(0.0)	1	(3.3)	7	(23.3)	6	(20.0)	7	(23.3)
Separate Covid/no-Covid patients pathway	0	(0.0)	0	(0.0)	1	(3.3)	28	(93.3)	18	(60.0)	27	(90.0)
Decrease in no-Covid patients management and admission capacities	0	(0.0)	0	(0.0)	0	(0.0)	13	(43.3)	5	(16.7)	13	(43.3)
Cathlabs (n=11)												
Coronary angiography room dedicated to Covid patients	0	(0.0)	0	(0.0)	0	(0.0)	2	(18.2)	2	(18.2)	2	(18.2)
Deprogramming of non-urgent procedures or hospitalizations	0	(0.0)	0	(0.0)	0	(0.0)	8	(72.7)	2	(18.2)	7	(63.6)
Decrease in bed capacity for no-Covid patients	0	(0.0)	0	(0.0)	0	(0.0)	5	(45.5)	2	(18.2)	5	(45.5)

* minimal and maximal number of structures having implemented each reorganisation among the three periods - (%) : percentage calculated on total number of structures concerned

Figure 1. Weekly cumulated number of care structures having implemented reorganizations, by reorganization category– Minimum and maximum number and proportion of care structures having implemented reorganization, by reorganization category and by period (pre, per, post-wave)

EMS=emergency medical service; EU=emergency unit

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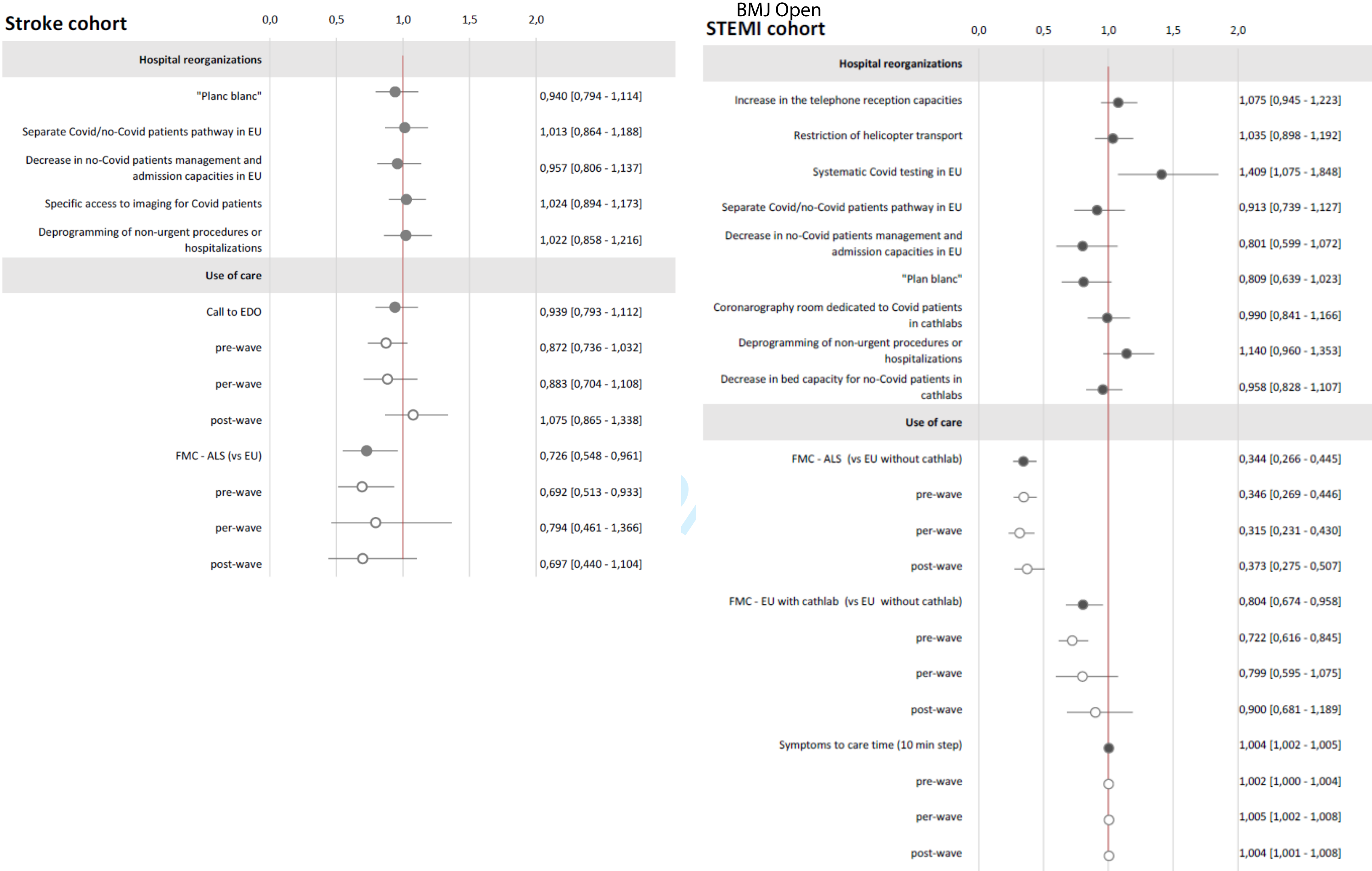
Stroke cohort
0,0
0,5
1,0
1,5
2,0
Hospital reorganizations
"Planc blanc" 0,940 [0,794 - 1,114]
Separate Covid/no-Covid patients pathway in EU 1,013 [0,864 - 1,188]
Decrease in no-Covid patients management and admission capacities in EU 0,957 [0,806 - 1,137]
Specific access to imaging for Covid patients 1,024 [0,894 - 1,173]
Deprogramming of non-urgent procedures or hospitalizations 1,022 [0,858 - 1,216]
Use of care
Call to EDO 0,939 [0,793 - 1,112]
pre-wave 0,872 [0,736 - 1,032]
per-wave 0,883 [0,704 - 1,108]
post-wave 1,075 [0,865 - 1,338]
FMC - ALS (vs EU) 0,726 [0,548 - 0,961]
pre-wave 0,692 [0,513 - 0,933]
per-wave 0,794 [0,461 - 1,366]
post-wave 0,697 [0,440 - 1,104]
STEMI cohort
0,0
0,5
1,0
1,5
2,0
Hospital reorganizations
Increase in the telephone reception capacities 1,075 [0,945 - 1,223]
Restriction of helicopter transport 1,035 [0,898 - 1,192]
Systematic Covid testing in EU 1,409 [1,075 - 1,848]
Separate Covid/no-Covid patients pathway in EU 0,913 [0,739 - 1,127]
Decrease in no-Covid patients management and admission capacities in EU 0,801 [0,599 - 1,072]
"Plan blanc" 0,809 [0,639 - 1,023]
Coronarography room dedicated to Covid patients in cathlabs 0,990 [0,841 - 1,166]
Deprogramming of non-urgent procedures or hospitalizations 1,140 [0,960 - 1,353]
Decrease in bed capacity for no-Covid patients in cathlabs 0,958 [0,828 - 1,107]
Use of care
FMC - ALS (vs EU without cathlab) 0,344 [0,266 - 0,445]
pre-wave 0,346 [0,269 - 0,446]
per-wave 0,315 [0,231 - 0,430]
post-wave 0,373 [0,275 - 0,507]
FMC - EU with cathlab (vs EU without cathlab) 0,804 [0,674 - 0,958]
pre-wave 0,722 [0,616 - 0,845]
per-wave 0,799 [0,595 - 1,075]
post-wave 0,900 [0,681 - 1,189]
Symptoms to care time (10 min step) 1,004 [1,002 - 1,005]
pre-wave 1,002 [1,000 - 1,004]
per-wave 1,005 [1,002 - 1,008]
post-wave 1,004 [1,001 - 1,008]

Figure 2. Stroke and STEMI cohorts. Estimation of the reorganizations and use of care effects (95% confidence interval) on care management times.

Stroke cohort (N=4 603) – Estimated overall effects expressed as exp(β) with 95% CI; results of multivariate linear regression mixed models; variable to be explained: Y = log (EU admission-to-imaging time); results adjusted on period, age, gender, urbanicity of residence, FDep15, APL MG 18, residence-EU distance, presence of stroke unit, MRI 24 hours a day, presence of interventional neuroradiology unit, care during on-call activity, mode of transport, EDO activity, mRS less than 1 before stroke, NIHSS at entry, previous stroke or transient ischemic attack.

STEMI cohort (N=1 843) – Estimated overall effects expressed as exp(β) with 95% CI; results of multivariate linear regression mixed models; variable to be explained: Y=log (FMC-to-procedure time); results adjusted on period, age, gender, urbanicity of residence, FDep15, APL MG 18, residence-to-cathlab distance, cathlab hospital status, care during on-call activity, mode of transport, EDO activity, FMC-to-cathlab distance, diabetes mellitus, coronary artery disease or STEMI history).

Light grey: interaction with the COVID period, Dark grey: raw results without interaction with the COVID period

ALS= advanced life support; APL MG 2018=potential accessibility to general practitioners; EDO=emergency dispatch offices; EU=emergency unit; FDep15=deprivation index; FMC=first medical contact; MRI=magnetic resonance imaging; mRS=modified Rankin Scale; NIHSS=National Institute of Health Stroke Score;.STEMI=segment elevation myocardial infarction.

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Supplementary material 1.

Method of the scoping review

The method of the scoping review was conducted to retrieve the structural reorganizations implemented in care structures to deal with the first wave of the COVID-19 pandemic in the acute management of stroke or STEMI.
Two categories of information sources were systematically explored:

- **Written English or French-language documents**

All written English or French-language documents published between January and December 2020 were retrieved without geographical limitation:

- scientific articles analysing the impact of the first wave of Covid-19 pandemic on stroke and STEMI management;
- government reports, professional stroke or STEMI guidelines providing guidance on the management of stroke and STEMI patients during the COVID-19 pandemic;
- published feedback on hospital management of stroke and STEMI patients during the first wave of the COVID-19 pandemic.

The following sources were consulted:

- computerized bibliographic database “Pubmed” and “Scopus” with the following algorithm TITLE-ABS-KEY (Pathway OR organization OR use of care) AND (COVID-19 OR SARS-CoV-2) AND (stroke OR STEMI) AND (effect OR effectiveness OR impact);
- “Google" search engine with the keywords "Organizations", "hospital unit", or "hospital", "COVID-19";
- French Health Ministry (Ministère des solidarités et de la santé) website in search of reports on organizational recommendations for hospital in the management of the Covid-19 pandemic;
- French societies of cardiology, emergency medicine, and neurology (Société Française de Neuro-Vasculaire, Société Française de Cardiologie, Société Française de Médecine d’Urgence) websites in search of clinical recommendations in the management of stroke and STEMI patients in the context of the Covid-19 pandemic.

After a pre-selection on the title and the abstract, the complete reading of the articles allowed to filter out the articles that did not describe any structural organizations. Then, organizational data was independently collected on a dedicated collection grid. If necessary, a common reading was carried out.

- **Structured telephone interviews**

In December 2020, structured telephone interviews were conducted with healthcare professionals involved in stroke or STEMI management in hospitals in the Aquitaine Region, to question them on the organizations they had to cope with during the first wave of the pandemic in stroke and STEMI patients’ management. Among the 16 approached professionals, eight (2 nurses, 2 emergency physicians, 2 cardiologists, and 2 neurologists) from 8 hospitals accepted to participate. Questions asked were: "What reorganizations were implemented during the first wave?"; "Have you been provided with facilities for this reorganization?"; "Have you received help from professionals in other services?"; "Did you expand/reduce your capacity? ". Responses were transcribed as the interview progressed. Each verbatim was reviewed by the two interviewers in collaboration with the AVICOVID principal investigator.

Supplementary material 2.

Confounding variables introduced in the stroke and STEMI final model estimating the association between reorganizations and use of care effects on care management times

Category of variables	Stroke cohort Model	STEMI Cohort Model
Time	Period (pre, per, post-wave)	Period (pre, per, post-wave)
Socio-demographic characteristics	Age, gender	Age, gender
Geographical indexes	Urbanicity, FDep15, APL MG 2018, residence-EU distance	Urbanicity, FDep15, APL MG 2018, residence-to-cathlab distance
Clinical characteristics	mRS less than 1 before stroke, NIHSS at entry, previous stroke or transient ischemic attack	Diabetes mellitus, history of coronary artery disease or of STEMI
Acute care management quality	Mode of transport	Mode of transport
Structural characteristics of care	EDO activity during care, care during on-call activity, presence of stroke unit, availability of MRI 24 hours a day, presence of interventional neuroradiology unit	EDO activity during care, care during on-call activity, cathlab hospital status, FMC-to-cathlab distance

APL MG 2018=potential accessibility indicator to general practitioners; EDO=emergency dispatch offices; EU=emergency unit; FDep15=deprivation index; FMC=first medical contact; MRI=magnetic resonance imaging; mRS=modified Rankin Scale; NIHSS=National Institute of Health Stroke Score; STEMI=segment elevation myocardial infarction.
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Supplementary material 3.

Description of the stroke cohort study sample (N=6,436)

	Global (N=6,436)		pre-wave (N=4,140)		per-wave (N=1,080)		post-wave (N=1,216)	
	n	(%)	n	(%)	n	(%)	n	(%)
Patient socio-demographic characteristics								
Gender	6,436		4,140		1,080		1,216	
Male	3,533	(54.9)	2,264	(54.7)	589	(54.5)	680	(55.9)
Female	2,903	(45.1)	1,876	(45.3)	491	(45.5)	536	(44.1)
Age	6,436		4,140		1,080		1,216	
Median [IQR]	78	[68;87]	79	[69;87]	77	[68;86]	76	[68;85]
Urbanicity	6,153		3,882		1,072		1,199	
Urban	4,451	(72.3)	2,816	(72.5)	786	(73.3)	849	(70.8)
Rural	1,702	(27.7)	1,066	(27.5)	286	(26.7)	350	(29.2)
Missing values	283		258		8		17	
Fdep15	6,145		3,878		1,070		1,197	
Median [IQR]	0.10	[-0.96;1.14]	0.10	[-1.02;1.22]	-0.01	[-0.98;1.11]	0.08	[-0.88;1.11]
Missing values	291		262		10		19	
APL MG 2018	6,171		3,891		1,076		1,204	
Median [IQR]	4.3	[3.4;5.0]	4.3	[3.4;5.0]	4.3	[3.4;5.0]	4.2	[3.4;5.1]
Missing values	265		249		4		12	
Residence-EU distance (km)	6,179		3,897		1,077		1,205	
Median [IQR]	17	[6;32]	17	[6;33]	16	[5;28]	18	[7;34]
Missing values	*257*		*243*		*3*		*11*	
Patient clinical characteristics								
Stroke type	6,436		4,140		1,080		1,216	
Ischaemic	5,669	(88.1)	3,617	(87.4)	941	(87.1)	1,111	(91.4)
Haemorragic	767	(11.9)	523	(12.6)	139	(12.9)	105	(8.6)
Coronary artery disease	6,436		4,140		1,080		1,216	
Absence	5,877	(91.3)	3,778	(91.3)	987	(91.4)	1,112	(91.4)
Presence	559	(8.7)	362	(8.7)	93	(8.6)	104	(8.6)
Previous STEMI	6,436		4,140		1,080		1,216	
Absence	6,057	(94.1)	3,886	(93.9)	1,017	(94.2)	1,154	(94.9)
Presence	379	(5.9)	254	(6.1)	63	(5.8)	62	(5.1)
Previous stroke or transient ischemic attack	6,436		4,140		1,080		1,216	
Absence	5,166	(80.3)	3,305	(79.8)	882	(81.7)	979	(80.5)
Presence	1,270	(19.7)	835	(20.2)	198	(18.3)	237	(19.5)
Diabetes mellitus	6,436		4,140		1,080		1,216	
Absence	5,198	(80.8)	3,352	(81.0)	894	(82.8)	952	(78.3)
Presence	1,238	(19.2)	788	(19.0)	186	(17.2)	264	(21.7)
Hypertension	6,436		4,140		1,080		1,216	
Absence	2,419	(37.6)	1,538	(37.1)	437	(40.5)	444	(36.5)
Presence	4,017	(62.4)	2,602	(62.9)	643	(59.5)	772	(63.5)
Dyslipidemia	6,436		4,140		1,080		1,216	
Absence	4,618	(71.8)	2,973	(71.8)	786	(72.8)	859	(70.6)
Presence	1,818	(28.2)	1,167	(28.2)	294	(27.2)	357	(29.4)
Smoking	6,436		4,140		1,080		1,216	
Absence	5,103	(79.3)	3,290	(79.5)	846	(78.3)	967	(79.5)
Presence	1,333	(20.7)	850	(20.5)	234	(21.7)	249	(20.5)
Atheroma of the supra-aortic arteris	6,436		4,140		1,080		1,216	
Absence	6,213	(96.5)	4,015	(97.0)	1,027	(95.1)	1,171	(96.3)
Presence	223	(3.5)	125	(3.0)	53	(4.9)	45	(3.7)
Peripheral artery disease	6,436		4,140		1,080		1,216	
Absence	6,144	(95.5)	3,959	(95.6)	1,023	(94.7)	1,162	(95.6)
Presence	292	(4.5)	181	(4.4)	57	(5.3)	54	(4.4)
Atrial fibrillation	6,436		4,140		1,080		1,216	
Absence	5,348	(83.1)	3,432	(82.9)	885	(81.9)	1,031	(84.8)
Presence	1,088	(16.9)	708	(17.1)	195	(18.1)	185	(15.2)
Cardiac failure	6,436		4,140		1,080		1,216	
Absence	6,114	(95.0)	3,934	(95.0)	1,021	(94.5)	1,159	(95.3)
Presence	322	(5.0)	206	(5.0)	59	(5.5)	57	(4.7)
Psychiatry	6,436		4,140		1,080		1,216	
Absence	5,759	(89.5)	3,672	(88.7)	988	(91.5)	1,099	(90.4)
Presence	677	(10.5)	468	(11.3)	92	(8.5)	117	(9.6)
mRS less than 1 before stroke	6,436		4,140		1,080		1,216	
No	961	(14.9)	660	(15.9)	153	(14.2)	148	(12.2)
Yes	3,709	(57.6)	2,292	(55.4)	673	(62.3)	744	(61.2)
Unknown	1,766	(27.4)	1,188	(28.7)	254	(23.5)	324	(26.6)
NIHSS at entry	6,436		4,140		1,080		1,216	
[0-6]	3,489	(54.2)	2,185	(52.8)	607	(56.2)	697	(57.3)

[7-16]	1,128	(17.5)	749	(18.1)	184	(17)	195	(16.0)
[17-42]	761	(11.8)	522	(12.6)	110	(10.2)	129	(10.6)
Unknown	1,058	(16.4)	684	(16.5)	179	(16.6)	195	(16.0)
Structural characteristics of care								
EDO activity during care (intensity of daily number of calls)	6,436		4,140		1,080		1,216	
Not high	899	(14.0)	608	(14.7)	140	(13)	151	(12.4)
Moderate	1,948	(30.3)	1,268	(30.6)	264	(24.4)	416	(34.2)
High	1,184	(18.4)	669	(16.2)	303	(28.1)	212	(17.4)
Not concerned (no call to EDO)	2,405	(37.4)	1,595	(38.5)	373	(34.5)	437	(35.9)
Care during on-call activity	6,411		4,122		1,080		1,209	
Monday-Friday [8h-18h30]	3,351	(52.3)	2,178	(52.8)	565	(52.3)	608	(50.3)
Monday-Friday [18h30-20h]	338	(5.3)	212	(5.1)	55	(5.1)	71	(5.9)
Week-end and holiday [8h-20h]	1,328	(20.7)	829	(20.1)	233	(21.6)	266	(22.0)
Night [20h-8h]	1,394	(21.7)	903	(21.9)	227	(21.0)	264	(21.8)
Missing values	25		18		0		7	
EU hospital status	6,436		4,140		1,080		1,216	
University hospital	2,441	(37.9)	1,654	(40.0)	348	(32.2)	439	(36.1)
General hospital	3,879	(60.3)	2,410	(58.2)	715	(66.2)	754	(62.0)
Private hospital	116	(1.8)	76	(1.8)	17	(1.6)	23	(1.9)
Availability of MRI 24 hours a day	6,436		4,140		1,080		1,216	
No	1,694	(26.3)	1,061	(25.6)	291	(26.9)	342	(28.1)
Yes	4,742	(73.7)	3,079	(74.4)	789	(73.1)	874	(71.9)
Presence of stroke unit	6,436		4,140		1,080		1,216	
No	1,245	(19.3)	799	(19.3)	197	(18.2)	249	(20.5)
Yes	5,191	(80.7)	3,341	(80.7)	883	(81.8)	967	(79.5)
Presence of interventional neuroradiology unit	6,436		4,140		1,080		1,216	
No	3,304	(51.3)	2,102	(50.8)	551	(51.0)	651	(53.5)
Yes	3,132	(48.7)	2,038	(49.2)	529	(49.0)	565	(46.5)

APL MG 2018=potential accessibility indicator to general practitioners; EDO=emergency dispatch offices; EU=emergency unit; FDep15=deprivation index; MRI=magnetic resonance imaging; mRS=modified Rankin Scale; NIHSS=National Institute of Health Stroke Score; STEMI=segment elevation myocardial infarction.
Created by the authors

Description of the STEMI cohort study sample (N=2,782)

	Global (N=2,782)		Pre-wave (N=1,868)		Per-wave (N=407)		Post-wave (N=507)	
	n	**(%)**	**n**	**(%)**	**n**	**(%)**	**n**	**(%)**
Patient socio-demographic characteristics								
Gender	2,782		1,868		407		507	
Male	2,033	(73.1)	1,352	(72.4)	309	(75.9)	372	(73.4)
Female	749	(26.9)	516	(27.6)	98	(24.1)	135	(26.6)
Age	2,776		1,865		405		506	
Median [IQR]	65	[55;74]	65	[55;74]	65	[55;74]	64	[54;74]
Missing values	6		3		2		1	
Urbanicity	2,543		1,691		380		472	
Urban	1,843	(72.5)	1,221	(72.2)	277	(72.9)	345	(73.1)
Rural	700	(27.5)	470	(27.8)	103	(27.1)	127	(26.9)
Missing values	239		177		27		35	
Fdep15	2,537		1,690		380		467	
Median [IQR]	0.22	[-0.72;1.09]	0.23	[-0.70;1.09]	0.11	[-0.89;1.11]	0.22	[-0.72;1.09]
Missing values	245		178		27		40	
APL MG 2018	2,537		1,689		380		468	
Median [IQR]	4.3	[3.4;4.9]	4.3	[3.4;4.9]	4.2	[3.3;4.9]	4.4	[3.5;5.0]
Missing values	245		179		27		39	
Residence-to-cathlab distance (km)	2,541		1,692		379		470	
Median [IQR]	29	[10;54]	28	[10;54]	29	[10;52]	32	[12;58]
Missing values	241		176		28		37	
Patient clinical characteristics								
Coronary artery disease or STEMI history	2,782		1,868		407		507	
No	2,031	(73.0)	1,342	(71.8)	317	(77.9)	372	(73.4)
Yes	530	(19.1)	365	(19.5)	69	(16.9)	96	(18.9)
Unknown	221	(7.9)	161	(8.6)	21	(5.2)	39	(7.7)
Diabetes mellitus	2,782		1,868		407		507	
No	2,119	(76.2)	1,400	(74.9)	318	(78.1)	401	(79.1)
Yes	414	(12.9)	290	(15.5)	59	(14.5)	65	(12.8)
Unknown	249	(9.0)	178	(9.5)	30	(7.4)	41	(8.1)
Dyslipidemia	2,782		1,868		407		507	
No	1,708	(61.4)	1,133	(60.7)	249	(61.2)	326	(64.3)
Yes	887	(31.9)	601	(32.2)	135	(33.2)	151	(29.8)
Unknown	187	(6.7)	134	(7.2)	23	(5.7)	30	(5.9)
Active smoking	2,782		1,868		407		507	
No	1,194	(42.9)	787	(42.1)	183	(45.0)	224	(44.2)
Yes	1,163	(41.8)	785	(42.0)	164	(40.3)	214	(42.2)
Unknown	425	(15.3)	296	(15.8)	60	(14.7)	69	(13.6)
Familial history of coronary artery disease	2,782		1,868		407		507	
No	2,070	(74.4)	1,367	(73.2)	308	(75.7)	395	(77.9)
Yes	455	(16.4)	317	(17.0)	64	(15.7)	74	(14.6)
Unknown	257	(9.2)	184	(9.9)	35	(8.6)	38	(7.5)
Peripheral arterial disease	2,782		1,868		407		507	
No	2,245	(80.7)	1,487	(79.6)	339	(83.3)	419	(82.6)
Yes	70	(2.5)	40	(2.1)	16	(3.9)	14	(2.8)
Unknown	467	(16.8)	341	(18.3)	52	(12.8)	74	(14.6)
Obesity	2,782		1,868		407		507	
No	1,801	(64.7)	1,229	(65.8)	252	(61.9)	320	(63.1)
Yes	513	(18.4)	332	(17.8)	87	(21.4)	94	(18.5)
Unknown	468	(16.8)	307	(16.4)	68	(16.7)	93	(18.3)
Familial history of coronary artery disease	2,782		1,868		407		507	
No	2,070	(74.4)	1,367	(73.2)	308	(75.7)	395	(77.9)
Yes	455	(16.4)	317	(17.0)	64	(15.7)	74	(14.6)
Unknown	257	(9.2)	184	(9.9)	35	(8.6)	38	(7.5)
Chronic renal failure	2,782		1,868		407		507	
No	2,264	(81.4)	1,493	(79.9)	344	(84.5)	427	(84.2)
Yes	47	(1.7)	31	(1.7)	10	(2.5)	6	(1.2)
Unknown	471	(16.9)	344	(18.4)	53	(13.0)	74	(14.6)
Arterial hypertension	1,868		1,868		407		507	
No	866	(46.4)	866	(46.4)	168	(41.3)	244	(48.1)
Yes	897	(48.0)	897	(48.0)	220	(54.1)	239	(47.1)
Unknown	148	(7.9)	105	(5.6)	19	(4.7)	24	(4.7)
Structural characteristics of care								
EDO activity (intensity of daily number of calls)	2,782		1,868		407		507	
Not high	440	(15.8)	303	(16.2)	63	(15.5)	74	(14.6)
Moderate	1,093	(39.3)	744	(39.8)	143	(35.1)	206	(40.6)

High	642	(23.1)	399	(21.4)	127	(31.2)	116	(22.9)
Not concerned (no call to EDO)	607	(21.8)	422	(22.6)	74	(18.2)	111	(21.9)
Care during on-call activity	2,712		1,821		395		496	
Monday-Friday [8h-18h30]	1,116	(41.2)	741	(40.7)	164	(41.5)	211	(42.5)
Monday-Friday [18h30-20h]	133	(4.9)	90	(4.9)	21	(5.3)	22	(4.4)
Week-end and holiday [8h-20h]	547	(20.2)	368	(20.2)	68	(17.2)	111	(22.4)
Night [20h-8h]	916	(33.8)	622	(34.2)	142	(35.9)	152	(30.6)
Missing values	70		47		12		11	
EU hospital status	2,782		1,868		407		507	
University hospital	71	(2.6)	48	(2.6)	7	(1.7)	16	(3.2)
General hospital	839	(30.2)	564	(30.2)	114	(28)	161	(31.8)
Private hospital	275	(9.9)	187	(10)	39	(9.6)	49	(9.7)
Not concerned (not managed by EU)	1,597	(57.4)	1,069	(57.2)	247	(60.7)	281	(55.4)
Cathlab hospital status	2,782		1,868		407		507	
University hospital	624	(22.4)	417	(22.3)	96	(23.6)	111	(21.9)
General hospital	1,015	(36.5)	661	(35.4)	154	(37.8)	200	(39.4)
Private hospital	975	(35.0)	666	(35.7)	136	(33.4)	173	(34.1)
Not concerned (not managed by cathlab)	168	(6.0)	124	(6.6)	21	(5.2)	23	(4.5)
FMC-to-cathlab distance (km)	2,555		1,703		379		473	
Median [IQR]	21	[0;50]	21	[0;50]	21	[4;48]	24	[0;52]
Missing values	227		165		28		34	

APL MG 2018=potential accessibility indicator to general practitioners; EDO=emergency dispatch offices; EU=emergency unit; FDep15=deprivation index; FMC=first medical contact; STEMI=segment elevation myocardial infarction.

Created by the authors

Supplementary material 4.

Results of the final model estimating the association between reorganizations and use of care effects on care management times: p-value of the type III global fixed effects test - Stroke cohort (N=4,603)

Variable	p-value
Hospital reorganizations	
'Plan Blanc'	0.372
Separate Covid/no-Covid patients pathway in EU	0.830
Decrease in no-Covid patients management and admission capacities in EU	0.532
Specific access to imaging for Covid patients	0.658
Deprogramming of non-urgent procedures or hospitalizations	0.752
Use of care	
Call to EDO	0.360
Interaction period x call to EDO	0.039
FMC	0.034
Interaction period x FMC	0.807

Results of multivariate linear regression mixed model; variable to be explained: Y = log (EU admission-to-imaging time); results adjusted on period, age, gender, urbanicity, FDep15, APL MG 18, residence-EU distance, presence of stroke unit, MRI 24 hours a day, presence of interventional neuroradiology unit, care during on-call activity, mode of transport, EDO activity, mRS less than 1 before stroke, NIHSS at entry, previous stroke or transient ischemic attack

ALS=advanced life support; APL MG 2018=potential accessibility indicator to general practitioners; EDO=emergency dispatch offices; EU=emergency unit; FDep15=deprivation index; FMC=first medical contact; MRI=magnetic resonance imaging; mRS=modified Rankin Scale; NIHSS=National Institute of Health Stroke Score.

Created by the authors

Results of the final model estimating the association between reorganizations and use of care effects on care management times: estimation of regression coefficients - Stroke cohort (N=4,603)

Variable	Modalities		β	p-value
Intercept			4.767	<0.001
Hospital reorganizations				
'Plan Blanc'	yes (ref : no)		-0.061	0.372
Separate Covid/no-Covid patients pathway in EU	yes (ref : no)		0.013	0.830
Decrease in no-Covid patients management and admission capacities in EU	yes (ref : no)		-0.044	0.532
Specific access to imaging for Covid patients	yes (ref : no)		0.024	0.658
Deprogramming of non-urgent procedures or hospitalizations	yes (ref : no)		0.021	0.752
Use of care				
Call to EDO	yes (ref : no)		-0.137	0.087
Interaction period x call to EDO	*pre-wave*	*no*	-	.
	pre-wave	*yes*	-	.
	per-wave	*no*	-	.
	per-wave	*yes*	0.013	0.850
	post-wave	*no*	-	.
	post-wave	*yes*	0.210	0.014
FMC	ALS (ref : EU)		-0.369	0.027
interaction period x FMC	*pre-wave*	*EU*	-	.
	pre-wave	*ALS*	-	.
	per-wave	*EU*	-	.
	per-wave	*ALS*	0.138	0.536
	post-wave	*EU*	-	.
	post-wave	*ALS*	0.008	0.968

Results of multivariate linear regression mixed model; variable to be explained: Y = log (EU admission-to-imaging time); results adjusted on period, age, gender, urbanicity, FDep15, APL MG 18, residence-EU distance, presence of stroke unit, MRI 24 hours a day, presence of interventional neuroradiology unit, care during on-call activity, mode of transport, EDO activity, mRS less than 1 before stroke, NIHSS at entry, previous stroke or transient ischemic attack

ALS=advanced life support; APL MG 2018=potential accessibility indicator to general practitioners; EDO=emergency dispatch offices; EU=emergency unit; FDep15=deprivation index; FMC=first medical contact; MRI=magnetic resonance imaging; mRS=modified Rankin Scale; NIHSS=National Institute of Health Stroke Score.

Created by the authors

Results of the final model estimating the association between reorganizations and use of care effects on care management times: p-value of the type III global fixed effects test - STEMI cohort (N=1,843)

Variable	p-value
Hospital reorganizations	
Increase in the telephone reception capacities	0.273
Restriction of helicopter transport for Covid patients	0.637
'Plan blanc'	0.077
Systematic covid testing in EU	0.013
Separate Covid/no-Covid patients pathway in EU	0.395
Decrease in no-Covid patients management and admission capacities in EU	0.135
Coronarography room dedicated to Covid patients in cathlabs	0.907
Deprogramming of non-urgent procedures or hospitalizations	0.134
Decrease in bed capacity for no-Covid patients in cathlabs	0.557
Use of care	
FMC	<0.001
Interaction period x FMC	0.492
Symptoms-to-care time (10 min step)	<0.001
Interaction period x symptoms-to-care time	0.206

Results of a multivariate linear regression mixed model; variable to be explained: Y=log (FMC-to-procedure time); results adjusted on period, age, gender, urbanicity, FDep15, APL MG 18, residence-to-cathlab distance, cathlab hospital status, care during on-call activity, mode of transport, EDO activity, FMC-to-cathlab distance, diabetes mellitus, coronary artery disease or STEMI history).
ALS= advanced life support; APL MG 2018=potential accessibility indicator to general practitioners; EDO=emergency dispatch offices; EU=emergency unit; FDep15=deprivation index; FMC=first medical contact; STEMI=segment elevation myocardial infarction.
Created by the authors

Results of the final model estimating the association between reorganizations and use of care effects on care management times: estimation of regression coefficients - STEMI cohort (N=1,843)

Variable	Modalities		β	p-value
Intercept			4.475	<0.001
Hospital reorganizations				
Increase in the telephone reception capacities	yes (ref : no)		0.072	0.273
Restriction of helicopter transport for Covid patients	yes (ref : no)		0.034	0.637
'Plan blanc'	yes (ref : no)		-0.212	0.077
Systematic covid testing in EU	yes (ref : no)		0.343	0.013
Separate Covid/no-Covid patients pathway in EU	yes (ref : no)		-0.092	0.395
Decrease in no-Covid patients management and admission capacities in EU	yes (ref : no)		-0.222	0.135
Coronarography room dedicated to Covid patients in cathlabs	yes (ref : no)		-0.010	0.907
Deprogramming of non-urgent procedures or hospitalizations	yes (ref : no)		0.131	0.134
Decrease in bed capacity for no-Covid patients in cathlabs	yes (ref : no)		-0.043	0.557
Use of care				
FMC	EU without cathlab (ref)		-	.
	ALS		-1.061	<0.001
	EU with cathlab		-0.326	<0.001
interaction period x FMC	*pre-wave*	*EU without cathlab*	-	
	pre-wave	*ALS*	-	
	pre-wave	*EU with cathlab*	-	
	per-wave	*EU without cathlab*	-	
	per-wave	*ALS*	-0.094	0.419
	per-wave	*EU with cathlab*	0.102	0.505
	post-wave	*EU without cathlab*	-	
	post-wave	*ALS*	0.075	0.514
	post-wave	*EU with cathlab*	0.221	0.14
Symptoms-to-care time (10 min step)			0.002	0.016
Interaction period x symptoms-to-care time	*pre-wave (ref)*		-	
	per-wave		0.003	0.137
	post-wave		0.002	0.209

Results of a multivariate linear regression mixed model; variable to be explained: Y=log (FMC-to-procedure time); results adjusted on period, age, gender, urbanicity, FDep15, APL MG 18, residence-to-cathlab distance, cathlab hospital status, care during on-call activity, mode of transport, EDO activity, FMC-to-cathlab distance, diabetes mellitus, coronary artery disease or STEMI history).

ALS=advanced life support; APL MG 2018=potential accessibility indicator to general practitioners; EDO=emergency dispatch offices; EU=emergency unit; FDep15=deprivation index; FMC=first medical contact; STEMI=segment elevation myocardial infarction.

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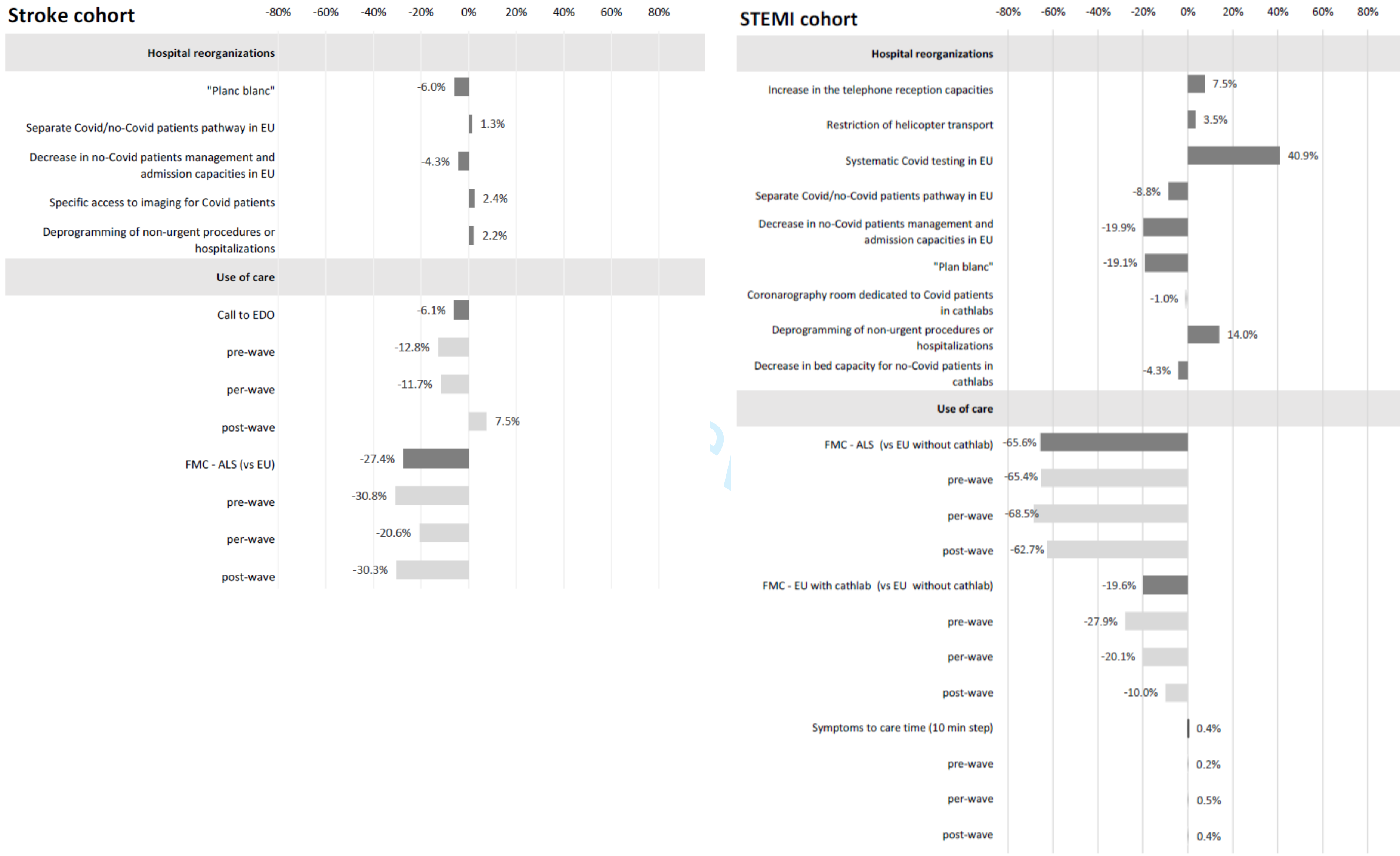
Stroke cohort
-80% -60% -40% -20% 0% 20% 40% 60% 80%
Hospital reorganizations
"Planc blanc" -6.0%
Separate Covid/no-Covid patients pathway in EU 1.3%
Decrease in no-Covid patients management and admission capacities in EU -4.3%
Specific access to imaging for Covid patients 2.4%
Deprogramming of non-urgent procedures or hospitalizations 2.2%
Use of care
Call to EDO -6.1%
pre-wave -12.8%
per-wave -11.7%
post-wave 7.5%
FMC - ALS (vs EU) -27.4%
pre-wave -30.8%
per-wave -20.6%
post-wave -30.3%
STEMI cohort
-80% -60% -40% -20% 0% 20% 40% 60% 80%
Hospital reorganizations
Increase in the telephone reception capacities 7.5%
Restriction of helicopter transport 3.5%
Systematic Covid testing in EU 40.9%
Separate Covid/no-Covid patients pathway in EU -8.8%
Decrease in no-Covid patients management and admission capacities in EU -19.9%
"Plan blanc" -19.1%
Coronarography room dedicated to Covid patients in cathlabs -1.0%
Deprogramming of non-urgent procedures or hospitalizations 14.0%
Decrease in bed capacity for no-Covid patients in cathlabs -4.3%
Use of care
FMC - ALS (vs EU without cathlab) -65.6%
pre-wave -65.4%
per-wave -68.5%
post-wave -62.7%
FMC - EU with cathlab (vs EU without cathlab) -19.6%
pre-wave -27.9%
per-wave -20.1%
post-wave -10.0%
Symptoms to care time (10 min step) 0.4%
pre-wave 0.2%
per-wave 0.5%
post-wave 0.4%

5

Figure. Stroke and STEMI cohorts. Variation percentages of the estimations of the reorganizations and use of care effects on care management times

A: Stroke cohort (N=4,603) – Percentage change in overall effects; results of multivariate linear regression mixed models; variable to be explained: Y = log (EU admission-to-imaging time); results adjusted on period, age, gender, urbanicity of residence, FDep15, APL MG 18, residence-EU distance, presence of stroke unit, MRI 24 hours a day, presence of interventional neuroradiology unit, care during on-call activity, mode of transport, EDO activity, mRS less than 1 before stroke, NIHSS at entry, previous stroke or transient ischemic attack.

B: STEMI cohort (N=1,843) – Percentage change in overall effects; results of multivariate linear regression mixed models; variable to be explained: Y=log (FMC-to-procedure time); results adjusted on period, age, gender, urbanicity of residence, FDep15, APL MG 18, residence-to-cathlab distance, cathlab hospital status, care during on-call activity, mode of transport, EDO activity, FMC-to-cathlab distance, diabetes mellitus, coronary artery disease or STEMI history).

Light grey: interaction with the COVID period, Dark grey: raw results without interaction with the COVID period

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STROBE Statement—Checklist of items that should be included in reports of cohort studies

	Item No	Recommendation	Page No
Title and abstract	1	(*a*) Indicate the study's design with a commonly used term in the title or the abstract	ok
		(*b*) Provide in the abstract an informative and balanced summary of what was done and what was found	ok, page 1
Introduction			
Background/rationale	2	Explain the scientific background and rationale for the investigation being reported	ok, page 4
Objectives	3	State specific objectives, including any prespecified hypotheses	ok, page 4
Methods			
Study design	4	Present key elements of study design early in the paper	ok, page 4
Setting	5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection	ok, pages 4, 5
Participants	6	(*a*) *Cohort study*—Give the eligibility criteria, and the sources and methods of selection of participants. Describe methods of follow-up	ok, pages 4, 5
		(*b*) *Cohort study*—For matched studies, give matching criteria and number of exposed and unexposed	NA
Variables	7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable	ok, pages 5, 6, 7
Data sources/ measurement	8*	For each variable of interest, give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group	ok, pages 5, 6
Bias	9	Describe any efforts to address potential sources of bias	ok, page 7
Study size	10	Explain how the study size was arrived at	ok, page 5
Quantitative variables	11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why	ok, page 7
Statistical methods	12	(*a*) Describe all statistical methods, including those used to control for confounding	ok, page 7
		(*b*) Describe any methods used to examine subgroups and interactions	ok, page 7
		(*c*) Explain how missing data were addressed	ok, page 7
		(*d*) *Cohort study*—If applicable, explain how loss to follow-up was addressed	NA
		(*e*) Describe any sensitivity analyses	ok, page 7
Results			
Participants	13*	(a) Report numbers of individuals at each stage of study—eg numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed	ok, page 7
		(b) Give reasons for non-participation at each stage	NA
		(c) Consider use of a flow diagram	NA
Descriptive data	14*	(a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders	ok, page 7, suppl mat.
		(b) Indicate number of participants with missing data for each variable of interest	ok, pages 9, 10

		(c) *Cohort study*—Summarise follow-up time (eg, average and total amount)	NA
Outcome data	15*	*Cohort study*—Report numbers of outcome events or summary measures over time	ok, page 11
Main results	16	(*a*) Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (eg, 95% confidence interval). Make clear which confounders were adjusted for and why they were included	ok, page 11
		(*b*) Report category boundaries when continuous variables were categorized	ok, pages 9, 10
		(*c*) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period	NA
Other analyses	17	Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses	ok, page 11
Discussion			
Key results	18	Summarise key results with reference to study objectives	ok, pages 11, 12
Limitations	19	Discuss limitations of the study, taking into account sources of potential bias or imprecision. Discuss both direction and magnitude of any potential bias	ok, pages 13, 14
Interpretation	20	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence	ok, pages 12
Generalisability	21	Discuss the generalisability (external validity) of the study results	ok, pages 14
Other information			
Funding	22	Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based	ok, page 15

NA= not applicable

BMJ Open

The impact of the healthcare system transformations spurred by the COVID-19 pandemic on stroke and STEMI management: cohorts of patients included in a French regional Cardio-neuro-vascular registry

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Keywords:	COVID-19, Health policy < HEALTH SERVICES ADMINISTRATION & MANAGEMENT, Organisation of health services < HEALTH SERVICES ADMINISTRATION & MANAGEMENT, Quality in health care < HEALTH

	SERVICES ADMINISTRATION & MANAGEMENT, Myocardial infarction < CARDIOLOGY, Stroke < NEUROLOGY

The impact of the healthcare system transformations spurred by the COVID-19 pandemic on stroke and STEMI management: cohorts of patients included in a French regional Cardio-neuro-vascular registry

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ABSTRACT

Objective: To assess the impact of changes in use of care and implementation of hospital reorganizations, spurred by the COVID-19 pandemic (first wave) on acute management times of strokes and ST-segment elevation myocardial infarctions (STEMI).

Design: two cohorts of STEMI and stroke patients included in the Aquitaine Cardio-Neuro-vascular (CNV) registry.

Setting: Six emergency medical services, 30 emergency units, 14 hospitalization units and 11 cathlabs of the Aquitaine region.

Participants: 9,218 patients (6,436 stroke and 2,782 STEMI patients) included in the CNV registry between January 2019 and August 2020.

Method: Hospital reorganizations, retrieved through a scoping review, were collected from heads of hospital departments. Other data were from the CNV registry. The associations between reorganizations, use of care, and care management times were analyzed through multivariate linear regression mixed models. Interaction terms between use of care variables and period (pre, per, post-wave) were introduced.

Main outcome measures: STEMI cohort: first medical contact-to-procedure time; stroke cohort: emergency unit admission-to-imaging time.

Results: Per-wave period management times deteriorated for stroke but maintained for STEMI. Per-wave changes in use of care did not have any impact on STEMI management. No association was found between reorganizations and stroke management times. In the STEMI cohort, the implementation of a systematic testing at admission was associated with an increase of 41% in care management times (exp=1.409, 95%CI [1.075-1.848], p=0.013); the implementation of the global “plan blanc”, concentrating resources in emergency activities, was associated with a decrease of 19% in management times (exp=0.801, 95%CI [0.639-1.023], p=0.077).

Conclusions: The pandemic induced no deep altering of emergency pathway structuration. In contrast with stroke patient management that deteriorated, the resilience of the STEMI pathway is interpreted as linked with its stronger structuration. Transversal reorganizations aiming at concentrate resources on emergency care contributed to maintaining quality of care.

STRENGTHS AND LIMITATIONS OF THIS STUDY

- The study was based on two large high quality data cohorts including nearly 10,000 stroke and STEMI patients, managed in a large panel of care structures spread throughout the Aquitaine region, over a period of several months before and after the first wave allowing high historical depth of the data.
- We conducted an original, systematic and exhaustive collection of reorganizations implemented by the involved care structures to cope with the COVID-19 pandemic in the management of stroke and STEMI patients.
- The explanatory analyses present robust results due to the large panel of data collected in the two cohorts (clinical characteristics, socio-geographical factors, acute care management pathway data) that allowed the integration of all the confusion factors identified with the DAG (directed acyclic graph) method.
- The exclusion of patients who did not enter into the health care system prevented us to quantify avoidance of the health care system that is supposed to have been more frequent during the COVID-19 crisis.
- The data collection restricted to the Aquitaine region, less affected by the pandemic during the first wave, questions the geographical generalizability of results regarding the impact of reorganizations focused on emergency units, which were more sensitive to patient influx.

INTRODUCTION

Around the world, governments were responding the COVID-19 pandemic with unprecedented policies affecting societies functioning and healthcare systems, designed to slow the growth rate of the infection.(1–3) France was one of the most affected countries in the early months of the pandemic.(4) From March to May 2020, French authorities implemented a nationwide lockdown and a series of policies to curb the surge of patients requiring critical care. The French health care system was at that time almost entirely devoted to fight against SARS-CoV2.

It is expected that these profound changes have had a negative impact on the delivery of medical and surgical services. Use of care have already been shown to have been modified;(5) all the countries having implemented a policy to prevent the spread of the virus have noticed a huge decrease in the flow of patients entering emergency rooms for reasons other than COVID-19, revealing a tendency to delay or even forego care.(6–9)

Concerns rose about the quality of management of acute conditions other than COVID-19 disease, particularly those of stroke and ST-segment elevation myocardial infarction (STEMI), the both most highly time-sensitive frequent conditions.(10,11) For these two diseases, management pathways have been clearly established for decades, based initially on the patient's use of the emergency medical service (EMS) system in the event of an extreme emergency, followed by relays between emergency structures and specialized technical platforms (cathlabs, stroke units). These care pathways depend on a close collaboration between various professionals both in pre and intra-hospital areas. These pre-defined pathways may have been undermined by the organizational and societal upheavals associated with the COVID-19 pandemic. Indeed, international literature agree that the COVID-19 pandemic has led to a substantial decrease in the rate of stroke and STEMI admissions, reductions in the number of procedures, and longer delays between the onset of the symptoms and hospital treatment; these latest appearing driven predominantly by delays in use of care and transfers.(12)

However, works showed discrepant results on the impact of the COVID-19 pandemic on the intra hospital quality of care of these two diseases.(13–16) We hypothesized that these conflicting results may be due to the organizational environment of each hospital and particularly to the timing and the type of organizations implemented to cope with the COVID-pandemic control. Beyond the application of national directives, each hospital had total autonomy to prioritize its reorganizations, according to local capacities. To date, no study has quantified the effect of the COVID-19 work pattern on the delivery of stroke and STEMI.

Since 2012, the Aquitaine region (South Western France, 3 million inhabitants) has implemented a regional registry of cardio-neuro-vascular pathologies called "CNV Registry" allowing to analyzing the care pathway of STEMI and stroke patients managed in the Aquitaine hospitals, providing a unique opportunity to study the differences in care management in the region and their evolution over time.(17)

Our main objective was to assess the impact of changes in use of care and health reorganizations implementation, spurred by the first wave of the COVID-19 pandemic on care management times of STEMI and stroke patients hospitalized in the Aquitaine region. We also sought to analyze use of care as well as the quality of care provided to these patients during the COVID-19 pandemic.

METHODS

Study design and population

This study was based on two exhaustive retrospective cohorts of stroke and STEMI patients. We performed an ad hoc collection of the reorganizations implemented by health care structures in the Aquitaine region during the first wave of the COVID-19 pandemic.

The two cohorts were constituted of all adult patients, living in metropolitan France, and admitted to a care structure involved in the CNV registry with recent stroke or STEMI, between January 1st 2019 and August 31 2020.(17) The STEMI cohort included recent STEMI patients less than 24h from symptoms onset, managed in all the 6 EMS, 14 emergency unit (EU) and 11 cathlabs of Aquitaine. The stroke cohort included recent ischemic or haemorrhagic stroke patients diagnosed by brain imaging with validation by a neurovascular physician (exclusion of transient ischemic attacks), managed in 5 of the 6 EMS and 14 (including 7 stroke units) of the 20 hospitals caring more than 30 strokes per year in Aquitaine. The CNV registry has been approved by the French authority on data protection and met regulatory requirements for patient information (file 2216283).

Data collection

Stroke and STEMI cohorts

Data is collected from each care structure managing patients throughout his pathway:

1) in EMS, data previously entered in electronic care records are extracted from the hospital information system,

2) in emergency units (EU), data are entered prospectively by physicians in a dedicated paper or electronic care records then extracted or collected retrospectively by clinical research assistants,

3) in cathlabs or in stroke hospitalization units, data are entered prospectively by physicians then extracted.

Data of the two cohorts are consolidated and incorporated, into one data warehouse allowing the reconstructing of the whole patient STEMI or stroke management pathway.

The CNV registry collects information on:

1) patient socio-demographic characteristics: age, gender, place of residence,

2) patient clinical characteristics: medical history, cardio-vascular risk factors, stroke clinical severity (modified Rankin Scale –mRS- and National Institute of Health Stroke Score –NIHSS) and stroke type (ischaemic/haemorrhagic),

3) use of care (table 1): call to the emergency services, first medical contact (FMC), symptoms-to-care time,

4) acute care management quality (table 1): times between key management steps (stroke: EU admission-to-imaging time; STEMI: FMC-to-procedure time), pre hospital and hospital pathway type, mode of transport to EU, orientation to specialized technical platforms (stroke unit or cathlab), treatment (stroke: first imaging type, intravenous thrombolysis (IVT) in ischemic stroke, mechanical thrombectomy in ischemic stroke; STEMI: fibrinolysis, percutaneous coronary intervention - PCI, coronary angiography alone),

5) structural characteristics of care: care during on-call activity, call to the emergency services activity during care, administrative status of the taking care hospital, FMC-to-cathlab distance, and specifically for the stroke cohort, availability of Magnetic Resonance Imaging (MRI) 24 hours a day, presence of stroke unit, presence of interventional neuroradiology unit.

Place of residence allowed the determination of three geographical indexes: urbanicity, deprivation index (Fdep15), potential accessibility indicator to general practitioners (APL MG 2018) (table 1), and distances between residence and care structures. (18–20)

Table 1. Definition of use of care variables, acute care management quality variables and geographical indexes

Variables	Definition
Use of care	
Call to the emergency services	Patient call to the emergency services after the onset of symptoms
FMC	First medical team to take care of the patient: - in the stroke cohort, two categories of FMC: 1) MICU in case of call to, 2) EU in case of no call to the emergency services; - in the STEMI cohort, three categories of FMC: 1) MICU, 2) EU with cathlab, 3) EU without cathlab.
Symptoms-to-care time	Delay in minutes between symptoms onset and start of management by the healthcare system, either call to the emergency services or EU admission in case of no call to the emergency services
Acute care management quality	
EU admission-to-imaging time	Delay in minutes between EU admission and start of the first imaging (MRI or CT scan)
FMC-to-procedure time	Delay in minutes between FMC and the start of the treatment procedure (coronary angiography or PCI)
IVT in ischemic stroke	Two variables: 1) IVT in all ischemic stroke patients, 2) IVT in "IVT alert" patients *ie*. patients with symptoms-to-EU admission time less than 4 hours.
Geographical indexes	
Urbanicity	Urban defined as commune or group of communes with a continuous built-up area with at least 2,000 inhabitants
FDep15	Validated social level index calculated from four variables attributed to each commune: median household income, proportion of baccalaureate, proportion of workers in the active population and unemployment rate
APL MG 2018	Index calculated from the supply of general practitioners, the demand for care and the distance between the place of residence and the supply of care

APL MG 2018=potential accessibility indicator to general practitioners; CT=computerized tomography scan; EU=emergency unit; FDep15=deprivation index; FMC=first medical contact; IVT=intravenous thrombolysis; MICU=mobile intensive care units; MRI=magnetic resonance imaging; PCI=Percutaneous Coronary Intervention; STEMI=segment elevation myocardial infarction.
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Reorganizations implemented in the health care structures

A scoping review was conducted in compliance with the PRISMA recommendations (21) to retrieve the structural reorganizations implemented in care structures to deal with the first wave of the COVID-19 pandemic in the acute management of stroke and STEMI (supplementary material 1).(22) The retrieved reorganizations were classified according to care structure concerned: in EMS ("increase in the telephone reception capacities", "restriction of helicopter transport for COVID patients"), in EU ("systematic COVID testing", "separate COVID/no-COVID patients pathway", "decrease in no-COVID patients management and admission capacities", "Plan blanc" - global emergency plan to face a sudden increase of activity), in stroke or STEMI hospitalization units ("coronary angiography room dedicated to COVID patients in cathlabs", "deprogramming of non-urgent procedures or hospitalizations", "decrease in bed capacity for no-COVID patients", "specific access to imaging for COVID patients"). The retrieved reorganizations were compiled in a questionnaire addressed to the care structure heads who were asked to indicate, for each reorganization identified, whether it had been implemented and, if so, its dates of implementation and of termination.

Care management times

The primary endpoints were: for the STEMI cohort, FMC-to-procedure time and for the stroke cohort, EU admission-to-imaging time.

Statistical analyses

Analyses were performed separately for each cohort. Three periods were defined according to the dates of implementation of first hospital reorganizations and termination of national lockdown: pre-wave (from January 1, 2019 to February 9, 2020), per-wave (from February 10 to May 10, 2020), and post-wave (from May 11 to August 31, 2020).

Use of care and acute care management quality variables were compared between the three periods (Khi2 test or Fisher exact test for qualitative variables, Kruskal-Wallis test for quantitative variables – p corrected by False Discovery Rate - FDR- to take into account the multiplicity of tests).

The associations between reorganizations (STEMI: 9 variables; stroke: 5 variables), use of care (STEMI: 2 variables; stroke: 2 variables), and care management times (introduced as continuous variables after logarithmic transformation) were analyzed through a multivariate linear regression mixed model (two random effects on hospital and health territory). Interaction terms between the use of care variables and the period (pre, per, post-wave) were introduced. The confounding variables were identified through a directed acyclic graph (DAG) (supplementary material 2).

The relationships between reorganizations or use of care and care management times were quantified (β) by the contrast method (statistical significance reached if P-value less than 0.05) then the exponentials of the betas (exp (β)), their 95% confidence intervals and percentage change (1 - exp (β)) were calculated.

For the stroke cohort, a sensitivity analysis was carried out by adding the variable symptoms-to-care time in the model. This variable was not introduced in principal analysis because it presented more than 20% missing data. Statistical analysis were conducted using SAS 9.4.

Patient and Public Involvement statement

As members of the CNV registry scientific boards, association of patient representatives were involved in the conception of the study, implementation and dissemination; they validated data collection and analysis, results diffusion. Dissemination of results involved information delivered on the CNV registry website, to the scientific boards and to care structure physicians.

This study is reported in accordance with the STROBE guideline and is registered with ClinicalTrials.gov NCT04979208.

RESULTS

Description of the study sample (supplementary material 3)

Study sample included a total of 9,218 patients: 6,008 in the pre-wave period, 1,487 in the per-wave period and 1,723 in the post-wave period. Patient inclusion rhythm was stable during the pre and post-wave periods (weekly mean number (SD) of inclusions: 32 (6) STEMI pre-wave, 32 (5) STEMI post-wave, 83 (8) strokes pre-wave, 75 (7) strokes post-wave); in the beginning of the per-wave period (week 7 to week 15) was observed a coming down of inclusions of stroke (lowest weekly number of stroke inclusions: 56) and STEMI patients (lowest weekly number of STEMI inclusions: 22), followed by a slow increase that lasted after the start of the post-wave period.

A total of 6,436 stroke patients (5,669-88.1% with ischemic stroke and 767 with haemorrhagic stroke) were managed in 5 EMS, 14 EU, and 14 hospitalization units (7 stroke units); 2,782 STEMI patients were managed in 6 EMS, 30 EU, and 11 cathlabs. The analysis of the demographic characteristics of the study sample highlights lower median age in the stroke cohort during the per and post-wave periods (77 and 76 years vs. 79 years) and a stable median age of STEMI patients along the three periods; in the STEMI cohort, a lower proportion of women (24.1% vs. 27.6% and 26.6%) and a higher proportion of patient with hypertension history (54.1% vs. 48.0% and 47.1%) were observed during the per-wave period compared to the pre and post-wave periods. The main notable clinical feature to point out was, in the stroke cohort, lower frequency of severe strokes in the per and post-waves (respectively, 56.2% and 57.3% of stroke patients with NIHSS<7) than in the pre-wave period (52.8% of stroke patients with NIHSS<7).

Reorganizations implemented in care structures (figure 1)

First reorganizations have been implemented from early February 2020, then spread in a few weeks; in the midst of the per-wave period, 83% of EMS, 90% of EU, 93% of stroke hospitalization units, and 64% of cathlabs had implemented at least one reorganization. The two most frequently implemented reorganizations were “increase in the telephone reception capacities” (implemented in all EMS) and “separate COVID/no-COVID patient’s pathway in EU” (implemented by 93% of EU - n=13 for stroke cohort, n=28 for STEMI cohort). Half of the EU have implemented the “Plan blanc”. Most frequent reorganizations implemented during the per-wave period were maintained in the post-wave period.

Comparison of use of care and acute care management quality between the pre, per, and post-wave periods (tables 2, 3)

Use of care

During the per-wave with regard to the pre-wave period, were observed in both cohorts an increase in calls to emergency services (stroke cohort: 65.5% versus 61.5%; STEMI cohort: 81.8% versus 77.4%) and in median time from symptoms-to-care time (stroke cohort: 139 minutes versus 121 minutes; STEMI cohort: 84 minutes versus 76 minutes). These findings returned to their previous levels during the post-wave period, with the exception of calls to emergency services for stroke, which remained high.

Care management quality

There was an increase in stroke median EU admission-to-imaging time (91 minutes vs. 83 minutes) and a decrease in STEMI median FMC-to-procedure time (95 minutes vs. 100 minutes) during the per-wave with regard to the pre-wave period. This management time remained high for stroke (88 minutes) and increased for STEMI (102 minutes) in the post-wave period.

Specifically in the stroke cohort, the proportion of IVT decreased during the per-wave compared to the pre and post-wave periods (all ischemic strokes: 14.6% vs. 19.4% and 16.7%, p=0.011; IVT alert patients: 31.3% vs. 42.4% and 38.8%, p=0.011) and the proportion of patients with an optimal pathway (call to the emergency services/MICU transport/EU) was higher during the per-wave period (59.5%) compared to the pre (57.3%) and post-wave periods (58.3%, p=0.040).

Table 2. Comparison of use of care and acute care management quality characteristics between the pre, per, post-wave periods - Stroke cohort (N=6,436)

	Global (N=6,436)		Pre-wave (N=4,140)		Per-wave (N=1,080)		Post-wave (N=1,216)		p-value corrected (FDR)
	n	(%)	n	(%)	n	(%)	n	(%)	
Use of care									
Call to the emergency services	6,430		4,135		1,079		1,216		0.083 *
No	2,399	(37.3)	1,590	(38.5)	372	(34.5)	437	(35.9)	
Yes	4,031	(62.7)	2,545	(61.5)	707	(65.5)	779	(64.1)	
Missing values	*6*		*5*		*1*		*0*		
FMC	6,436		4,140		1,080		1,216		0.332 *
EU	6,278	(97.5)	4,040	(97.6)	1,059	(98.1)	1,179	(9.0)	
MICU	158	(2.5)	100	(2.4)	21	(1.9)	37	(3.0)	
Symptoms-to-care time (min)	3,157		1,991		556		610		0.232 **
Median [IQR]	126	[38;401]	121	[38;384]	139	[46;488]	125	[38;392]	
Missing values	*3,279*		*2,149*		*524*		*606*		
Acute care management quality									
EU admission-to-imaging time (min)	4,819		3,014		889		916		0.332 **
Median [IQR]	86	[47;194]	83	[45;201]	91	[51;175]	88	[52;191]	
Missing values	*1,617*		*1,126*		*191*		*300*		
Pre-hospital pathway type	6,430		4,135		1,079		1,216		0.040 *
Optimal pathway: call to the emergency services/MICU transport/EU	3,719	(57.8)	2,368	(57.3)	642	(59.5)	709	(58.3)	
Call to the emergency services /non-MICU transport/EU	312	(4.9)	177	(4.3)	65	(6.0)	70	(5.8)	
EU direct entry	2,399	(37.3)	1,590	(38.5)	372	(34.5)	437	(35.9)	
Missing values	*6*		*5*		*1*		*0*		
Mode of transport to the EU	6,436		4,140		1,080		1,216		0.812 *
Personal transport	732	(11.4)	475	(11.5)	117	(10.8)	140	(11.5)	
Non-MICU transport	4,495	(69.8)	2,902	(70.1)	758	(70.2)	835	(68.7)	
MICU transport	222	(3.4)	149	(3.6)	34	(3.1)	39	(3.2)	
Unknown	987	(15.3)	614	(14.8)	171	(15.8)	202	(16.6)	
Transfer to a stroke unit	6,436		4,140		1,080		1,216		0.923 *
No	752	(11.7)	484	(11.7)	123	(11.4)	145	(11.9)	
Yes	5,684	(88.3)	3,656	(88.3)	957	(88.6)	1,071	(88.1)	
First imaging type	6,041		3,870		1,019		1,152		0.332 ***
MRI	3,782	(62.6)	2,395	(61.9)	650	(63.8)	737	(64.0)	
CT scan	2,245	(37.2)	1,463	(37.8)	369	(36.2)	413	(35.9)	
None	14	(0.2)	12	(0.3)	0	(0.0)	2	(0.2)	
Missing values	*395*		*270*		*61*		*64*		
IVT (all ischemic strokes)	5,660		3,616		938		1,106		0.011 *
No	4,635	(81.9)	2,913	(80.6)	801	(85.4)	921	(83.3)	
Yes	1,025	(18.1)	703	(19.4)	137	(14.6)	185	(16.7)	
Missing values	*9*		*1*		*3*		*5*		
Exclusion	*767*		*523*		*139*		*105*		
IVT in 'Thrombolysis alert' patients (ischemic stroke)	1,758		1,100		310		348		0.011 *
No	1,060	(60.3)	634	(57.6)	213	(68.7)	213	(61.2)	
Yes	698	(39.7)	466	(42.4)	97	(31.3)	135	(38.8)	
Missing values	*2*		*1*		*0*		*1*		
Exclusion	*4,676*		*3,039*		*770*		*867*		
Mechanical thrombectomy (all ischemic stroke)	5,620		3,585		938		1,097		0.332 *
No	4,998	(88.9)	3,170	(88.4)	842	(89.8)	986	(89.9)	
Yes	622	(11.1)	415	(11.6)	96	(10.2)	111	(10.1)	
Missing values	*49*		*32*		*3*		*14*		
Exclusion	*767*		*523*		*139*		*105*		

Test realized=Khi2 test (*), Kruskal-Wallis test (**), Fisher exact test (***); CT scan=computerized tomography scan; EU=emergency unit; FDR=correction of p-value by False Discovery Rate method; FMC=first medical contact; IVT=intravenous thrombolysis; MICU=mobile intensive care units; MRI=magnetic resonance imaging.
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Table 3. Comparison of use of care and acute care management quality characteristics between the pre, per, post-wave periods - STEMI cohort (N=2,782)

	Global (N=2,782)		Pre-wave (N=1,868)		Per-wave (N=407)		Post-wave (N=507)		p-value corrected (FDR)	
	n	(%)	n	(%)	n	(%)	n	(%)		
Use of care										
Call to the emergency services	2,782		1,868		407		507		0.704	*
No	607	(21.8)	422	(22.6)	74	(18.2)	111	(21.9)		
Yes	2,175	(78.2)	1,446	(77.4)	333	(81.8)	396	(78.1)		
FMC	2,782		1,868		407		507		0.704	*
MICU	1,597	(57.4)	1,069	(57.2)	247	(60.7)	281	(55.4)		
EU with cathlab	458	(16.5)	321	(17.2)	51	(12.5)	86	(17.0)		
EU without cathlab	727	(26.1)	478	(25.6)	109	(26.8)	140	(27.6)		
Symptoms-to-care time (min)	2,360		1,581		349		430		0.799	**
Median [IQR]	77	[30;206]	76	[30;212]	84	[31;202]	75	[30;178]		
Missing values	*422*		*287*		*58*		*77*			
Acute care management quality										
FMC-to-procedure time (min)	2,364		1,577		353		434		0.799	**
Median [IQR]	99	[71;157]	100	[71;158]	95	[69;152]	102	[71;153]		
Missing values	*418*		*291*		*54*		*73*			
Pathway type	2,742		1,841		400		501		0.799	*
Optimal pathway: call to the emergency services/ MICU transport/direct referral to cathlab	1,557	(56.8)	1,042	(56.6)	240	(60.0)	275	(54.9)		
Call to the emergency services /EU/direct referral to cathlab	550	(20.1)	356	(19.3)	82	(20.5)	112	(22.4)		
No call to the emergency services /EU/direct referral to cathlab	591	(21.6)	412	(22.4)	72	(18.0)	107	(21.4)		
Call to the emergency services /EU/no direct referral to cathlab	28	(1.0)	20	(1.1)	4	(1.0)	4	(0.8)		
No call to the emergency services /EU/no direct referral to cathlab	16	(0.6)	11	(0.6)	2	(0.5)	3	(0.6)		
Missing values	*40*		*27*		*7*		*6*			
Mode of transport to the first hospital	2,782		1,868		407		507		0.722	*
Personal transport	444	(16.0)	311	(16.6)	55	(13.5)	78	(15.4)		
Non- MICU transport	558	(20.1)	372	(19.9)	77	(18.9)	109	(21.5)		
MICU transport (road)	1,523	(54.7)	1,010	(54.1)	243	(59.7)	270	(53.3)		
MICU transport (helicopter)	123	(4.4)	84	(4.5)	11	(2.7)	28	(5.5)		
Unknown	134	(4.8)	91	(4.9)	21	(5.2)	22	(4.3)		
Direct referral to cathlab	2,782		1,868		407		507		0.799	*
No	84	(3.0)	58	(3.1)	13	(3.2)	13	(2.6)		
Yes	2,698	(97.0)	1,810	(96.9)	394	(96.8)	494	(97.4)		
Fibrinolysis	2,560		1,724		366		470		0.799	*
No	2,428	(94.8)	1,633	(94.7)	345	(94.3)	450	(95.7)		
Yes	132	(5.2)	91	(5.3)	21	(5.7)	20	(4.3)		
Missing values	*222*		*144*		*41*		*37*			
PCI	2,364		1,577		353		434		0.799	*
No	330	(14.0)	211	(13.4)	50	(14.2)	69	(15.9)		
Yes	2,034	(86.0)	1,366	(86.6)	303	(85.8)	365	(84.1)		
Missing values	*418*		*291*		*54*		*73*			
Fibrinolysis or PCI	2,359		1,576		349		434		0.704	*
No	292	(12.4)	190	(12.1)	38	(10.9)	64	(14.7)		
Yes	2,067	(87.6)	1,386	(87.9)	311	(89.1)	370	(85.3)		
Missing values	*423*		*292*		*58*		*73*			

Test realized=Khi2 test (*), Kruskal-Wallis test (**), Fisher exact test (***); EU=emergency unit; FDR=correction of p-value by False Discovery Rate method; FMC=first medical contact; MICU=mobile intensive care units; PCI=Percutaneous Coronary Intervention.
Created by the authors

Association between use of care, reorganizations, and care management times (figure 2, supplementary material 4)

Stroke cohort model (4,603 patients)

The final model showed no statistically significant association between reorganizations and EU admission-to-imaging time. FMC by MICU transport was associated with a global statistically significant decrease of 27% of the EU admission-to-imaging time (expβ=0.726, 95%CI [0.548-0.961], p=0.034), without any interaction with the COVID period (p=0.807). The association between call to the emergency services and EU admission-to-imaging time, not statistically significant (expβ=0.939, 95%CI [0.793-1.112], p=0.360) on the whole study period, differed according to the COVID period (significant interaction with the Covid period p=0.039): call to the emergency services was associated with an increase of 8% in admission-to-imaging time during the post-wave period, compared to the pre and per-wave periods. The sensitivity analysis conducted on 2,458 patients confirmed the absence of any association between reorganizations or use of care changes along the COVID period and care management times.

STEMI cohort model (1,843 patients)

COVID systematic testing was associated with an increase of 41% (expβ=1.409, 95%CI [1.075-1.848], p=0.013) of the FMC-to-procedure time. The implementation of the "plan blanc" was associated with a decrease of 19% (expβ=0.801, 95%CI [0.639-1.023], p=0.077) of the FMC-to-procedure time. Compared with FMC "EU without cathlab », FMC "MICU transport pathway" was globally associated with a decrease of 66% (expβ=0.344, 95%CI [0.266-0.445], p<0.001) of the FMC-to-procedure time and FMC "EU with cathlab" associated with a decrease of 20% (expβ=0.804, 95%CI [0.674-0.958], p<0.001) of this time. The interaction with the COVID period was not significant (p=0.492). Finally, each 10-minute delay of the symptoms-to-care time affects the FMC-to-procedure with an increase of 0.36% (expβ=1.004, 95%CI [1.002-1.005], p<0.001), with no effect of the COVID period (p=0.206).

DISCUSSION

Main Results

Our study adds a better understanding of the global impact of the societal changes and the health system transformation, spurred by the first wave of the COVID-19 health crisis, on use of care and acute management of stroke and STEMI patients.

Most hospitals of the Aquitaine region have adapted their organization from the beginning of the per-wave period to cope with the COVID-pandemic control and most of the implemented reorganizations were maintained several months after the end of the national lockdown. Globally, the stroke management times deteriorated during the pandemic, but this deterioration did not seem to be directly related to the reorganizations implemented. In contrast, STEMI patients' quality of care was maintained during the first wave of the COVID-19 pandemic; the reorganization "plan blanc" consisting in concentrate resources in emergency activities contributed to this improvement. Systematic COVID-19 screening implementation at admission was associated with an increase in STEMI patient time management. In both STEMI and stroke cohorts, more frequent calls to emergency services and longer times to health care system were observed during the per-wave period with regard to the pre-wave period.

Results interpretation

The contrasting results in the management times evolution during the per crisis period, observed in cardio and neurovascular sectors, may find explanation in the different structuring and performance of these two networks in France. The STEMI network is indeed structured in a dedicated pathway, organized and implemented since decades in France. On the contrary, the stroke network is of younger implementation and is not fully structured in a dedicated way. Many works have highlighted the value of highly structured patient centred clinical pathway on quality of care of whether chronic or acute conditions with predictable trajectories.(23–27) Moreover, all the guidelines on stroke and STEMI patients management and national stroke and STEMI improvement programs recommend the implementation of structured pathways including close collaboration between health care professionals, patient orientation to specialized technical platforms (cathlabs, stroke units) and to the EMS system.(28,29).

Even if the resilience to the COVID-19 crisis was contrasted between these two pathways, our results are in favour of the absence of a deep and global altering of these emergency pathways structuration during the pandemic. Indeed, call to the emergency services by STEMI patients and orientation to optimal pathway using MICU was associated with a decrease of stroke and STEMI management times. This fundamental root of the management organization of these two highly time-sensitive pathologies was not disrupted during the crisis.

The "plan blanc", implemented in the whole acute pathway to create an organizational environment favorable to the quality of care of COVID patients, helped to improve the one of STEMI patients by decreasing management times. In the stroke cohort, this organization tended to decrease management times without reaching statistical significance. These different results may be explained by different primary endpoints in the two cohorts; in the STEMI cohort, the FMC-to-procedure time that took into account the coordination of care between the multiple actors involved in pre-hospital and in-hospital care was spread enough to allow an effect showing; in the stroke cohort, the EU admission-to-imaging time, that focused on the short stage of the very beginning of intra-hospital care, involving too few different actors to reveal any effect. In a concordant way, most organizations implemented more specifically in EU or in hospitalization units have had little effect on STEMI and stroke care management times.

Only the reorganization "systematic COVID-19 testing in EU" increased STEMI management times. This deleterious effect was marked in patients arriving late after symptom onset. In these patients, whose symptoms were often less typical and may include respiratory signs suggestive of COVID, management could have been delayed up to the screening results delivery. STEMI patients arriving at a very early stage were managed as conditions requiring extreme emergency management before screening. This organization was not integrated in the stroke cohort model but similar results to those of the STEMI cohort were found in the only hospital of the stroke cohort having implemented it.

Comparison with the literature

Our results showing an increase in the times taken by stroke and STEMI patients to contact the health care system during the COVID pandemic are consistent with the literature, both internationally and in France.(6,13,30) Mesnier et al, in a French cohort of 1,167 STEMI patients, found stable symptom onset to hospital admission times along the study period (from 4 weeks before to 4 weeks after the lockdown implementation). However, any comparison between our two studies is made difficult by differences in the management times studied and the study periods.(7)

Elsewhere, by calling the emergency services more frequently, patients followed the national recommendations, which were widely publicised in the French media at the time of the health crisis. While some studies have found a global decrease of STEMI and stroke patient admissions during the per-wave period, based on average figures over the whole period,(31) we have highlighted variation of these admissions in two steps, with a first decrease at the beginning of the per-wave period followed by a progressive increase afterward. This findings, also retrieved by other surveys conducted at the regional or national level in France, emerge from the detailed and precise analysis of the evolution of hospital admissions during the per-wave period.(32,33) Our descriptive results highlighted that stroke patients were younger, and had less severe strokes during the per-wave compared to the pre-wave period. If some studies, including one meta-analysis, retrieved more severe and older patients during the first wave of the pandemic, several others found consistent results with ours.(31,34–38) Wallace and al interpreted these inconsistent results as a consequence of the variations between regions of the virus spread and of the fear of contracting Covid-19 at the hospital. Another explanation is linked to the various inclusion criteria, most studies having–included patients with transient ischemic attacks; this condition was excluded from ours. These patients with resolving and lighter symptoms were more likely to avoid hospital admission by fear of contracting the Covid-19 virus at the hospital. Lastly, the knowledge of the origin of hospitalized patients (home, nursing homes, other hospital) would have been useful to analyze this result; this information was however not available in our databases.

The literature presents mixed results on the impact of the COVID-19 pandemic on the quality of stroke and STEMI management.(13–16) Our data help to validate the hypothesis that these discordant results could be explained by the various policies implemented and to the heterogeneity of the hospital organizations. To our knowledge, no study has analyzed at regional level the impact of reorganizations implemented by hospitals to deal with the health care crisis in the management of stroke and STEMI patients. Only a few studies can be retrieved consisting in feedbacks on reorganizations implemented at a local level.(11,39,40)

Strength and weaknesses

Our study is based on the analysis of two high quality databases including a large number of stroke and STEMI patients managed in a large panel of care structures in the Aquitaine region. The broad geographical scope of patient inclusion, ensuring a wide range of clinical and management characteristics and the historical depth of the data constitutes a major strength of the study.

Our sample was representative of stroke and STEMI patients managed at hospital. However, patients who did not enter into the health care system, because either they have died before or they did not benefit from hospital care, were not included. These inclusion criteria prevented us to quantify this phenomenon of avoidance of the health care system that is supposed to have been more frequent during the COVID-19 crisis and may have generated selection bias. Moreover, the STEMI cohort included recent STEMI patients less than 24 hours old. Literature found a higher proportion of « late comers » STEMI (admitted over 24h after the symptom onset) during the COVID-19 pandemic, with more mechanical complications and higher mortality.(41) The exclusion of these patients from our study may have generated a selection bias inducing a risk of underestimation of the increase delay to use of care.

We conducted an original systematic and exhaustive ad hoc collection of the reorganizations implemented by hospitals to cope with the COVID-19 pandemic in the management of stroke and STEMI patients. However, we cannot exclude errors in the answers given in the questionnaires field by the health care professionals, particularly concerning the dates on which organizations were implemented or terminated, due to memory bias. For reasons of feasibility, it was not possible to interview several different people for the same questionnaire and to cross-check the answers.

The explanatory analyses present robust results, including appropriate confusion variables identified by the DAG method. The large panel of data collected allowed the integration of a large variety of confusion factors, including clinical characteristics, socio-geographical factors, and acute care management pathway data and hospital activity. In the stroke cohort, the symptoms-to-FMC time containing a lot of missing data (20%), we have taken the decision to exclude this variable from the main model to favor the power of our analysis. The absence of a systematic mechanism identified to explain these missing data did not allow us to take them into account through multiple imputations. A sensitivity analysis carried out by including this variable as an explanatory variable did not change our main results and confirmed their robustness.

Our primary endpoints were the care management times, which are major prognostic issues in the management of stroke and STEMI, and sensitive to intra-hospital organizational changes. They were used as continuous variables, to optimize the power of the study. Use of an end-point expressed as a proportion of patients managed within the recommended time frame would have been interesting as it would have had strong operational implications. For statistical reasons, it was not possible to do this (only 3.3% of patients with a first imaging within 20 minutes, recommended target time).

A major methodological issue consisted in the setting up of the per-wave period time limits that were defined according to the implementation of the health care reorganizations and society functioning transformations to fight against the Covid-19 pandemic. Therefore, we had the per-wave period begin in the same time with the first hospital reorganizations implementation, and end at the end of the lockdown, corresponding with the restoration of a more sustained hospital activity and the beginning of the gradual reduction of reorganizations. The post-wave period was also an important issue of our study to analyze the evolution of patient management. However, while the CNV registry proceed to continuous data collection and inclusions, we had to stop follow-up period at the end of august, to be able to produce not too late results. The inclusion of the summer period was inescapable but we think it did generate any bias because no summer season variation has been shown neither in stroke and STEMI inclusion nor in stroke and STEMI management delays during the previous years.

The geographical data perimeter was limited to the Aquitaine region, which have been one of the regions least affected by the pandemic during the first wave.(6) We hypothesis that some reorganizations such as "decrease in no-COVID patients management and admission capacities in EU" that have had no impact on STEMI and stroke patient management times in our study, would have had negative effects on the management of no-COVID conditions in regions with saturated EU. Indeed, the impact of these EU focused reorganizations may be more sensitive to patient influx. Moreover, there is every reason to believe that the impact of global and structural reorganizations such as "Plan blanc" should be the same in any place, whatever the spread of the outbreak. As use of care have been shown not to vary according to the strength of the pandemic's spread, our results on this topic are thought not to be specific of our region.(33) All the same, it would be interesting to conduct the same study in another region of France or another country, more affected by the pandemic to test the external validity of our results.

Finally, the question of the generalizability of our results to other conditions than stroke and STEMI is posed. Stroke and STEMI constitutes two models of conditions managed in emergency within a defined pathway. We think our results may be extend to other similar conditions requiring urgent management in a coordinated pathway, such as respiratory distress or life-threatening bleeding.

Perspectives

This is the first of a three-step project on the impact of the COVID-19 pandemic on stroke and STEMI patient management. Two other questions are arising concerning: 1) the clinical and social health inequalities in stroke and STEMI patient management, induced or reinforced by the Covid-19 crisis. 2) the impact of the COVID-19 pandemic on the stroke and STEMI patient long term mortality and morbidity.

Conclusions

Our study results are in favour of the absence of a deep and global altering of emergency pathways structuration during the pandemic with however a deterioration of stroke patient management. The resilience of the STEMI pathway was interpreted as linked with its stronger structuration. Our results seem also to show that transversal reorganizations aiming at concentrate resources on the whole emergency care network, such as "plan blanc", contributed to maintaining quality of care of stroke and

STEMI, the two most-frequent conditions requiring emergency management. These results can be extended to other time-sensitive conditions that require coordination of all EMS and benefit from a defined pathway.

- **Data sharing statement**

Deidentified participant data will be available upon reasonable request. Proposals may be submitted to the corresponding author. Data requestors will need to sign a data access agreement

- **Ethics statements**

Patient consent for publication

Not applicable.

According to French authority on data protection "Commission Nationale Informatique et Libertés", in the category of studies not involving humans based on secondary use of health data, the CNV registry met regulatory requirements for patient information and do not require a patient consent form.

Ethics approval

The CNV registry has been approved by the French authority on data protection (file 2216283).

- **Authors' contributions**

Conceiving, design and coordination of the study: FSG, EL, SD, FS
Literature search: FSG, EL, FF, MB, QL
Data collection: EL, FS, MB, QL
Data analysis: SD, SMH
Data interpretation: FSG, EL, SD, FS, FF, LC, PC, FR, IS, CP
Writing: FSG, EL, SD, FF, LC, PC, FR, IS, CP

- **Competing interests statement**

The authors declare that they have no competing interests with this study.

- **Funding statement**

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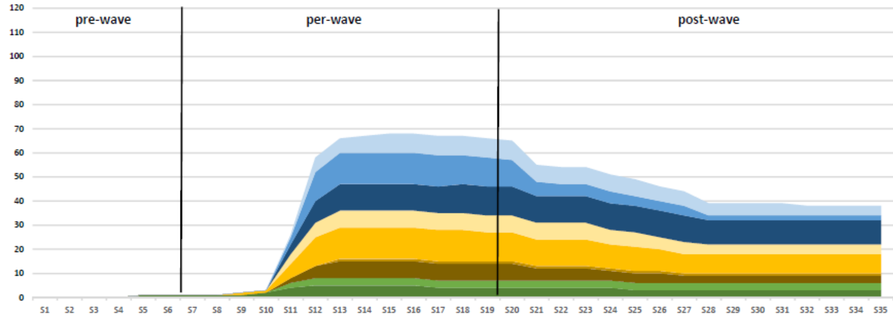
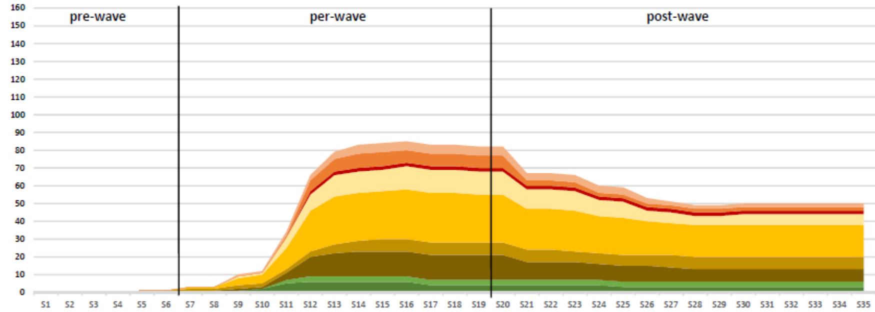
Stroke cohort



Reorganization categories*	pre-wave				per-wave				post-wave			
	min	(%)	max	(%)	min	(%)	max	(%)	min	(%)	max	(%)
EMS (N=5)												
Increase in the telephone reception capacities	0	(0.0)	1	(20.0)	1	(20.0)	5	(100.0)	3	(60.0)	4	(80.0)
Restriction of helicopter transport for Covid patients	0	(0.0)	0	(0.0)	0	(0.0)	3	(60.0)	3	(60.0)	3	(60.0)
Emergency unit (N=14)												
"Plan blanc"	0	(0.0)	0	(0.0)	0	(0.0)	7	(50.0)	3	(21.4)	7	(50.0)
Systematic Covid testing	0	(0.0)	0	(0.0)	0	(0.0)	1	(7.1)	1	(7.1)	1	(7.1)
Separate Covid/no-Covid patients pathway	0	(0.0)	0	(0.0)	0	(0.0)	13	(92.9)	8	(57.1)	12	(85.7)
Decrease in no-Covid patients management and admission capacities	0	(0.0)	0	(0.0)	0	(0.0)	7	(50.0)	4	(28.6)	7	(50.0)
Hospitalisation unit (N=14)												
Specific access to imaging for Covid patients	0	(0.0)	0	(0.0)	0	(0.0)	12	(85.7)	10	(71.4)	12	(85.7)
Deprogramming of non-urgent procedures or hospitalizations	0	(0.0)	0	(0.0)	0	(0.0)	13	(92.9)	2	(14.3)	11	(78.6)
Decrease in bed capacity for no-Covid patients	0	(0.0)	0	(0.0)	0	(0.0)	8	(57.1)	4	(28.6)	8	(57.1)

* minimal and maximal number of structures having implemented each reorganisation among the three periods - (%) : percentage calculated on total number of structures concerned

STEMI cohort



Reorganization categories*	pre-wave				per-wave				post-wave			
	min	(%)	max	(%)	min	(%)	max	(%)	min	(%)	max	(%)
EMS (N=6)												
Increase in the telephone reception capacities	0	(0.0)	1	(16.7)	1	(16.7)	6	(100.0)	3	(50.0)	4	(66.7)
Restriction of helicopter transport for Covid patients	0	(0.0)	0	(0.0)	0	(0.0)	3	(50.0)	3	(50.0)	3	(50.0)
Emergency unit (n=30)												
"Plan blanc"	0	(0.0)	0	(0.0)	0	(0.0)	14	(46.7)	7	(23.3)	14	(46.7)
Systematic Covid testing	0	(0.0)	0	(0.0)	1	(3.3)	7	(23.3)	6	(20.0)	7	(23.3)
Separate Covid/no-Covid patients pathway	0	(0.0)	0	(0.0)	1	(3.3)	28	(93.3)	18	(60.0)	27	(90.0)
Decrease in no-Covid patients management and admission capacities	0	(0.0)	0	(0.0)	0	(0.0)	13	(43.3)	5	(16.7)	13	(43.3)
Cathlabs (n=11)												
Coronary angiography room dedicated to Covid patients	0	(0.0)	0	(0.0)	0	(0.0)	2	(18.2)	2	(18.2)	2	(18.2)
Deprogramming of non-urgent procedures or hospitalizations	0	(0.0)	0	(0.0)	0	(0.0)	8	(72.7)	2	(18.2)	7	(63.6)
Decrease in bed capacity for no-Covid patients	0	(0.0)	0	(0.0)	0	(0.0)	5	(45.5)	2	(18.2)	5	(45.5)

* minimal and maximal number of structures having implemented each reorganisation among the three periods - (%) : percentage calculated on total number of structures concerned

Figure 1. Weekly cumulated number of care structures having implemented reorganizations, by reorganization category– Minimum and maximum number and proportion of care structures having implemented reorganization, by reorganization category and by period (pre, per, post-wave)

EMS=emergency medical service; EU=emergency unit

Created by the authors

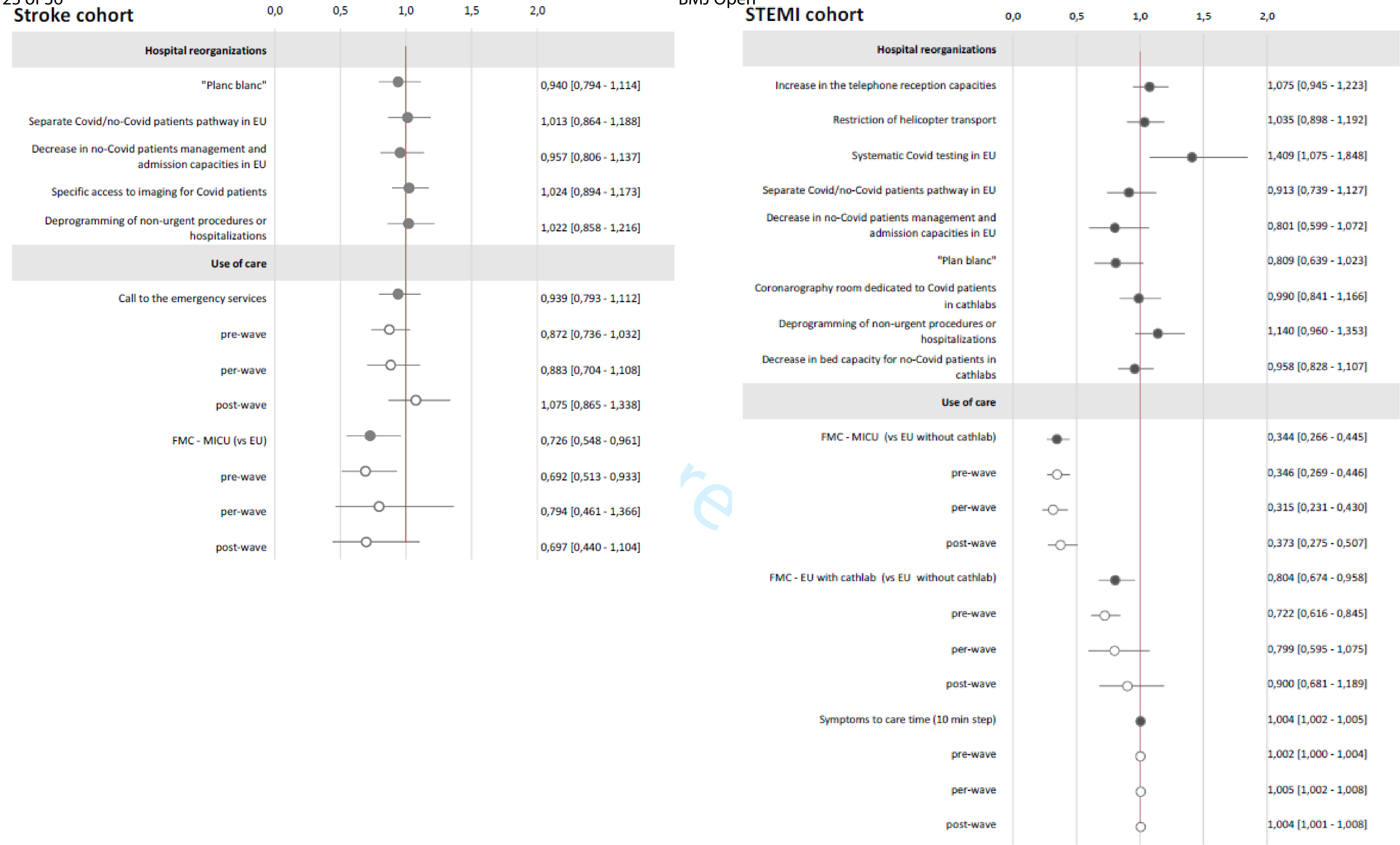

Stroke cohort
0,0
0,5
1,0
1,5
2,0
Hospital reorganizations
"Planc blanc" 0,940 [0,794 - 1,114]
Separate Covid/no-Covid patients pathway in EU 1,013 [0,864 - 1,188]
Decrease in no-Covid patients management and admission capacities in EU 0,957 [0,806 - 1,137]
Specific access to imaging for Covid patients 1,024 [0,894 - 1,173]
Deprogramming of non-urgent procedures or hospitalizations 1,022 [0,858 - 1,216]
Use of care
Call to the emergency services 0,939 [0,793 - 1,112]
pre-wave 0,872 [0,736 - 1,032]
per-wave 0,883 [0,704 - 1,108]
post-wave 1,075 [0,865 - 1,338]
FMC - MICU (vs EU) 0,726 [0,548 - 0,961]
pre-wave 0,692 [0,513 - 0,933]
per-wave 0,794 [0,461 - 1,366]
post-wave 0,697 [0,440 - 1,104]
STEMI cohort
0,0
0,5
1,0
1,5
2,0
Hospital reorganizations
Increase in the telephone reception capacities 1,075 [0,945 - 1,223]
Restriction of helicopter transport 1,035 [0,898 - 1,192]
Systematic Covid testing in EU 1,409 [1,075 - 1,848]
Separate Covid/no-Covid patients pathway in EU 0,913 [0,739 - 1,127]
Decrease in no-Covid patients management and admission capacities in EU 0,801 [0,599 - 1,072]
"Plan blanc" 0,809 [0,639 - 1,023]
Coronarography room dedicated to Covid patients in cathlabs 0,990 [0,841 - 1,166]
Deprogramming of non-urgent procedures or hospitalizations 1,140 [0,960 - 1,353]
Decrease in bed capacity for no-Covid patients in cathlabs 0,958 [0,828 - 1,107]
Use of care
FMC - MICU (vs EU without cathlab) 0,344 [0,266 - 0,445]
pre-wave 0,346 [0,269 - 0,446]
per-wave 0,315 [0,231 - 0,430]
post-wave 0,373 [0,275 - 0,507]
FMC - EU with cathlab (vs EU without cathlab) 0,804 [0,674 - 0,958]
pre-wave 0,722 [0,616 - 0,845]
per-wave 0,799 [0,595 - 1,075]
post-wave 0,900 [0,681 - 1,189]
Symptoms to care time (10 min step) 1,004 [1,002 - 1,005]
pre-wave 1,002 [1,000 - 1,004]
per-wave 1,005 [1,002 - 1,008]
post-wave 1,004 [1,001 - 1,008]

Figure 2. Stroke and STEMI cohorts. Estimation of the reorganizations and use of care effects (95% confidence interval) on care management times.

Stroke cohort (N=4 603) – Estimated overall effects expressed as exp(β) with 95% CI; results of multivariate linear regression mixed models; variable to be explained: Y = log (EU admission-to-imaging time); results adjusted on period, age, gender, urbanicity of residence, FDep15, APL MG 18, residence-EU distance, presence of stroke unit, MRI 24 hours a day, presence of interventional neuroradiology unit, care during on-call activity, mode of transport, call to the emergency services activity, mRS less than 1 before stroke, NIHSS at entry, previous stroke or transient ischemic attack.

STEMI cohort (N=1 843) – Estimated overall effects expressed as exp(β) with 95% CI; results of multivariate linear regression mixed models; variable to be explained: Y=log (FMC-to-procedure time); results adjusted on period, age, gender, urbanicity of residence, FDep15, APL MG 18, residence-to-cathlab distance, cathlab hospital status, care during on-call activity, mode of transport, call to the emergency services activity, FMC-to-cathlab distance, diabetes mellitus, coronary artery disease or STEMI history).

Light grey: interaction with the COVID period, Dark grey: raw results without interaction with the COVID period

APL MG 2018=potential accessibility to general practitioners; EU=emergency unit; FDep15=deprivation index; FMC=first medical contact; MICU=mobile intensive care units; MRI=magnetic resonance imaging; mRS=modified Rankin Scale; NIHSS=National Institute of Health Stroke Score; STEMI=segment elevation myocardial infarction.

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Supplementary material 1.

Method of the scoping review

The method of the scoping review was conducted to retrieve the structural reorganizations implemented in care structures to deal with the first wave of the COVID-19 pandemic in the acute management of stroke or STEMI.
Two categories of information sources were systematically explored:

- **Written English or French-language documents**

All written English or French-language documents published between January and December 2020 were retrieved without geographical limitation:

- scientific articles analysing the impact of the first wave of Covid-19 pandemic on stroke and STEMI management;
- government reports, professional stroke or STEMI guidelines providing guidance on the management of stroke and STEMI patients during the COVID-19 pandemic;
- published feedback on hospital management of stroke and STEMI patients during the first wave of the COVID-19 pandemic.

The following sources were consulted:

- computerized bibliographic database “Pubmed” and “Scopus” with the following algorithm TITLE-ABS-KEY (Pathway OR organization OR use of care) AND (COVID-19 OR SARS-CoV-2) AND (stroke OR STEMI) AND (effect OR effectiveness OR impact);
- “Google" search engine with the keywords "Organizations", "hospital unit", or "hospital", "COVID-19";
- French Health Ministry (Ministère des solidarités et de la santé) website in search of reports on organizational recommendations for hospital in the management of the Covid-19 pandemic;
- French societies of cardiology, emergency medicine, and neurology (Société Française de Neuro-Vasculaire, Société Française de Cardiologie, Société Française de Médecine d’Urgence) websites in search of clinical recommendations in the management of stroke and STEMI patients in the context of the Covid-19 pandemic.

After a pre-selection on the title and the abstract, the complete reading of the articles allowed to filter out the articles that did not describe any structural organizations. Then, organizational data was independently collected on a dedicated collection grid. If necessary, a common reading was carried out.

- **Structured telephone interviews**

In December 2020, structured telephone interviews were conducted with healthcare professionals involved in stroke or STEMI management in hospitals in the Aquitaine Region, to question them on the organizations they had to cope with during the first wave of the pandemic in stroke and STEMI patients’ management. Among the 16 approached professionals, eight (2 nurses, 2 emergency physicians, 2 cardiologists, and 2 neurologists) from 8 hospitals accepted to participate. Questions asked were: "What reorganizations were implemented during the first wave?"; "Have you been provided with facilities for this reorganization?"; "Have you received help from professionals in other services?"; "Did you expand/reduce your capacity? ". Responses were transcribed as the interview progressed. Each verbatim was reviewed by the two interviewers in collaboration with the AVICOVID principal investigator.

Supplementary material 2.

Confounding variables introduced in the stroke and STEMI final model estimating the association between reorganizations and use of care effects on care management times

Category of variables	Stroke cohort Model	STEMI Cohort Model
Time	Period (pre, per, post-wave)	Period (pre, per, post-wave)
Socio-demographic characteristics	Age, gender	Age, gender
Geographical indexes	Urbanicity, FDep15, APL MG 2018, residence-EU distance	Urbanicity, FDep15, APL MG 2018, residence-to-cathlab distance
Clinical characteristics	mRS less than 1 before stroke, NIHSS at entry, previous stroke or transient ischemic attack	Diabetes mellitus, history of coronary artery disease or of STEMI
Acute care management quality	Mode of transport	Mode of transport
Structural characteristics of care	call to the emergency services activity during care, care during on-call activity, presence of stroke unit, availability of MRI 24 hours a day, presence of interventional neuroradiology unit	call to the emergency services activity during care, care during on-call activity, cathlab hospital status, FMC-to-cathlab distance

APL MG 2018=potential accessibility indicator to general practitioners; EU=emergency unit; FDep15=deprivation index; FMC=first medical contact; MRI=magnetic resonance imaging; mRS=modified Rankin Scale; NIHSS=National Institute of Health Stroke Score; STEMI=segment elevation myocardial infarction.

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Supplementary material 3.

Description of the stroke cohort study sample (N=6,436)

	Global (N=6,436)		pre-wave (N=4,140)		per-wave (N=1,080)		post-wave (N=1,216)	
	n	(%)	n	(%)	n	(%)	n	(%)
Patient socio-demographic characteristics								
Gender	6,436		4,140		1,080		1,216	
Male	3,533	(54.9)	2,264	(54.7)	589	(54.5)	680	(55.9)
Female	2,903	(45.1)	1,876	(45.3)	491	(45.5)	536	(44.1)
Age	6,436		4,140		1,080		1,216	
Median [IQR]	78	[68;87]	79	[69;87]	77	[68;86]	76	[68;85]
Urbanicity	6,153		3,882		1,072		1,199	
Urban	4,451	(72.3)	2,816	(72.5)	786	(73.3)	849	(70.8)
Rural	1,702	(27.7)	1,066	(27.5)	286	(26.7)	350	(29.2)
Missing values	283		258		8		17	
Fdep15	6,145		3,878		1,070		1,197	
Median [IQR]	0.10	[-0.96;1.14]	0.10	[-1.02;1.22]	-0.01	[-0.98;1.11]	0.08	[-0.88;1.11]
Missing values	291		262		10		19	
APL MG 2018	6,171		3,891		1,076		1,204	
Median [IQR]	4.3	[3.4;5.0]	4.3	[3.4;5.0]	4.3	[3.4;5.0]	4.2	[3.4;5.1]
Missing values	265		249		4		12	
Residence-EU distance (km)	6,179		3,897		1,077		1,205	
Median [IQR]	17	[6;32]	17	[6;33]	16	[5;28]	18	[7;34]
Missing values	*257*		*243*		*3*		*11*	
Patient clinical characteristics								
Stroke type	6,436		4,140		1,080		1,216	
Ischaemic	5,669	(88.1)	3,617	(87.4)	941	(87.1)	1,111	(91.4)
Haemorragic	767	(11.9)	523	(12.6)	139	(12.9)	105	(8.6)
Coronary artery disease	6,436		4,140		1,080		1,216	
Absence	5,877	(91.3)	3,778	(91.3)	987	(91.4)	1,112	(91.4)
Presence	559	(8.7)	362	(8.7)	93	(8.6)	104	(8.6)
Previous STEMI	6,436		4,140		1,080		1,216	
Absence	6,057	(94.1)	3,886	(93.9)	1,017	(94.2)	1,154	(94.9)
Presence	379	(5.9)	254	(6.1)	63	(5.8)	62	(5.1)
Previous stroke or transient ischemic attack	6,436		4,140		1,080		1,216	
Absence	5,166	(80.3)	3,305	(79.8)	882	(81.7)	979	(80.5)
Presence	1,270	(19.7)	835	(20.2)	198	(18.3)	237	(19.5)
Diabetes mellitus	6,436		4,140		1,080		1,216	
Absence	5,198	(80.8)	3,352	(81.0)	894	(82.8)	952	(78.3)
Presence	1,238	(19.2)	788	(19.0)	186	(17.2)	264	(21.7)
Hypertension	6,436		4,140		1,080		1,216	
Absence	2,419	(37.6)	1,538	(37.1)	437	(40.5)	444	(36.5)
Presence	4,017	(62.4)	2,602	(62.9)	643	(59.5)	772	(63.5)
Dyslipidemia	6,436		4,140		1,080		1,216	
Absence	4,618	(71.8)	2,973	(71.8)	786	(72.8)	859	(70.6)
Presence	1,818	(28.2)	1,167	(28.2)	294	(27.2)	357	(29.4)
Smoking	6,436		4,140		1,080		1,216	
Absence	5,103	(79.3)	3,290	(79.5)	846	(78.3)	967	(79.5)
Presence	1,333	(20.7)	850	(20.5)	234	(21.7)	249	(20.5)
Atheroma of the supra-aortic arteris	6,436		4,140		1,080		1,216	
Absence	6,213	(96.5)	4,015	(97.0)	1,027	(95.1)	1,171	(96.3)
Presence	223	(3.5)	125	(3.0)	53	(4.9)	45	(3.7)
Peripheral artery disease	6,436		4,140		1,080		1,216	
Absence	6,144	(95.5)	3,959	(95.6)	1,023	(94.7)	1,162	(95.6)
Presence	292	(4.5)	181	(4.4)	57	(5.3)	54	(4.4)
Atrial fibrillation	6,436		4,140		1,080		1,216	
Absence	5,348	(83.1)	3,432	(82.9)	885	(81.9)	1,031	(84.8)
Presence	1,088	(16.9)	708	(17.1)	195	(18.1)	185	(15.2)
Cardiac failure	6,436		4,140		1,080		1,216	
Absence	6,114	(95.0)	3,934	(95.0)	1,021	(94.5)	1,159	(95.3)
Presence	322	(5.0)	206	(5.0)	59	(5.5)	57	(4.7)
Psychiatry	6,436		4,140		1,080		1,216	
Absence	5,759	(89.5)	3,672	(88.7)	988	(91.5)	1,099	(90.4)
Presence	677	(10.5)	468	(11.3)	92	(8.5)	117	(9.6)
mRS less than 1 before stroke	6,436		4,140		1,080		1,216	
No	961	(14.9)	660	(15.9)	153	(14.2)	148	(12.2)
Yes	3,709	(57.6)	2,292	(55.4)	673	(62.3)	744	(61.2)
Unknown	1,766	(27.4)	1,188	(28.7)	254	(23.5)	324	(26.6)
NIHSS at entry	6,436		4,140		1,080		1,216	
[0-6]	3,489	(54.2)	2,185	(52.8)	607	(56.2)	697	(57.3)
[7-16]	1,128	(17.5)	749	(18.1)	184	(17)	195	(16.0)

[17-42]	761	(11.8)	522	(12.6)	110	(10.2)	129	(10.6)
Unknown	1,058	(16.4)	684	(16.5)	179	(16.6)	195	(16.0)
Structural characteristics of care								
Call to the emergency services activity during care (intensity of daily number of calls)	6,436		4,140		1,080		1,216	
Not high	899	(14.0)	608	(14.7)	140	(13)	151	(12.4)
Moderate	1,948	(30.3)	1,268	(30.6)	264	(24.4)	416	(34.2)
High	1,184	(18.4)	669	(16.2)	303	(28.1)	212	(17.4)
Not concerned (no call to the emergency services)	2,405	(37.4)	1,595	(38.5)	373	(34.5)	437	(35.9)
Care during on-call activity	6,411		4,122		1,080		1,209	
Monday-Friday [8h-18h30]	3,351	(52.3)	2,178	(52.8)	565	(52.3)	608	(50.3)
Monday-Friday [18h30-20h]	338	(5.3)	212	(5.1)	55	(5.1)	71	(5.9)
Week-end and holiday [8h-20h]	1,328	(20.7)	829	(20.1)	233	(21.6)	266	(22.0)
Night [20h-8h]	1,394	(21.7)	903	(21.9)	227	(21.0)	264	(21.8)
Missing values	25		18		0		7	
EU hospital status	6,436		4,140		1,080		1,216	
University hospital	2,441	(37.9)	1,654	(40.0)	348	(32.2)	439	(36.1)
General hospital	3,879	(60.3)	2,410	(58.2)	715	(66.2)	754	(62.0)
Private hospital	116	(1.8)	76	(1.8)	17	(1.6)	23	(1.9)
Availability of MRI 24 hours a day	6,436		4,140		1,080		1,216	
No	1,694	(26.3)	1,061	(25.6)	291	(26.9)	342	(28.1)
Yes	4,742	(73.7)	3,079	(74.4)	789	(73.1)	874	(71.9)
Presence of stroke unit	6,436		4,140		1,080		1,216	
No	1,245	(19.3)	799	(19.3)	197	(18.2)	249	(20.5)
Yes	5,191	(80.7)	3,341	(80.7)	883	(81.8)	967	(79.5)
Presence of interventional neuroradiology unit	6,436		4,140		1,080		1,216	
No	3,304	(51.3)	2,102	(50.8)	551	(51.0)	651	(53.5)
Yes	3,132	(48.7)	2,038	(49.2)	529	(49.0)	565	(46.5)

APL MG 2018=potential accessibility indicator to general practitioners; EU=emergency unit; FDep15=deprivation index; MRI=magnetic resonance imaging; mRS=modified Rankin Scale; NIHSS=National Institute of Health Stroke Score; STEMI=segment elevation myocardial infarction.
Created by the authors

Description of the STEMI cohort study sample (N=2,782)

	Global (N=2,782)		Pre-wave (N=1,868)		Per-wave (N=407)		Post-wave (N=507)	
	n	(%)	n	(%)	n	(%)	n	(%)
Patient socio-demographic characteristics								
Gender	2,782		1,868		407		507	
Male	2,033	(73.1)	1,352	(72.4)	309	(75.9)	372	(73.4)
Female	749	(26.9)	516	(27.6)	98	(24.1)	135	(26.6)
Age	2,776		1,865		405		506	
Median [IQR]	65	[55;74]	65	[55;74]	65	[55;74]	64	[54;74]
Missing values	6		3		2		1	
Urbanicity	2,543		1,691		380		472	
Urban	1,843	(72.5)	1,221	(72.2)	277	(72.9)	345	(73.1)
Rural	700	(27.5)	470	(27.8)	103	(27.1)	127	(26.9)
Missing values	239		177		27		35	
Fdep15	2,537		1,690		380		467	
Median [IQR]	0.22	[-0.72;1.09]	0.23	[-0.70;1.09]	0.11	[-0.89;1.11]	0.22	[-0.72;1.09]
Missing values	245		178		27		40	
APL MG 2018	2,537		1,689		380		468	
Median [IQR]	4.3	[3.4;4.9]	4.3	[3.4;4.9]	4.2	[3.3;4.9]	4.4	[3.5;5.0]
Missing values	245		179		27		39	
Residence-to-cathlab distance (km)	2,541		1,692		379		470	
Median [IQR]	29	[10;54]	28	[10;54]	29	[10;52]	32	[12;58]
Missing values	241		176		28		37	
Patient clinical characteristics								
Coronary artery disease or STEMI history	2,782		1,868		407		507	
No	2,031	(73.0)	1,342	(71.8)	317	(77.9)	372	(73.4)
Yes	530	(19.1)	365	(19.5)	69	(16.9)	96	(18.9)
Unknown	221	(7.9)	161	(8.6)	21	(5.2)	39	(7.7)
Diabetes mellitus	2,782		1,868		407		507	
No	2,119	(76.2)	1,400	(74.9)	318	(78.1)	401	(79.1)
Yes	414	(12.9)	290	(15.5)	59	(14.5)	65	(12.8)
Unknown	249	(9.0)	178	(9.5)	30	(7.4)	41	(8.1)
Dyslipidemia	2,782		1,868		407		507	
No	1,708	(61.4)	1,133	(60.7)	249	(61.2)	326	(64.3)
Yes	887	(31.9)	601	(32.2)	135	(33.2)	151	(29.8)
Unknown	187	(6.7)	134	(7.2)	23	(5.7)	30	(5.9)
Active smoking	2,782		1,868		407		507	
No	1,194	(42.9)	787	(42.1)	183	(45.0)	224	(44.2)
Yes	1,163	(41.8)	785	(42.0)	164	(40.3)	214	(42.2)
Unknown	425	(15.3)	296	(15.8)	60	(14.7)	69	(13.6)
Peripheral arterial disease	2,782		1,868		407		507	
No	2,245	(80.7)	1,487	(79.6)	339	(83.3)	419	(82.6)
Yes	70	(2.5)	40	(2.1)	16	(3.9)	14	(2.8)
Unknown	467	(16.8)	341	(18.3)	52	(12.8)	74	(14.6)
Obesity	2,782		1,868		407		507	
No	1,801	(64.7)	1,229	(65.8)	252	(61.9)	320	(63.1)
Yes	513	(18.4)	332	(17.8)	87	(21.4)	94	(18.5)
Unknown	468	(16.8)	307	(16.4)	68	(16.7)	93	(18.3)
Familial history of coronary artery disease	2,782		1,868		407		507	
No	2,070	(74.4)	1,367	(73.2)	308	(75.7)	395	(77.9)
Yes	455	(16.4)	317	(17.0)	64	(15.7)	74	(14.6)
Unknown	257	(9.2)	184	(9.9)	35	(8.6)	38	(7.5)
Chronic renal failure	2,782		1,868		407		507	
No	2,264	(81.4)	1,493	(79.9)	344	(84.5)	427	(84.2)
Yes	47	(1.7)	31	(1.7)	10	(2.5)	6	(1.2)
Unknown	471	(16.9)	344	(18.4)	53	(13.0)	74	(14.6)
Arterial hypertension	2,782		1,868		407		507	
No	1,278	(45.9)	866	(46.4)	168	(41.3)	244	(48.1)
Yes	1,356	(48.7)	897	(48.0)	220	(54.1)	239	(47.1)
Unknown	148	(5.3)	105	(5.6)	19	(4.7)	24	(4.7)
Structural characteristics of care								
Call to the emergency services activity (intensity of daily number of calls)	2,782		1,868		407		507	
Not high	440	(15.8)	303	(16.2)	63	(15.5)	74	(14.6)
Moderate	1,093	(39.3)	744	(39.8)	143	(35.1)	206	(40.6)
High	642	(23.1)	399	(21.4)	127	(31.2)	116	(22.9)
Not concerned (no call to the emergency services)	607	(21.8)	422	(22.6)	74	(18.2)	111	(21.9)
Care during on-call activity	2,712		1,821		395		496	

Monday-Friday [8h-18h30]	1,116	(41.2)	741	(40.7)	164	(41.5)	211	(42.5)
Monday-Friday [18h30-20h]	133	(4.9)	90	(4.9)	21	(5.3)	22	(4.4)
Week-end and holiday [8h-20h]	547	(20.2)	368	(20.2)	68	(17.2)	111	(22.4)
Night [20h-8h]	916	(33.8)	622	(34.2)	142	(35.9)	152	(30.6)
Missing values	70		47		12		11	
EU hospital status	2,782		1,868		407		507	
University hospital	71	(2.6)	48	(2.6)	7	(1.7)	16	(3.2)
General hospital	839	(30.2)	564	(30.2)	114	(28)	161	(31.8)
Private hospital	275	(9.9)	187	(10)	39	(9.6)	49	(9.7)
Not concerned (not managed by EU)	1,597	(57.4)	1,069	(57.2)	247	(60.7)	281	(55.4)
Cathlab hospital status	2,782		1,868		407		507	
University hospital	624	(22.4)	417	(22.3)	96	(23.6)	111	(21.9)
General hospital	1,015	(36.5)	661	(35.4)	154	(37.8)	200	(39.4)
Private hospital	975	(35.0)	666	(35.7)	136	(33.4)	173	(34.1)
Not concerned (not managed by cathlab)	168	(6.0)	124	(6.6)	21	(5.2)	23	(4.5)
FMC-to-cathlab distance (km)	2,555		1,703		379		473	
Median [IQR]	21	[0;50]	21	[0;50]	21	[4;48]	24	[0;52]
Missing values	227		165		28		34	

APL MG 2018=potential accessibility indicator to general practitioners; EU=emergency unit; FDep15=deprivation index; FMC=first medical contact; STEMI=segment elevation myocardial infarction.
Created by the authors

Supplementary material 4.

Results of the final model estimating the association between reorganizations and use of care effects on care management times: p-value of the type III global fixed effects test - Stroke cohort (N=4,603)

Variable	p-value
Hospital reorganizations	
'Plan Blanc'	0.372
Separate Covid/no-Covid patients pathway in EU	0.830
Decrease in no-Covid patients management and admission capacities in EU	0.532
Specific access to imaging for Covid patients	0.658
Deprogramming of non-urgent procedures or hospitalizations	0.752
Use of care	
Call to the emergency services	0.360
Interaction period x call to the emergency services	0.039
FMC	0.034
Interaction period x FMC	0.807

Results of multivariate linear regression mixed model; variable to be explained: Y = log (EU admission-to-imaging time); results adjusted on period, age, gender, urbanicity, FDep15, APL MG 18, residence-EU distance, presence of stroke unit, MRI 24 hours a day, presence of interventional neuroradiology unit, care during on-call activity, mode of transport, call to the emergency services activity, mRS less than 1 before stroke, NIHSS at entry, previous stroke or transient ischemic attack

APL MG 2018=potential accessibility indicator to general practitioners; EU=emergency unit; FDep15=deprivation index; FMC=first medical contact; MRI=magnetic resonance imaging; mRS=modified Rankin Scale; NIHSS=National Institute of Health Stroke Score.

Created by the authors

Results of the final model estimating the association between reorganizations and use of care effects on care management times: estimation of regression coefficients - Stroke cohort (N=4,603)

Variable	Modalities		β	p-value
Intercept			4.767	<0.001
Hospital reorganizations				
'Plan Blanc'	yes (ref : no)		-0.061	0.372
Separate Covid/no-Covid patients pathway in EU	yes (ref : no)		0.013	0.830
Decrease in no-Covid patients management and admission capacities in EU	yes (ref : no)		-0.044	0.532
Specific access to imaging for Covid patients	yes (ref : no)		0.024	0.658
Deprogramming of non-urgent procedures or hospitalizations	yes (ref : no)		0.021	0.752
Use of care				
Call to the emergency services	yes (ref : no)		-0.137	0.087
Interaction period x call to the emergency services	*pre-wave*	*no*	-	.
	pre-wave	*yes*	-	.
	per-wave	*no*	-	.
	per-wave	*yes*	0.013	0.850
	post-wave	*no*	-	.
	post-wave	*yes*	0.210	0.014
FMC	MICU (ref : EU)		-0.369	0.027
interaction period x FMC	*pre-wave*	*EU*	-	.
	pre-wave	*MICU*	-	.
	per-wave	*EU*	-	.
	per-wave	*MICU*	0.138	0.536
	post-wave	*EU*	-	.
	post-wave	*MICU*	0.008	0.968

Results of multivariate linear regression mixed model; variable to be explained: Y = log (EU admission-to-imaging time); results adjusted on period, age, gender, urbanicity, FDep15, APL MG 18, residence-EU distance, presence of stroke unit, MRI 24 hours a day, presence of interventional neuroradiology unit, care during on-call activity, mode of transport, call to the emergency services activity, mRS less than 1 before stroke, NIHSS at entry, previous stroke or transient ischemic attack

APL MG 2018=potential accessibility indicator to general practitioners; EU=emergency unit; FDep15=deprivation index; FMC=first medical contact; MICU=mobile intensive care units; MRI=magnetic resonance imaging; mRS=modified Rankin Scale; NIHSS=National Institute of Health Stroke Score.

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Results of the final model estimating the association between reorganizations and use of care effects on care management times: p-value of the type III global fixed effects test - STEMI cohort (N=1,843)

Variable	p-value
Hospital reorganizations	
Increase in the telephone reception capacities	0.273
Restriction of helicopter transport for Covid patients	0.637
'Plan blanc'	0.077
Systematic covid testing in EU	0.013
Separate Covid/no-Covid patients pathway in EU	0.395
Decrease in no-Covid patients management and admission capacities in EU	0.135
Coronarography room dedicated to Covid patients in cathlabs	0.907
Deprogramming of non-urgent procedures or hospitalizations	0.134
Decrease in bed capacity for no-Covid patients in cathlabs	0.557
Use of care	
FMC	<0.001
Interaction period x FMC	0.492
Symptoms-to-care time (10 min step)	<0.001
Interaction period x symptoms-to-care time	0.206

Results of a multivariate linear regression mixed model; variable to be explained: Y=log (FMC-to-procedure time); results adjusted on period, age, gender, urbanicity, FDep15, APL MG 18, residence-to-cathlab distance, cathlab hospital status, care during on-call activity, mode of transport, call to the emergency services activity, FMC-to-cathlab distance, diabetes mellitus, coronary artery disease or STEMI history).
APL MG 2018=potential accessibility indicator to general practitioners; EU=emergency unit; FDep15=deprivation index; FMC=first medical contact; STEMI=segment elevation myocardial infarction.
Created by the authors

Results of the final model estimating the association between reorganizations and use of care effects on care management times: estimation of regression coefficients - STEMI cohort (N=1,843)

Variable	Modalities		β	p-value
Intercept			4.475	<0.001
Hospital reorganizations				
Increase in the telephone reception capacities	yes (ref : no)		0.072	0.273
Restriction of helicopter transport for Covid patients	yes (ref : no)		0.034	0.637
'Plan blanc'	yes (ref : no)		-0.212	0.077
Systematic covid testing in EU	yes (ref : no)		0.343	0.013
Separate Covid/no-Covid patients pathway in EU	yes (ref : no)		-0.092	0.395
Decrease in no-Covid patients management and admission capacities in EU	yes (ref : no)		-0.222	0.135
Coronarography room dedicated to Covid patients in cathlabs	yes (ref : no)		-0.010	0.907
Deprogramming of non-urgent procedures or hospitalizations	yes (ref : no)		0.131	0.134
Decrease in bed capacity for no-Covid patients in cathlabs	yes (ref : no)		-0.043	0.557
Use of care				
FMC	EU without cathlab (ref)		-	.
	MICU		-1.061	<0.001
	EU with cathlab		-0.326	<0.001
interaction period x FMC	*pre-wave*	*EU without cathlab*	-	
	pre-wave	*MICU*	-	
	pre-wave	*EU with cathlab*	-	
	per-wave	*EU without cathlab*	-	
	per-wave	*MICU*	-0.094	0.419
	per-wave	*EU with cathlab*	0.102	0.505
	post-wave	*EU without cathlab*	-	
	post-wave	*MICU*	0.075	0.514
	post-wave	*EU with cathlab*	0.221	0.14
Symptoms-to-care time (10 min step)			0.002	0.016
Interaction period x symptoms-to-care time	*pre-wave (ref)*		-	
	per-wave		0.003	0.137
	post-wave		0.002	0.209

Results of a multivariate linear regression mixed model; variable to be explained: Y=log (FMC-to-procedure time); results adjusted on period, age, gender, urbanicity, FDep15, APL MG 18, residence-to-cathlab distance, cathlab hospital status, care during on-call activity, mode of transport, call to the emergency services activity, FMC-to-cathlab distance, diabetes mellitus, coronary artery disease or STEMI history).

APL MG 2018=potential accessibility indicator to general practitioners; EU=emergency unit; FDep15=deprivation index; FMC=first medical contact; MICU=mobile intensive care units; STEMI=segment elevation myocardial infarction.

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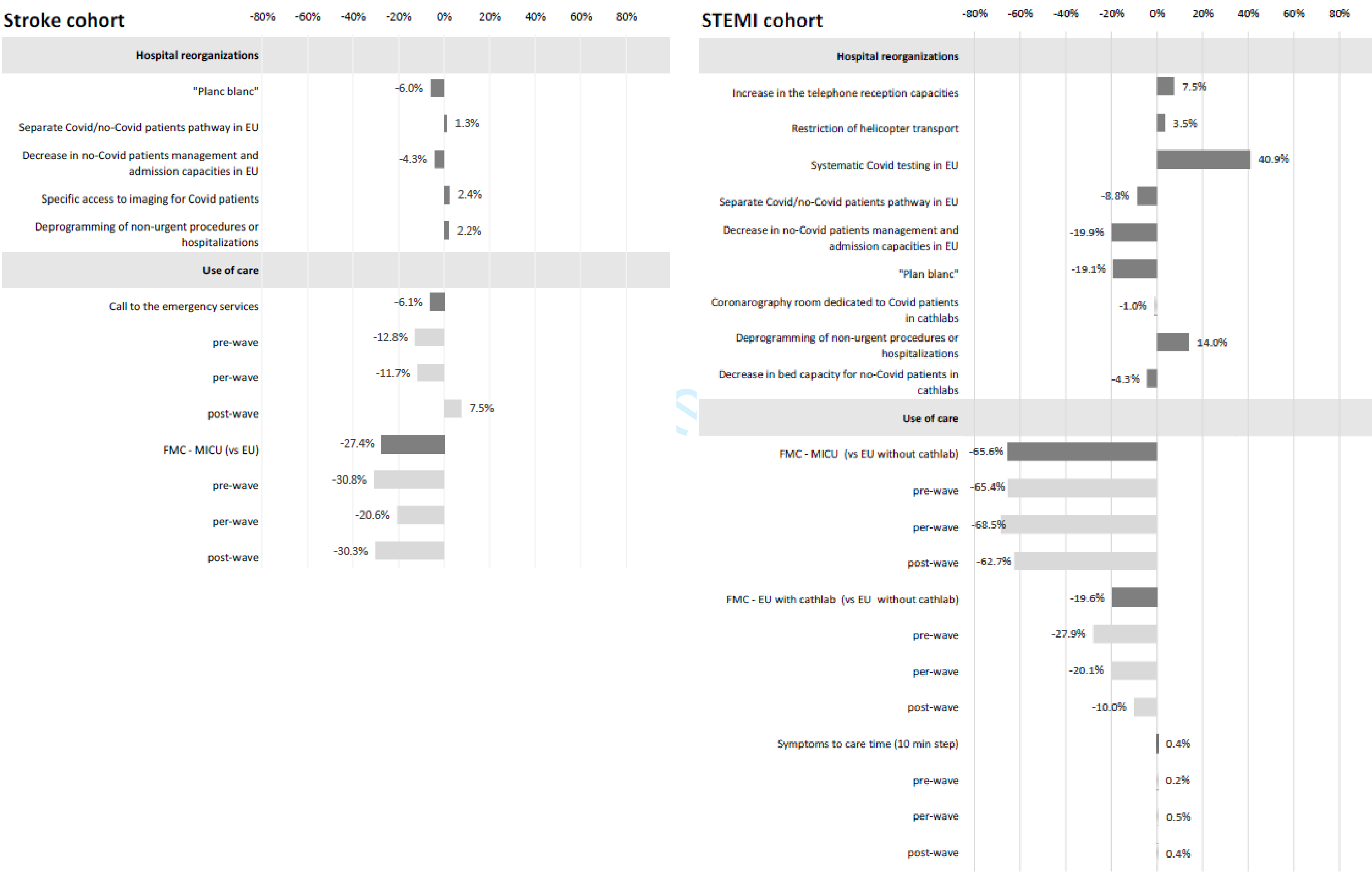

Stroke cohort
-80% -60% -40% -20% 0% 20% 40% 60% 80%
Hospital reorganizations
"Planc blanc" -6.0%
Separate Covid/no-Covid patients pathway in EU 1.3%
Decrease in no-Covid patients management and admission capacities in EU -4.3%
Specific access to imaging for Covid patients 2.4%
Deprogramming of non-urgent procedures or hospitalizations 2.2%
Use of care
Call to the emergency services -6.1%
pre-wave -12.8%
per-wave -11.7%
post-wave 7.5%
FMC - MICU (vs EU) -27.4%
pre-wave -30.8%
per-wave -20.6%
post-wave -30.3%
STEMI cohort
-80% -60% -40% -20% 0% 20% 40% 60% 80%
Hospital reorganizations
Increase in the telephone reception capacities 7.5%
Restriction of helicopter transport 3.5%
Systematic Covid testing in EU 40.9%
Separate Covid/no-Covid patients pathway in EU -8.8%
Decrease in no-Covid patients management and admission capacities in EU -19.9%
"Plan blanc" -19.1%
Coronarography room dedicated to Covid patients in cathlabs -1.0%
Deprogramming of non-urgent procedures or hospitalizations 14.0%
Decrease in bed capacity for no-Covid patients in cathlabs -4.3%
Use of care
FMC - MICU (vs EU without cathlab) -65.6%
pre-wave -65.4%
per-wave -68.5%
post-wave -62.7%
FMC - EU with cathlab (vs EU without cathlab) -19.6%
pre-wave -27.9%
per-wave -20.1%
post-wave -10.0%
Symptoms to care time (10 min step) 0.4%
pre-wave 0.2%
per-wave 0.5%
post-wave 0.4%

Figure. Stroke and STEMI cohorts. Variation percentages of the estimations of the reorganizations and use of care effects on care management times

A: Stroke cohort (N=4,603) – Percentage change in overall effects; results of multivariate linear regression mixed models; variable to be explained: Y = log (EU admission-to-imaging time); results adjusted on period, age, gender, urbanicity of residence, FDep15, APL MG 18, residence-EU distance, presence of stroke unit, MRI 24 hours a day, presence of interventional neuroradiology unit, care during on-call activity, mode of transport, call to the emergency services activity, mRS less than 1 before stroke, NIHSS at entry, previous stroke or transient ischemic attack.

B: STEMI cohort (N=1,843) – Percentage change in overall effects; results of multivariate linear regression mixed models; variable to be explained: Y=log (FMC-to-procedure time); results adjusted on period, age, gender, urbanicity of residence, FDep15, APL MG 18, residence-to-cathlab distance, cathlab hospital status, care during on-call activity, mode of transport, call to the emergency services activity, FMC-to-cathlab distance, diabetes mellitus, coronary artery disease or STEMI history).

Light grey: interaction with the COVID period, Dark grey: raw results without interaction with the COVID period

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STROBE Statement—Checklist of items that should be included in reports of cohort studies

	Item No	Recommendation	Page No
Title and abstract	1	(*a*) Indicate the study's design with a commonly used term in the title or the abstract	ok
		(*b*) Provide in the abstract an informative and balanced summary of what was done and what was found	ok, page 1
Introduction			
Background/rationale	2	Explain the scientific background and rationale for the investigation being reported	ok, page 4
Objectives	3	State specific objectives, including any prespecified hypotheses	ok, page 4
Methods			
Study design	4	Present key elements of study design early in the paper	ok, page 4
Setting	5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection	ok, pages 4, 5
Participants	6	(*a*) *Cohort study*—Give the eligibility criteria, and the sources and methods of selection of participants. Describe methods of follow-up	ok, pages 4, 5
		(*b*) *Cohort study*—For matched studies, give matching criteria and number of exposed and unexposed	NA
Variables	7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable	ok, pages 5, 6, 7
Data sources/ measurement	8*	For each variable of interest, give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group	ok, pages 5, 6
Bias	9	Describe any efforts to address potential sources of bias	ok, page 7
Study size	10	Explain how the study size was arrived at	ok, page 5
Quantitative variables	11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why	ok, page 7
Statistical methods	12	(*a*) Describe all statistical methods, including those used to control for confounding	ok, page 7
		(*b*) Describe any methods used to examine subgroups and interactions	ok, page 7
		(*c*) Explain how missing data were addressed	ok, page 7
		(*d*) *Cohort study*—If applicable, explain how loss to follow-up was addressed	NA
		(*e*) Describe any sensitivity analyses	ok, page 7
Results			
Participants	13*	(a) Report numbers of individuals at each stage of study—eg numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed	ok, page 7
		(b) Give reasons for non-participation at each stage	NA
		(c) Consider use of a flow diagram	NA
Descriptive data	14*	(a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders	ok, page 7, suppl mat.
		(b) Indicate number of participants with missing data for each variable of interest	ok, pages 9, 10

		(c) *Cohort study*—Summarise follow-up time (eg, average and total amount)	NA
Outcome data	15*	*Cohort study*—Report numbers of outcome events or summary measures over time	ok, page 11
Main results	16	(*a*) Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (eg, 95% confidence interval). Make clear which confounders were adjusted for and why they were included	ok, page 11
		(*b*) Report category boundaries when continuous variables were categorized	ok, pages 9, 10
		(*c*) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period	NA
Other analyses	17	Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses	ok, page 11
Discussion			
Key results	18	Summarise key results with reference to study objectives	ok, pages 11, 12
Limitations	19	Discuss limitations of the study, taking into account sources of potential bias or imprecision. Discuss both direction and magnitude of any potential bias	ok, pages 13, 14
Interpretation	20	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence	ok, pages 12
Generalisability	21	Discuss the generalisability (external validity) of the study results	ok, pages 14
Other information			
Funding	22	Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based	ok, page 15

NA= not applicable

BMJ Open

Effects of healthcare system transformations spurred by the coronavirus disease 2019 pandemic on stroke and STEMI management: Patients in a French regional cardio-neuro-vascular registry

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Effects of healthcare system transformations spurred by the coronavirus disease 2019 pandemic on stroke and STEMI management: Patients in a French regional cardio-neuro-vascular registry

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ABSTRACT

Objective: To assess the impact of changes in use of care and implementation of hospital reorganisations spurred by the coronavirus disease 2019 (COVID-19) pandemic (first wave) on the acute management times of stroke and ST-segment elevation myocardial infarction (STEMI) patients.

Design: Two cohorts of STEMI and stroke patients in the Aquitaine Cardio-Neuro-Vascular (CNV) registry.

Setting: Six emergency medical services, 30 emergency units, 14 hospitalisation units, and 11 cathlabs in the Aquitaine region.

Participants: This study involved 9218 patients (6436 stroke and 2782 STEMI patients) in the CNV registry from January 2019 to August 2020.

Method: Hospital reorganisations, retrieved in a scoping review, were collected from heads of hospital departments. Other data were from the CNV registry. Associations between reorganisations, use of care, and care management times were analysed using multivariate linear regression mixed models. Interaction terms between use-of-care variables and period (pre-, per-, and post-wave) were introduced.

Main outcome measures: STEMI cohort, first medical contact-to-procedure time; stroke cohort, emergency unit admission-to-imaging time.

Results: Per-wave period management times deteriorated for stroke but were maintained for STEMI. Per-wave changes in use of care did not affect STEMI management. No association was found between reorganisations and stroke management times. In the STEMI cohort, the implementation of systematic testing at admission was associated with a 41% increase in care management time (exp = 1.409, 95%CI 1.075-1.848, p = 0.013). Implementation of *Plan Blanc*, which concentrated resources in emergency activities, was associated with a 19% decrease in management time (exp = 0.801, 95%CI 0.639-1.023, p = 0.077).

Conclusions: The pandemic did not markedly alter the functioning of the emergency network. Although stroke patient management deteriorated, the resilience of the STEMI pathway was linked to its stronger structuring. Transversal reorganisations, aiming at concentrating resources on emergency care, contributed to maintenance of the quality of care.

STRENGTHS AND LIMITATIONS OF THIS STUDY

- The study analysed two large high-quality data cohorts comprising almost 10000 stroke and STEMI patients, managed in a large panel of care structures throughout the Aquitaine region, over a period of several months before and after the first wave.
- We evaluated reorganisations implemented by care structures in the management of stroke and STEMI patients to cope with the COVID-19 pandemic.
- The explanatory analyses yielded robust results due to the large amount of data collected (clinical characteristics, socio-geographical factors, acute care management pathway data), enabling integration of confounding factors identified by the directed acyclic graph method.
- The exclusion of patients who did not enter the healthcare system prevented quantification of avoidance of the health care system, which is thought to have been more frequent during the COVID-19 pandemic.
- Data were restricted to the Aquitaine region, which was less affected by the first wave of the pandemic; this hampers the geographical generalisability of results on the effects of reorganisations focused on emergency units, which were more sensitive to patient influx.

INTRODUCTION

Governments worldwide responded to the COVID-19 pandemic with unprecedented policies that affected healthcare systems, and that were designed to slow the growth rate of the infection.(1–3) France was one of the most affected countries in the early months of the pandemic.(4) From March to May 2020, French authorities implemented a nationwide lockdown and a series of policies to curb the surge of patients requiring critical care. The French health care system was at that time almost entirely devoted to the fight against severe acute respiratory syndrome coronavirus-2 (SARS-CoV-2).

These profound changes were likely to have had a negative impact on the delivery of medical and surgical services. Use of care was altered;(5) all countries that implemented policies to prevent the spread of SARS-CoV-2 experienced a marked decrease in the number of patients entering emergency rooms for reasons other than COVID-19, revealing a tendency to delay or even forego care.(6–9)

Concerns rose about the quality of management of acute conditions other than COVID-19, particularly stroke and ST-segment elevation myocardial infarction (STEMI), the most highly time-sensitive conditions.(10,11) Management pathways for these two diseases have long been established, based initially on the patient's use of the emergency medical service (EMS) system in the event of an extreme emergency, followed by relays between emergency structures and specialised technical platforms (cathlabs, stroke units). These care pathways depend on collaboration among various professionals in pre- and intra-hospital areas. These pre-defined pathways may have been undermined by the organisational and societal upheavals associated with the COVID-19 pandemic. Indeed, international literature agrees that the COVID-19 pandemic substantially decreased the rate of stroke and STEMI admissions and the number of procedures, and increased the interval from symptom onset to hospital treatment; these latest appearing driven predominantly by delays in use of care and transfers.(12)

However, results on the effect of the COVID-19 pandemic on the intra-hospital quality of care of these two diseases are diverse.(13–16) We hypothesised that this may be due to the organisational environment of hospitals and the timing and type of re-organisations implemented to cope with the COVID-19 pandemic. Beyond national directives, each hospital had authority over its reorganisation, according to local capacity. To date, no study has quantified the effect of the COVID-19 pandemic on the delivery of stroke and STEMI care.

Since 2012, the Aquitaine region (southwestern France, 3 million inhabitants) has implemented a regional registry of cardio-neuro-vascular pathologies (CNV Registry), enabling analysis of the care pathway of STEMI and stroke patients in Aquitaine hospitals. Therefore, there is a unique opportunity to study changes in care management in the region over time.(17)

We assessed the impact of changes in use of care and health reorganisation spurred by the first wave of the COVID-19 pandemic on care management times of STEMI and stroke patients hospitalised in the Aquitaine region. We also analysed the use and quality of care provided to these patients during the COVID-19 pandemic.

METHODS

Study design and population

This study was based on two retrospective cohorts of stroke and STEMI patients. We performed ad hoc evaluation of the reorganisations implemented by healthcare structures in the Aquitaine region during the first wave of the COVID-19 pandemic.

The two cohorts comprised adult patients, living in metropolitan France, and admitted to a care structure involved in the CNV registry with recent stroke or STEMI, from January 1st 2019 to August 31 2020.(17) The STEMI cohort comprised recent STEMI patients < 24 h from symptom onset, managed in 6 EMSs, 14 emergency units (EUs), and 11 cathlabs in Aquitaine. The stroke cohort comprised recent ischaemic or haemorrhagic stroke patients diagnosed by brain imaging with validation by a neurovascular physician (exclusion of transient ischaemic attacks), managed in 5 of the 6 EMSs and 14 (including 7 stroke units) of the 20 hospitals caring for > 30 strokes per year in Aquitaine. The CNV registry has been approved by the French authority on data protection and meets the regulatory requirements for patient information (file 2216283).

Data collection

Stroke and STEMI cohorts

Data were collected from each care structure at each step of the care pathway:

1) In EMSs, data entered in electronic care records were extracted from the hospital information system.

2) In EUs, data were entered prospectively by physicians in dedicated paper or electronic care records and extracted or collected retrospectively by clinical research assistants.

3) In cathlabs or stroke hospitalisation units, data were entered prospectively by physicians, and then extracted.

Data of the two cohorts were consolidated and incorporated into one data warehouse, allowing the reconstruction of the STEMI or stroke management pathway.

The CNV registry collects information on:

1) Patient socio-demographic characteristics: age, gender, place of residence.

2) Patient clinical characteristics: medical history, cardiovascular risk factors, stroke clinical severity (modified Rankin Scale [mRS] and National Institute of Health Stroke Score [NIHSS]), and stroke type (ischaemic/haemorrhagic).

3) Use of care (Table 1): calls to emergency services, first medical contact (FMC), and symptom-to-care time.

4) Acute care management quality (Table 1): Intervals between key management steps (stroke, EU admission-to-imaging time; STEMI, FMC-to-procedure time), pre-hospital and hospital pathways, mode of transport to the EU, orientation to stroke unit or cathlab and treatment (stroke, first imaging type, intravenous thrombolysis [IVT] in ischaemic stroke, mechanical thrombectomy in ischaemic stroke; STEMI, fibrinolysis, percutaneous coronary intervention [PCI], coronary angiography alone).

5) Structural characteristics of care: Care during on-call activity, calls to emergency services during care, administrative status of the hospital and FMC-to-cathlab distance. For the stroke cohort, availability of magnetic resonance imaging (MRI) 24 hours a day, stroke unit and interventional neuroradiology unit.

Place of residence was used to calculate distances between residence and care structures and three geographical indices: Urbanicity, deprivation index (Fdep15), potential accessibility to general practitioners (APL MG 2018) (Table 1).(18–20)

Table 1. Definition of use of care variables, acute care management quality variables and geographical indexes

Variables	Definition
Use of care	
Calls to emergency services	Patient call to emergency services after the onset of symptoms
FMC	First medical team to take care of the patient: - in the stroke cohort, two categories of FMC: 1) MICU in case of call to, 2) EU in case of no call to emergency services; - in the STEMI cohort, three categories of FMC: 1) MICU, 2) EU with cathlab, 3) EU without cathlab.
Symptoms-to-care time	Delay in minutes between symptoms onset and start of management by the healthcare system, either call to emergency services or EU admission in case of no call to emergency services
Acute care management quality	
EU admission-to-imaging time	Delay in minutes between EU admission and start of the first imaging (MRI or CT scan)
FMC-to-procedure time	Delay in minutes between FMC and the start of the treatment procedure (coronary angiography or PCI)
IVT in ischaemic stroke	Two variables: 1) IVT in all ischaemic stroke patients, 2) IVT in "IVT alert" patients *ie*. patients with symptoms-to-EU admission time less than 4 hours.
Geographical indexes	
Urbanicity	Urban defined as commune or group of communes with a continuous built-up area with at least 2000 inhabitants
FDep15	Validated social level index calculated from four variables attributed to each commune: median household income, proportion of baccalaureate, proportion of workers in the active population and unemployment rate
APL MG 2018	Index calculated from the supply of general practitioners, the demand for care and the distance between the place of residence and the supply of care

APL MG 2018=potential accessibility indicator to general practitioners; CT=computerized tomography scan; EU=emergency unit; FDep15=deprivation index; FMC=first medical contact; IVT=intravenous thrombolysis; MICU=mobile intensive care units; MRI=magnetic resonance imaging; PCI=Percutaneous Coronary Intervention; STEMI=segment elevation myocardial infarction.
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<u>Reorganisations implemented in healthcare structures</u>

A scoping review was conducted in compliance with the PRISMA recommendations (21) to evaluate the structural reorganisations implemented in care structures related to acute management of stroke and STEMI patients, to deal with the first wave of the COVID-19 pandemic (Supplementary Material 1).(22) The retrieved reorganisations were classified according to care structure: in EMSs ("increase in the telephone reception capacities", "restriction of helicopter transport for COVID patients"), EUs ("systematic COVID testing", "separate COVID/non-COVID patients pathway", "decrease in non-COVID patients management and admission capacities", *Plan Blanc* [emergency plan to cope with a sudden increase of activity]) and stroke or STEMI hospitalisation units ("coronary angiography room dedicated to COVID patients in cathlabs", "deprogramming of non-urgent procedures or hospitalisations", "decrease in bed capacity for non-COVID patients", "specific access to imaging for COVID patients"). The retrieved reorganisations were compiled into a questionnaire addressed to the care-structure heads who were asked to indicate, for each reorganisation, whether it had been implemented and, if so, its dates of implementation and of termination.

Care management times

The primary endpoints were the FMC-to-procedure time and EU admission-to-imaging time for the STEMI and stroke cohorts, respectively.

Statistical analysis

Analyses were performed separately for each cohort. Three periods were defined according to the dates of implementation of the first hospital reorganisations and termination of national lockdown: pre-wave (January 1, 2019, to February 9, 2020), per-wave (February 10, to May 10, 2020), and post-wave (May 11, to August 31, 2020). Use-of-care and acute-care management quality variables were compared among the three periods (Khi2 test or Fisher exact test for qualitative variables, and Kruskal–Wallis test for quantitative variables. P-values were corrected by the false discovery rate [FDR] method to account for the multiplicity of tests).

The associations between reorganisations (STEMI, nine variables; stroke, five variables), use of care (STEMI, two variables; stroke, two variables), and care management times (introduced as continuous variables after logarithmic transformation) were analysed using a multivariate linear regression mixed model (two random effects on hospital and health territory). Interaction terms between the use-of-care variables and period (pre-, per-, and post-wave) were introduced. The confounding variables were identified by means of a directed acyclic graph (DAG) (Supplementary Material 2).

The relationships between reorganisations or use of care and care management times were quantified (β) by the contrast method (statistical significance $P < 0.05$) and the exponentials of the betas ($\exp(\beta)$); their 95% confidence intervals and percentage changes ($1 - \exp(\beta)$) were calculated.

For the stroke cohort, a sensitivity analysis was carried out by adding the variable symptoms-to-care time to the model. This variable was not introduced in principal analysis because it presented more than 20% missing data. Statistical analysis was conducted using SAS 9.4.

Patient and public involvement statement

As members of the CNV registry scientific boards, patient representatives were involved in study conception, implementation, and dissemination; they validated data collection and analysis, and results diffusion. Dissemination of results was conducted on the CNV registry website, to the scientific boards, and to care-structure physicians. This study is reported in accordance with the STROBE guidelines and is registered with ClinicalTrials.gov (NCT04979208).

RESULTS

Study sample (Supplementary Material 3)

The study sample comprised 9218 patients: 6008 pre-wave, 1487 per-wave, and 1723 post-wave. The mean number of included patients was stable during the pre- and post-wave periods (weekly mean number [SD] of inclusions: 32 [6] STEMIs pre-wave, 32 [5] STEMIs post-wave; 83 [8] strokes pre-wave, 75 [7] strokes post-wave). At the beginning of the per-wave period (weeks 7 to 15), inclusions of stroke (lowest weekly number, 56) and STEMI (lowest weekly number, 22) patients decreased, followed by a slow increase that continued into the post-wave period.

A total of 6436 stroke patients (5669 [88.1%] with ischaemic stroke and 767 [17.9%] with haemorrhagic stroke) was managed in 5 EMSs, 14 EUs, and 14 hospitalisation units (7 stroke units); the 2782 STEMI patients were managed in 6 EMSs, 30 EUs, and 11 cathlabs. The median age was younger in the stroke cohort during the per- and post-wave compared to the pre-wave periods (77 and 76 years vs. 79 years) and the median age of STEMI patients was similar in the three periods. In the STEMI cohort, a lower proportion of women (24.1% *vs*. 27.6% and 26.6%) and a higher proportion of patients with hypertension history (54.1% *vs*. 48.0% and 47.1%) were observed during the per-wave period compared to the pre- and post-wave periods. In the stroke cohort, the frequency of severe strokes was lower in the per- and post-wave periods (56.2% and 57.3%, respectively, of stroke patients with NIHSS < 7) than in the pre-wave period (52.8%).

Reorganisations implemented in care structures (figure 1)

Reorganisations began in early February 2020. In the middle of the per-wave period, 83% of EMSs, 90% of EUs, 93% of stroke hospitalisation units, and 64% of cathlabs had implemented at least one reorganisation. The two most frequently implemented reorganisations were "increase in the telephone reception capacities" (implemented in all EMSs) and "separate COVID/non-COVID patients pathways" (implemented by 93% of EUs; n = 13 for stroke, n = 28 for STEMI). Half of the EUs implemented *Plan Blanc*. Most reorganisations implemented during the per-wave period were maintained in the post-wave period.

Use of care and acute care management quality in the pre-, per-, and post-wave periods (Tables 2, 3)

Use of care

In the per-wave compared to the pre-wave periods, calls to emergency services (stroke, 65.5% *vs*. 61.5%; STEMI, 81.8% *vs*. 77.4%) and the median symptom-to-care interval (stroke, 139 min *vs*. 121 min; STEMI, 84 min *vs*. 76 min) increased in both cohorts. These values returned to their previous levels during the post-wave period, except for calls to emergency services for stroke, which remained high.

Care management quality

The stroke median EU admission-to-imaging time increased (91 min *vs*. 83 min) and the STEMI median FMC-to-procedure time decreased (95 min *vs*. 100 min) in the per-wave compared to the pre-wave period. The management time remained high for stroke (88 min) and increased for STEMI (102 min) in the post-wave period.

In the stroke cohort, the proportion of IVT decreased during the per-wave compared to the pre- and post-wave periods (all ischaemic strokes, 14.6% *vs*. 19.4% and 16.7%, p = 0.011; IVT alert patients, 31.3% *vs*. 42.4% and 38.8%, p = 0.011) and the proportion of patients with an optimal pathway (calls to emergency services/mobile intensive care units [MICU] transport/EU) was larger during the per-wave period (59.5%) compared to the pre- (57.3%) and post-wave (58.3%, p = 0.040) periods.

Table 2. Comparison of use of care and acute care management quality characteristics between the pre, per, post-wave periods - Stroke cohort (N=6436)

	Global (N=6436)		Pre-wave (N=4140)		Per-wave (N=1080)		Post-wave (N=1216)		p-value corrected (FDR)	
	n	(%)	n	(%)	n	(%)	n	(%)		
Use of care										
Calls to emergency services	6430		4135		1079		1216		0.083	*
No	2399	(37.3)	1590	(38.5)	372	(34.5)	437	(35.9)		
Yes	4031	(62.7)	2545	(61.5)	707	(65.5)	779	(64.1)		
Missing values	*6*		*5*		*1*		*0*			
FMC	6436		4140		1080		1216		0.332	*
EU	6278	(97.5)	4040	(97.6)	1059	(98.1)	1179	(9.0)		
MICU	158	(2.5)	100	(2.4)	21	(1.9)	37	(3.0)		
Symptoms-to-care time (min)	3157		1991		556		610		0.232	**
Median [IQR]	126	[38;401]	121	[38;384]	139	[46;488]	125	[38;392]		
Missing values	*3279*		*2149*		*524*		*606*			
Acute care management quality										
EU admission-to-imaging time (min)	4819		3014		889		916		0.332	**
Median [IQR]	86	[47;194]	83	[45;201]	91	[51;175]	88	[52;191]		
Missing values	*1617*		*1126*		*191*		*300*			
Pre-hospital pathway type	6430		4135		1079		1216		0.040	*
Optimal pathway: calls to emergency services/MICU transport/EU	3719	(57.8)	2368	(57.3)	642	(59.5)	709	(58.3)		
Calls to emergency services /non-MICU transport/EU	312	(4.9)	177	(4.3)	65	(6.0)	70	(5.8)		
EU direct entry	2399	(37.3)	1590	(38.5)	372	(34.5)	437	(35.9)		
Missing values	*6*		*5*		*1*		*0*			
Mode of transport to the EU	6436		4140		1080		1216		0.812	*
Personal transport	732	(11.4)	475	(11.5)	117	(10.8)	140	(11.5)		
Non-MICU transport	4495	(69.8)	2902	(70.1)	758	(70.2)	835	(68.7)		
MICU transport	222	(3.4)	149	(3.6)	34	(3.1)	39	(3.2)		
Unknown	987	(15.3)	614	(14.8)	171	(15.8)	202	(16.6)		
Transfer to a stroke unit	6436		4140		1080		1216		0.923	*
No	752	(11.7)	484	(11.7)	123	(11.4)	145	(11.9)		
Yes	5684	(88.3)	3656	(88.3)	957	(88.6)	1071	(88.1)		
First imaging type	6041		3870		1019		1152		0.332	***
MRI	3782	(62.6)	2395	(61.9)	650	(63.8)	737	(64.0)		
CT scan	2245	(37.2)	1463	(37.8)	369	(36.2)	413	(35.9)		
None	14	(0.2)	12	(0.3)	0	(0.0)	2	(0.2)		
Missing values	*395*		*270*		*61*		*64*			
IVT (all ischaemic strokes)	5660		3616		938		1106		0.011	*
No	4635	(81.9)	2913	(80.6)	801	(85.4)	921	(83.3)		
Yes	1025	(18.1)	703	(19.4)	137	(14.6)	185	(16.7)		
Missing values	*9*		*1*		*3*		*5*			
Exclusion	*767*		*523*		*139*		*105*			
IVT in 'Thrombolysis alert' patients (ischaemic stroke)	1758		1100		310		348		0.011	*
No	1060	(60.3)	634	(57.6)	213	(68.7)	213	(61.2)		
Yes	698	(39.7)	466	(42.4)	97	(31.3)	135	(38.8)		
Missing values	*2*		*1*		*0*		*1*			
Exclusion	*4676*		*3039*		*770*		*867*			
Mechanical thrombectomy (all ischaemic stroke)	5620		3585		938		1097		0.332	*
No	4998	(88.9)	3170	(88.4)	842	(89.8)	986	(89.9)		
Yes	622	(11.1)	415	(11.6)	96	(10.2)	111	(10.1)		
Missing values	*49*		*32*		*3*		*14*			
Exclusion	*767*		*523*		*139*		*105*			

Test realized=Khi2 test (*), Kruskal-Wallis test (**), Fisher exact test (***); CT scan=computerized tomography scan; EU=emergency unit; FDR=correction of p-value by False Discovery Rate method; FMC=first medical contact; IVT=intravenous thrombolysis; MICU=mobile intensive care units; MRI=magnetic resonance imaging.
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Table 3. Comparison of use of care and acute care management quality characteristics between the pre, per, post-wave periods - STEMI cohort (N=2782)

	Global (N=2782)		Pre-wave (N=1868)		Per-wave (N=407)		Post-wave (N=507)		p-value corrected (FDR)	
	n	(%)	n	(%)	n	(%)	n	(%)		
Use of care										
Calls to emergency services	2782		1868		407		507		0.704	*
No	607	(21.8)	422	(22.6)	74	(18.2)	111	(21.9)		
Yes	2175	(78.2)	1446	(77.4)	333	(81.8)	396	(78.1)		
FMC	2782		1868		407		507		0.704	*
MICU	1597	(57.4)	1069	(57.2)	247	(60.7)	281	(55.4)		
EU with cathlab	458	(16.5)	321	(17.2)	51	(12.5)	86	(17.0)		
EU without cathlab	727	(26.1)	478	(25.6)	109	(26.8)	140	(27.6)		
Symptoms-to-care time (min)	2360		1581		349		430		0.799	**
Median [IQR]	77	[30;206]	76	[30;212]	84	[31;202]	75	[30;178]		
Missing values	*422*		*287*		*58*		*77*			
Acute care management quality										
FMC-to-procedure time (min)	2364		1577		353		434		0.799	**
Median [IQR]	99	[71;157]	100	[71;158]	95	[69;152]	102	[71;153]		
Missing values	*418*		*291*		*54*		*73*			
Pathway type	2742		1841		400		501		0.799	*
Optimal pathway: calls to emergency services/ MICU transport/direct referral to cathlab	1557	(56.8)	1042	(56.6)	240	(60.0)	275	(54.9)		
Calls to emergency services /EU/direct referral to cathlab	550	(20.1)	356	(19.3)	82	(20.5)	112	(22.4)		
No call to emergency services /EU/direct referral to cathlab	591	(21.6)	412	(22.4)	72	(18.0)	107	(21.4)		
Calls to emergency services /EU/no direct referral to cathlab	28	(1.0)	20	(1.1)	4	(1.0)	4	(0.8)		
No call to emergency services /EU/no direct referral to cathlab	16	(0.6)	11	(0.6)	2	(0.5)	3	(0.6)		
Missing values	*40*		*27*		*7*		*6*			
Mode of transport to the first hospital	2782		1868		407		507		0.722	*
Personal transport	444	(16.0)	311	(16.6)	55	(13.5)	78	(15.4)		
Non- MICU transport	558	(20.1)	372	(19.9)	77	(18.9)	109	(21.5)		
MICU transport (road)	1523	(54.7)	1010	(54.1)	243	(59.7)	270	(53.3)		
MICU transport (helicopter)	123	(4.4)	84	(4.5)	11	(2.7)	28	(5.5)		
Unknown	134	(4.8)	91	(4.9)	21	(5.2)	22	(4.3)		
Direct referral to cathlab	2782		1868		407		507		0.799	*
No	84	(3.0)	58	(3.1)	13	(3.2)	13	(2.6)		
Yes	2698	(97.0)	1810	(96.9)	394	(96.8)	494	(97.4)		
Fibrinolysis	2560		1724		366		470		0.799	*
No	2428	(94.8)	1633	(94.7)	345	(94.3)	450	(95.7)		
Yes	132	(5.2)	91	(5.3)	21	(5.7)	20	(4.3)		
Missing values	*222*		*144*		*41*		*37*			
PCI	2364		1577		353		434		0.799	*
No	330	(14.0)	211	(13.4)	50	(14.2)	69	(15.9)		
Yes	2034	(86.0)	1366	(86.6)	303	(85.8)	365	(84.1)		
Missing values	*418*		*291*		*54*		*73*			
Fibrinolysis or PCI	2359		1576		349		434		0.704	*
No	292	(12.4)	190	(12.1)	38	(10.9)	64	(14.7)		
Yes	2067	(87.6)	1386	(87.9)	311	(89.1)	370	(85.3)		
Missing values	*423*		*292*		*58*		*73*			

Test realized=Khi2 test (*), Kruskal-Wallis test (**), Fisher exact test (***); EU=emergency unit; FDR=correction of p-value by False Discovery Rate method; FMC=first medical contact; MICU=mobile intensive care units; PCI=Percutaneous Coronary Intervention.
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Associations between use of care, reorganisations, and care management times (Figure 2, Supplementary Material 4)

<u>Stroke cohort model (4603 patients)</u>

The final model showed no statistically significant association between reorganisations and EU admission-to-imaging time. FMC by MICU transport was associated with a significant decrease of 27% in the EU admission-to-imaging time (expβ = 0.726, 95%CI 0.548-0.961, p = 0.034), with no interaction with COVID-19 period (p = 0.807). The association between calls to emergency services and EU admission-to-imaging time was not significant (expβ = 0.939, 95%CI 0.793-1.112, p = 0.360) during the study period but differed according to COVID-19 period (significant interaction with the COVID-19 period, p = 0.039). Calls to emergency services were associated with an 8% increase in admission-to-imaging time during the post-wave compared to the pre- and per-wave periods. Sensitivity analysis of 2458 patients confirmed the absence of an association between reorganisations or use-of-care changes during the COVID-19 pandemic and care management times.

<u>STEMI cohort model (1843 patients)</u>

Systematic COVID-19 testing was associated with a 41% increase (expβ = 1.409, 95%CI 1.075-1.848, p = 0.013) in the FMC-to-procedure time. The implementation of *Plan Blanc* was associated with a 19% decrease (expβ = 0.801, 95%CI 0.639-1.023, p = 0.077) in the FMC-to-procedure time. Compared to FMC "EU without cathlab", FMC "MICU transport pathway" was associated with a 66% decrease (expβ = 0.344, 95%CI 0.266-0.445, p < 0.001) in the FMC-to-procedure time and FMC "EU with cathlab" with a 20% decrease (expβ = 0.804, 95%CI 0.674-0.958, p < 0.001). The interaction with the COVID period was not significant (p = 0.492). Finally, each 10 min increase in symptom-to-care time increased the FMC-to-procedure time by 0.36% (expβ = 1.004, 95%CI 1.002-1.005, p < 0.001), and there was no effect of COVID-19 period (p = 0.206).

DISCUSSION

We evaluated the global impact of the health system transformations spurred by the first wave of the COVID-19 pandemic on use of care by, and the acute management of, stroke and STEMI patients.

Beginning in the per-wave period, most hospitals in Aquitaine adapted to the COVID-19 pandemic. Most of the reorganisations were maintained several months after the end of the national lockdown. Stroke management times deteriorated during the pandemic, but this was not directly related to the reorganisations implemented. By contrast, STEMI patients' quality of care was maintained during the first wave of the COVID-19 pandemic, to which *Plan Blanc*, by concentrating resources in emergency activities, contributed. Implementation of systematic COVID-19 screening at admission was associated with an increase in STEMI patient management time. In the STEMI and stroke cohorts, more frequent calls to emergency services and longer times to access the healthcare system were observed during the per-wave compared to the pre-wave period.

The contrasting changes in STEMI and stroke management times during the per-wave period may be explained by the different structures and performances of the related networks in France. The STEMI network is structured as a dedicated pathway. By contrast, the stroke network is more recent and not fully structured. Highly structured patient-centred clinical pathways improve the quality of care of chronic or acute conditions with predictable trajectories.(23–27) Moreover, guidelines on stroke and STEMI patient management and national stroke and STEMI improvement programs recommend the implementation of structured pathways that include close collaborations between healthcare professionals as well as patient orientation to specialised technical platforms (cathlabs, stroke units) and to the EMS system.(28,29).

The results suggest the absence of a change in the functioning of the emergency pathway during the pandemic. Indeed, calls to the emergency services by STEMI patients and orientation to the optimal pathway using MICU were associated with decreased stroke and STEMI management times. Therefore, the management of these two highly time-sensitive pathologies was not disrupted during the pandemic.

Plan Blanc, which enhanced the quality of care of COVID-19 patients, improved that of STEMI patients by decreasing management times. In the stroke cohort, *Plan Blanc* non-significantly decreased management times. The different results may be explained by use of different primary endpoints in the two cohorts. In the STEMI cohort, the FMC-to-procedure time, which accounted for coordination of care among multiple actors pre- and in-hospital, was sufficiently extensive to detect an effect. In the stroke cohort, the EU admission-to-imaging time, which focused on the beginning of in-hospital care, involved so little a part of the patient pathway that it had difficulty in detecting an effect. Most reorganisations implemented in EUs or hospitalisation units had little effect on STEMI and stroke care management times.

Only the "systematic COVID testing" reorganisation increased the STEMI management time. This effect was marked in patients arriving late after symptom onset. In these patients, whose symptoms were often atypical and included respiratory signs suggestive of COVID-19, management was delayed until availability of screening results. STEMI patients arriving very early were regarded as requiring extreme emergency management before screening. The "systematic COVID testing" reorganisation was not included in the stroke cohort model, but the only hospital in the stroke cohort that implemented it exhibited results similar to the STEMI cohort.

The increased time to contact the healthcare system during the COVID-19 pandemic is consistent with prior reports from France and elsewhere.(6,13,30) Mesnier *et al.*, in a French cohort of 1167 STEMI patients, found that symptom onset to hospital admission times were stable from 4 weeks before to 4 weeks after lockdown implementation. However, comparison of that work and ours is hampered by differences in management times and study periods.(7)

By calling the emergency services more frequently, patients followed the national recommendations, which were widely publicised in the French media during the COVID-19 pandemic. Although a global decrease in STEMI and stroke patient admissions during the per-wave period has been reported, the average figures over the period(31) suggest an initial decrease at the beginning of the per-wave period and a progressive increase thereafter. This findings, mirrored by other surveys at the regional or national level in France, are based on analysis of changes in hospital admissions during the per-wave period.(32,33) Stroke patients were younger, and had less severe strokes during the per-wave compared to the pre-wave period. Although several studies, including one meta-analysis, reported more severe and older patients during the first wave of the pandemic, others reported findings consistent with ours.(31,34–38) Wallace *et al*. suggested this to be a consequence of regional variation in virus spread and the fear of contracting COVID-19 in hospital. Alternatively, most studies included patients with transient ischaemic attacks; these were excluded in this work. Patients with resolving and less-severe symptoms were more likely to avoid hospital admission for fear of contracting COVID-19 in hospital. Lastly, information on the origin of hospitalised patients (home, nursing homes, other hospitals) would have been useful but was not available in the databases.

Prior studies on the effect of the COVID-19 pandemic on the quality of stroke and STEMI management reported diverse results.(13–16) Our data suggest that these discordant results are a result of the variety of policies implemented and the heterogeneity of hospital organisations. To our knowledge, no study has analysed at a regional level the effect of reorganisations implemented by hospitals to deal with the COVID-19 pandemic. Those extant simply provide feedback on reorganisations at a local level.(11,39,40)

We analysed two high-quality databases with a large number of stroke and STEMI patients managed in numerous healthcare institutions in Aquitaine. This broad geographical scope, which ensured diverse clinical and management characteristics, and the historical depth of the data are major strengths of this study.

The sample was representative of stroke and STEMI patients managed in hospitals. However, patients who did not enter the healthcare system because they had died or did not benefit from hospital care, were not included. This precluded quantification of avoidance of the healthcare system, which is thought to have been more frequent during the COVID-19 pandemic and may have generated selection bias. Moreover, the STEMI cohort included patients who experienced STEMI within 24 h of admission. The proportion of STEMI patients presenting > 24 h after symptom onset increased during the COVID-19 pandemic, and these individuals had more so called "mechanical complications" and a higher mortality rate.(41) Exclusion of these patients may have generated selection bias, leading to a risk of underestimation of the increased delay to use of care.

We conducted a systematic evaluation of hospital reorganisations implemented in response to the COVID-19 pandemic. However, we cannot exclude the possibility of errors in the responses of the healthcare professionals, particularly concerning the dates on which reorganisations were implemented or terminated, due to memory bias. It was not feasible to interview several individuals and cross-check the responses.

Explanatory analyses by the DAG method yielded several confounding factors. The large amount of data enabled integration of a variety of confounders—clinical and sociogeographic factors, acute care management pathways, and hospital activity. In the stroke cohort, 20% of the symptom-to-FMC data were missing, so we excluded this variable from the main model to increase the statistical power. The lack of a reason for these missing data precluded their analysis by the multiple imputation method. A sensitivity analysis with symptom-to-FMC time as an explanatory variable did not alter the results, confirming their robustness.

The primary endpoints were the care management times, which are major prognostic issues in the management of stroke and STEMI and sensitive to intrahospital organisational changes. They were used as continuous variables to maximise the statistical power. Use of the proportion of patients managed within the recommended time frame as an endpoint would have had marked operational implications. However, this was not possible for statistical reasons (3.3% of patients underwent the first imaging within 20 min, the target time).

A major methodological issue was per-wave period, which was defined according to implementation of healthcare reorganisations in response to the COVID-19 pandemic. Therefore, the per-wave period began simultaneously with the first hospital reorganisations, and ended at the end of the lockdown, which corresponded to restoration of normal hospital activity and a reduction in the number of reorganisations. The post-wave period was an important component of our analysis of changes in patient management. However, the follow-up ended at the end of August, to produce not too late results. The inclusion of summer is unlikely to have generated bias because no summer variation in stroke and STEMI inclusion or management delay has been reported.

This study was restricted to Aquitaine, one of the regions least affected by the first wave of the pandemic.(6) We hypothesised that the "decrease in non-COVID patients management and admission capacities", which did not affect STEMI and stroke patient management times, would have degraded the management of non-COVID-19 conditions in regions with many EUs. Indeed, the impact of EU reorganisations may be sensitive to patient influx. Moreover, the effects of global and structural reorganisations such as *Plan Blanc* should not differ geographically. Because use of care did not differ according to pandemic intensity, our results are unlikely to apply only to Aquitaine.(33) It would be interesting to repeat the study in another region of France or in another country more affected by the pandemic to test the external validity of the results.

Stroke and STEMI are managed by means of defined pathways. Our results may be extrapolated to similar conditions requiring urgent management in a coordinated pathway, such as respiratory distress or life-threatening bleeding.

Perspectives

This study is the first step of a three-step analysis of the effect of the COVID-19 pandemic on stroke and STEMI patient management. Other issues are the clinical and social health inequalities in stroke and STEMI patient management induced or reinforced by the COVID-19 pandemic, and the impact of the COVID-19 pandemic on the long-term mortality and morbidity of stroke and STEMI patients.

Conclusions

There was no alteration of emergency pathway structure during the COVID-19 pandemic, but stroke patient management deteriorated. The resilience of the STEMI pathway was due to its stronger structuring. Also, transversal reorganisations, aimed at concentrating resources within the emergency care network, such as *Plan Blanc*, contributed to maintaining the quality of care of stroke and STEMI patients. Our results can be extrapolated to other time-sensitive conditions that require coordination of EMSs and benefit from a defined pathway.

- **Figure Legend/Caption**

Figure 1. Weekly cumulated number of care structures having implemented reorganisations, by reorganisation category– Minimum and maximum number and proportion of care structures having implemented reorganisation, by reorganisation category and by period (pre, per, post-wave)
EMS=emergency medical service; EU=emergency unit; *Plan Blanc*=emergency plan to cope with a sudden increase of activity

Figure 2. Stroke and STEMI cohorts. Estimation of the reorganisations and use of care effects (95% confidence interval) on care management times.
Stroke cohort (N=4603) – Estimated overall effects expressed as exp(β) with 95% CI; results of multivariate linear regression mixed models; variable to be explained: Y = log (EU admission-to-imaging time); results adjusted on period, age, gender, urbanicity of residence, FDep15, APL MG 18, residence-EU distance, presence of stroke unit, MRI 24 hours a day, presence of interventional neuroradiology unit, care during on-call activity, mode of transport, calls to emergency services activity, mRS less than 1 before stroke, NIHSS at entry, previous stroke or transient ischaemic attack.
STEMI cohort (N=1843) – Estimated overall effects expressed as exp(β) with 95% CI; results of multivariate linear regression mixed models; variable to be explained: Y=log (FMC-to-procedure time); results adjusted on period, age, gender, urbanicity of residence, FDep15, APL MG 18, residence-to-cathlab distance, cathlab hospital status, care during on-call activity, mode of transport, calls to emergency services activity, FMC-to-cathlab distance, diabetes mellitus, coronary artery disease or STEMI history).
Light grey: interaction with the COVID period, Dark grey: raw results without interaction with the COVID period
APL MG 2018=potential accessibility to general practitioners; EU=emergency unit; FDep15=deprivation index; FMC=first medical contact; MICU=mobile intensive care units; MRI=magnetic resonance imaging; mRS=modified Rankin Scale; NIHSS=National Institute of Health Stroke Score; *Plan Blanc*=emergency plan to cope with a sudden increase of activity; STEMI=segment elevation myocardial infarction.

- **Data sharing statement**

Deidentified participant data will be available upon reasonable request. Proposals may be submitted to the corresponding author. Data requestors will need to sign a data access agreement

- **Ethics statements**

Patient consent for publication
Not applicable.
According to French authority on data protection “Commission Nationale Informatique et Libertés”, in the category of studies not involving humans based on secondary use of health data, the CNV registry met regulatory requirements for patient information and do not require a patient consent form.
Ethics approval
The CNV registry has been approved by the French authority on data protection (file 2216283).

- **Authors’ contributions**

Conceiving, design and coordination of the study: FSG, EL, SD, FS
Literature search: FSG, EL, FF, MB, QL
Data collection: EL, FS, MB, QL
Data analysis: SD, SMH
Data interpretation: FSG, EL, SD, FS, FF, LC, PC, FR, IS, CP
Writing: FSG, EL, SD, FF, LC, PC, FR, IS, CP

- **Competing interests statement**

The authors declare that they have no competing interests with this study.

- **Funding statement**

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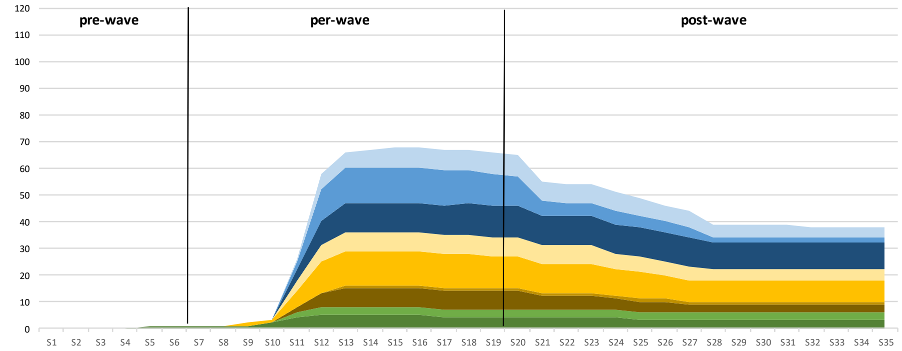
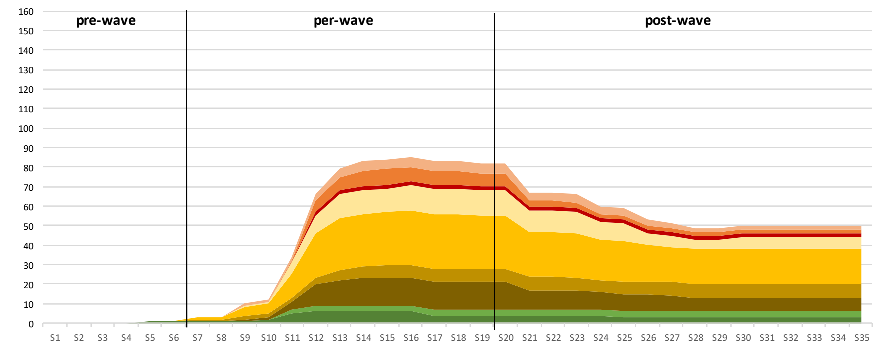
Stroke cohort



reorganisation categories*	pre-wave min	(%)	max	(%)	per-wave min	(%)	max	(%)	post-wave min	(%)	max	(%)
EMS (N=5)												
Increase in the telephone reception capacities	0	(0.0)	1	(20.0)	1	(20.0)	5	(100.0)	3	(60.0)	4	(80.0)
Restriction of helicopter transport for COVID patients	0	(0.0)	0	(0.0)	0	(0.0)	3	(60.0)	3	(60.0)	3	(60.0)
Emergency unit (N=14)												
Plan Blanc	0	(0.0)	0	(0.0)	0	(0.0)	7	(50.0)	3	(21.4)	7	(50.0)
Systematic COVID testing	0	(0.0)	0	(0.0)	0	(0.0)	1	(7.1)	1	(7.1)	1	(7.1)
Separate COVID/non-COVID patients pathway	0	(0.0)	0	(0.0)	0	(0.0)	13	(92.9)	8	(57.1)	12	(85.7)
Decrease in non-COVID patients management and admission capacities	0	(0.0)	0	(0.0)	0	(0.0)	7	(50.0)	4	(28.6)	7	(50.0)
Hospitalisation unit (N=14)												
Specific access to imaging for COVID patients	0	(0.0)	0	(0.0)	0	(0.0)	12	(85.7)	10	(71.4)	12	(85.7)
Deprogramming of non-urgent procedures or hospitalisations	0	(0.0)	0	(0.0)	0	(0.0)	13	(92.9)	2	(14.3)	11	(78.6)
Decrease in bed capacity for non-COVID patients	0	(0.0)	0	(0.0)	0	(0.0)	8	(57.1)	4	(28.6)	8	(57.1)

* minimal and maximal number of structures having implemented each reorganisation among the three periods - (%) : percentage calculated on total number of structures concerned

STEMI cohort



reorganisation categories*	pre-wave min	(%)	max	(%)	per-wave min	(%)	max	(%)	post-wave min	(%)	max	(%)
EMS (N=6)												
Increase in the telephone reception capacities	0	(0.0)	1	(16.7)	1	(16.7)	6	(100.0)	3	(50.0)	4	(66.7)
Restriction of helicopter transport for COVID patients	0	(0.0)	0	(0.0)	0	(0.0)	3	(50.0)	3	(50.0)	3	(50.0)
Emergency unit (n=30)												
Plan Blanc	0	(0.0)	0	(0.0)	0	(0.0)	14	(46.7)	7	(23.3)	14	(46.7)
Systematic COVID testing	0	(0.0)	0	(0.0)	1	(3.3)	7	(23.3)	6	(20.0)	7	(23.3)
Separate COVID/non-COVID patients pathway	0	(0.0)	0	(0.0)	1	(3.3)	28	(93.3)	18	(60.0)	27	(90.0)
Decrease in non-COVID patients management and admission capacities	0	(0.0)	0	(0.0)	0	(0.0)	13	(43.3)	5	(16.7)	13	(43.3)
Cathlabs (n=11)												
Coronary angiography room dedicated to COVID patients in cathlabs	0	(0.0)	0	(0.0)	0	(0.0)	2	(18.2)	2	(18.2)	2	(18.2)
Deprogramming of non-urgent procedures or hospitalisations	0	(0.0)	0	(0.0)	0	(0.0)	8	(72.7)	2	(18.2)	7	(63.6)
Decrease in bed capacity for non-COVID patients	0	(0.0)	0	(0.0)	0	(0.0)	5	(45.5)	2	(18.2)	5	(45.5)

* minimal and maximal number of structures having implemented each reorganisation among the three periods - (%) : percentage calculated on total number of structures concerned

Figure 1. Weekly cumulated number of care structures having implemented reorganisations, by reorganisation category– Minimum and maximum number and proportion of care structures having implemented reorganisation, by reorganisation category and by period (pre, per, post-wave)

EMS=emergency medical service; EU=emergency unit; *Plan Blanc*=emergency plan to cope with a sudden increase of activity

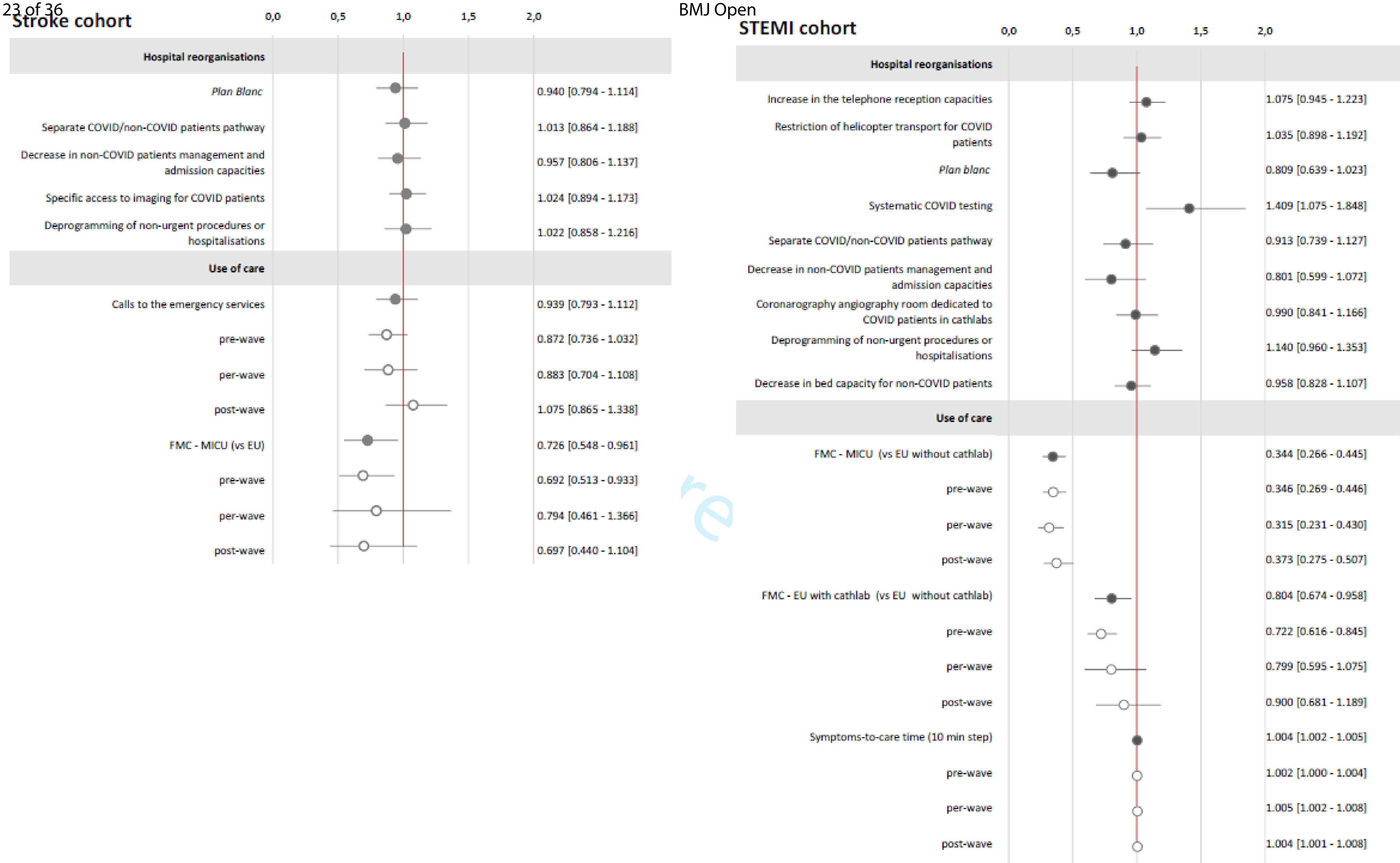

Stroke cohort
0,0
0,5
1,0
1,5
2,0
Hospital reorganisations
Plan Blanc
0.940 [0.794 - 1.114]
Separate COVID/non-COVID patients pathway
1.013 [0.864 - 1.188]
Decrease in non-COVID patients management and admission capacities
0.957 [0.806 - 1.137]
Specific access to imaging for COVID patients
1.024 [0.894 - 1.173]
Deprogramming of non-urgent procedures or hospitalisations
1.022 [0.858 - 1.216]
Use of care
Calls to the emergency services
0.939 [0.793 - 1.112]
pre-wave
0.872 [0.736 - 1.032]
per-wave
0.883 [0.704 - 1.108]
post-wave
1.075 [0.865 - 1.338]
FMC - MICU (vs EU)
0.726 [0.548 - 0.961]
pre-wave
0.692 [0.513 - 0.933]
per-wave
0.794 [0.461 - 1.366]
post-wave
0.697 [0.440 - 1.104]
STEMI cohort
0,0
0,5
1,0
1,5
2,0
Hospital reorganisations
Increase in the telephone reception capacities
1.075 [0.945 - 1.223]
Restriction of helicopter transport for COVID patients
1.035 [0.898 - 1.192]
Plan blanc
0.809 [0.639 - 1.023]
Systematic COVID testing
1.409 [1.075 - 1.848]
Separate COVID/non-COVID patients pathway
0.913 [0.739 - 1.127]
Decrease in non-COVID patients management and admission capacities
0.801 [0.599 - 1.072]
Coronarography angiography room dedicated to COVID patients in cathlabs
0.990 [0.841 - 1.166]
Deprogramming of non-urgent procedures or hospitalisations
1.140 [0.960 - 1.353]
Decrease in bed capacity for non-COVID patients
0.958 [0.828 - 1.107]
Use of care
FMC - MICU (vs EU without cathlab)
0.344 [0.266 - 0.445]
pre-wave
0.346 [0.269 - 0.446]
per-wave
0.315 [0.231 - 0.430]
post-wave
0.373 [0.275 - 0.507]
FMC - EU with cathlab (vs EU without cathlab)
0.804 [0.674 - 0.958]
pre-wave
0.722 [0.616 - 0.845]
per-wave
0.799 [0.595 - 1.075]
post-wave
0.900 [0.681 - 1.189]
Symptoms-to-care time (10 min step)
1.004 [1.002 - 1.005]
pre-wave
1.002 [1.000 - 1.004]
per-wave
1.005 [1.002 - 1.008]
post-wave
1.004 [1.001 - 1.008]

Figure 2. Stroke and STEMI cohorts. Estimation of the reorganisations and use of care effects (95% confidence interval) on care management times.

Stroke cohort (N=4603) – Estimated overall effects expressed as exp(β) with 95% CI; results of multivariate linear regression mixed models; variable to be explained: Y = log (EU admission-to-imaging time); results adjusted on period, age, gender, urbanicity of residence, FDep15, APL MG 18, residence-EU distance, presence of stroke unit, MRI 24 hours a day, presence of interventional neuroradiology unit, care during on-call activity, mode of transport, calls to emergency services activity, mRS less than 1 before stroke, NIHSS at entry, previous stroke or transient ischaemic attack.
STEMI cohort (N=1843) – Estimated overall effects expressed as exp(β) with 95% CI; results of multivariate linear regression mixed models; variable to be explained: Y=log (FMC-to-procedure time); results adjusted on period, age, gender, urbanicity of residence, FDep15, APL MG 18, residence-to-cathlab distance, cathlab hospital status, care during on-call activity, mode of transport, calls to emergency services activity, FMC-to-cathlab distance, diabetes mellitus, coronary artery disease or STEMI history).
Light grey: interaction with the COVID period, Dark grey: raw results without interaction with the COVID period
APL MG 2018=potential accessibility to general practitioners; EU=emergency unit; FDep15=deprivation index; FMC=first medical contact; MICU=mobile intensive care units; MRI=magnetic resonance imaging; mRS=modified Rankin Scale; NIHSS=National Institute of Health Stroke Score; *Plan Blanc*=emergency plan to cope with a sudden increase of activity; STEMI=segment elevation myocardial infarction.

Supplementary material 1.

Method of the scoping review

The method of the scoping review was conducted to retrieve the structural reorganisations implemented in care structures to deal with the first wave of the COVID-19 pandemic in the acute management of stroke or STEMI.
Two categories of information sources were systematically explored:

- **Written English or French-language documents**

All written English or French-language documents published between January and December 2020 were retrieved without geographical limitation:

- scientific articles analysing the impact of the first wave of Covid-19 pandemic on stroke and STEMI management;
- government reports, professional stroke or STEMI guidelines providing guidance on the management of stroke and STEMI patients during the COVID-19 pandemic;
- published feedback on hospital management of stroke and STEMI patients during the first wave of the COVID-19 pandemic.

The following sources were consulted:

- computerised bibliographic database “Pubmed” and “Scopus” with the following algorithm TITLE-ABS-KEY (Pathway OR organisation OR use of care) AND (COVID-19 OR SARS-CoV-2) AND (stroke OR STEMI) AND (effect OR effectiveness OR impact);
- “Google" search engine with the keywords "Organisations", "hospital unit", or "hospital", "COVID-19";
- French Health Ministry (Ministère des solidarités et de la santé) website in search of reports on organisational recommendations for hospital in the management of the Covid-19 pandemic;
- French societies of cardiology, emergency medicine, and neurology (Société Française de Neuro-Vasculaire, Société Française de Cardiologie, Société Française de Médecine d’Urgence) websites in search of clinical recommendations in the management of stroke and STEMI patients in the context of the Covid-19 pandemic.

After a pre-selection on the title and the abstract, the complete reading of the articles allowed to filter out the articles that did not describe any structural organisations. Then, organisational data was independently collected on a dedicated collection grid. If necessary, a common reading was carried out.

- **Structured telephone interviews**

In December 2020, structured telephone interviews were conducted with healthcare professionals involved in stroke or STEMI management in hospitals in the Aquitaine Region, to question them on the organisations they had to cope with during the first wave of the pandemic in stroke and STEMI patients’ management. Among the 16 approached professionals, eight (2 nurses, 2 emergency physicians, 2 cardiologists, and 2 neurologists) from 8 hospitals accepted to participate. Questions asked were: "What reorganisations were implemented during the first wave?"; "Have you been provided with facilities for this reorganisation?"; "Have you received help from professionals in other services?"; "Did you expand/reduce your capacity? ". Responses were transcribed as the interview progressed. Each verbatim was reviewed by the two interviewers in collaboration with the AVICOVID principal investigator.

Supplementary material 2.

Confounding variables introduced in the stroke and STEMI final model estimating the association between reorganizations and use of care effects on care management times

Category of variables	Stroke cohort Model	STEMI Cohort Model
Time	Period (pre, per, post-wave)	Period (pre, per, post-wave)
Socio-demographic characteristics	Age, gender	Age, gender
Geographical indexes	Urbanicity, FDep15, APL MG 2018, residence-EU distance	Urbanicity, FDep15, APL MG 2018, residence-to-cathlab distance
Clinical characteristics	mRS less than 1 before stroke, NIHSS at entry, previous stroke or transient ischaemic attack	Diabetes mellitus, history of coronary artery disease or of STEMI
Acute care management quality	Mode of transport	Mode of transport
Structural characteristics of care	call to the emergency services activity during care, care during on-call activity, presence of stroke unit, availability of MRI 24 hours a day, presence of interventional neuroradiology unit	call to the emergency services activity during care, care during on-call activity, cathlab hospital status, FMC-to-cathlab distance

APL MG 2018=potential accessibility indicator to general practitioners; EU=emergency unit; FDep15=deprivation index; FMC=first medical contact; MRI=magnetic resonance imaging; mRS=modified Rankin Scale; NIHSS=National Institute of Health Stroke Score; STEMI=segment elevation myocardial infarction.
Created by the authors

Supplementary material 3.

Description of the stroke cohort study sample (N=6436)

	Global (N=6436)		pre-wave (N=4140)		per-wave (N=1080)		post-wave (N=1216)	
	n	(%)	n	(%)	n	(%)	n	(%)
Patient socio-demographic characteristics								
Gender	6436		4140		1080		1216	
Male	3533	(54.9)	2264	(54.7)	589	(54.5)	680	(55.9)
Female	2903	(45.1)	1876	(45.3)	491	(45.5)	536	(44.1)
Age	6436		4140		1080		1216	
Median [IQR]	78	[68;87]	79	[69;87]	77	[68;86]	76	[68;85]
Urbanicity	6153		3882		1072		1199	
Urban	4451	(72.3)	2816	(72.5)	786	(73.3)	849	(70.8)
Rural	1702	(27.7)	1066	(27.5)	286	(26.7)	350	(29.2)
Missing values	283		258		8		17	
Fdep15	6145		3878		1070		1197	
Median [IQR]	0.10	[-0.96;1.14]	0.10	[-1.02;1.22]	-0.01	[-0.98;1.11]	0.08	[-0.88;1.11]
Missing values	291		262		10		19	
APL MG 2018	6171		3891		1076		1204	
Median [IQR]	4.3	[3.4;5.0]	4.3	[3.4;5.0]	4.3	[3.4;5.0]	4.2	[3.4;5.1]
Missing values	265		249		4		12	
Residence-EU distance (km)	6179		3897		1077		1205	
Median [IQR]	17	[6;32]	17	[6;33]	16	[5;28]	18	[7;34]
Missing values	*257*		*243*		*3*		*11*	
Patient clinical characteristics								
Stroke type	6436		4140		1080		1216	
Ischaemic	5669	(88.1)	3617	(87.4)	941	(87.1)	1111	(91.4)
Haemorragic	767	(11.9)	523	(12.6)	139	(12.9)	105	(8.6)
Coronary artery disease	6436		4140		1080		1216	
Absence	5877	(91.3)	3778	(91.3)	987	(91.4)	1112	(91.4)
Presence	559	(8.7)	362	(8.7)	93	(8.6)	104	(8.6)
Previous STEMI	6436		4140		1080		1216	
Absence	6057	(94.1)	3886	(93.9)	1017	(94.2)	1154	(94.9)
Presence	379	(5.9)	254	(6.1)	63	(5.8)	62	(5.1)
Previous stroke or transient ischaemic attack	6436		4140		1080		1216	
Absence	5166	(80.3)	3305	(79.8)	882	(81.7)	979	(80.5)
Presence	1270	(19.7)	835	(20.2)	198	(18.3)	237	(19.5)
Diabetes mellitus	6436		4140		1080		1216	
Absence	5198	(80.8)	3352	(81.0)	894	(82.8)	952	(78.3)
Presence	1238	(19.2)	788	(19.0)	186	(17.2)	264	(21.7)
Hypertension	6436		4140		1080		1216	
Absence	2419	(37.6)	1538	(37.1)	437	(40.5)	444	(36.5)
Presence	4017	(62.4)	2602	(62.9)	643	(59.5)	772	(63.5)
Dyslipidemia	6436		4140		1080		1216	
Absence	4618	(71.8)	2973	(71.8)	786	(72.8)	859	(70.6)
Presence	1818	(28.2)	1167	(28.2)	294	(27.2)	357	(29.4)
Smoking	6436		4140		1080		1216	
Absence	5103	(79.3)	3290	(79.5)	846	(78.3)	967	(79.5)
Presence	1333	(20.7)	850	(20.5)	234	(21.7)	249	(20.5)
Atheroma of the supra-aortic arteris	6436		4140		1080		1216	
Absence	6213	(96.5)	4015	(97.0)	1027	(95.1)	1171	(96.3)
Presence	223	(3.5)	125	(3.0)	53	(4.9)	45	(3.7)
Peripheral artery disease	6436		4140		1080		1216	
Absence	6144	(95.5)	3959	(95.6)	1023	(94.7)	1162	(95.6)
Presence	292	(4.5)	181	(4.4)	57	(5.3)	54	(4.4)
Atrial fibrillation	6436		4140		1080		1216	
Absence	5348	(83.1)	3432	(82.9)	885	(81.9)	1031	(84.8)
Presence	1088	(16.9)	708	(17.1)	195	(18.1)	185	(15.2)
Cardiac failure	6436		4140		1080		1216	
Absence	6114	(95.0)	3934	(95.0)	1021	(94.5)	1159	(95.3)
Presence	322	(5.0)	206	(5.0)	59	(5.5)	57	(4.7)
Psychiatry	6436		4140		1080		1216	
Absence	5759	(89.5)	3672	(88.7)	988	(91.5)	1099	(90.4)
Presence	677	(10.5)	468	(11.3)	92	(8.5)	117	(9.6)
mRS less than 1 before stroke	6436		4140		1080		1216	
No	961	(14.9)	660	(15.9)	153	(14.2)	148	(12.2)
Yes	3709	(57.6)	2292	(55.4)	673	(62.3)	744	(61.2)
Unknown	1766	(27.4)	1188	(28.7)	254	(23.5)	324	(26.6)
NIHSS at entry	6436		4140		1080		1216	
[0-6]	3489	(54.2)	2185	(52.8)	607	(56.2)	697	(57.3)

[7-16]	1128	(17.5)	749	(18.1)	184	(17)	195	(16.0)
[17-42]	761	(11.8)	522	(12.6)	110	(10.2)	129	(10.6)
Unknown	1058	(16.4)	684	(16.5)	179	(16.6)	195	(16.0)
Structural characteristics of care								
Calls to emergency services activity during care (intensity of daily number of calls)	6436		4140		1080		1216	
Not high	899	(14.0)	608	(14.7)	140	(13)	151	(12.4)
Moderate	1948	(30.3)	1268	(30.6)	264	(24.4)	416	(34.2)
High	1184	(18.4)	669	(16.2)	303	(28.1)	212	(17.4)
Not concerned (no calls to emergency services)	2405	(37.4)	1595	(38.5)	373	(34.5)	437	(35.9)
Care during on-call activity	6411		4122		1080		1209	
Monday-Friday [8h-18h30]	3351	(52.3)	2178	(52.8)	565	(52.3)	608	(50.3)
Monday-Friday [18h30-20h]	338	(5.3)	212	(5.1)	55	(5.1)	71	(5.9)
Week-end and holiday [8h-20h]	1328	(20.7)	829	(20.1)	233	(21.6)	266	(22.0)
Night [20h-8h]	1394	(21.7)	903	(21.9)	227	(21.0)	264	(21.8)
Missing values	25		18		0		7	
EU hospital status	6436		4140		1080		1216	
University hospital	2441	(37.9)	1654	(40.0)	348	(32.2)	439	(36.1)
General hospital	3879	(60.3)	2410	(58.2)	715	(66.2)	754	(62.0)
Private hospital	116	(1.8)	76	(1.8)	17	(1.6)	23	(1.9)
Availability of MRI 24 hours a day	6436		4140		1080		1216	
No	1694	(26.3)	1061	(25.6)	291	(26.9)	342	(28.1)
Yes	4742	(73.7)	3079	(74.4)	789	(73.1)	874	(71.9)
Presence of stroke unit	6436		4140		1080		1216	
No	1245	(19.3)	799	(19.3)	197	(18.2)	249	(20.5)
Yes	5191	(80.7)	3341	(80.7)	883	(81.8)	967	(79.5)
Presence of interventional neuroradiology unit	6436		4140		1080		1216	
No	3304	(51.3)	2102	(50.8)	551	(51.0)	651	(53.5)
Yes	3132	(48.7)	2038	(49.2)	529	(49.0)	565	(46.5)

APL MG 2018=potential accessibility indicator to general practitioners; EU=emergency unit; FDep15=deprivation index; MRI=magnetic resonance imaging; mRS=modified Rankin Scale; NIHSS=National Institute of Health Stroke Score; STEMI=segment elevation myocardial infarction.

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Description of the STEMI cohort study sample (N=2782)

	Global (N=2782)		Pre-wave (N=1868)		Per-wave (N=407)		Post-wave (N=507)	
	n	(%)	n	(%)	n	(%)	n	(%)
Patient socio-demographic characteristics								
Gender	2782		1868		407		507	
Male	2033	(73.1)	1352	(72.4)	309	(75.9)	372	(73.4)
Female	749	(26.9)	516	(27.6)	98	(24.1)	135	(26.6)
Age	2776		1865		405		506	
Median [IQR]	65	[55;74]	65	[55;74]	65	[55;74]	64	[54;74]
Missing values	6		3		2		1	
Urbanicity	2543		1691		380		472	
Urban	1843	(72.5)	1221	(72.2)	277	(72.9)	345	(73.1)
Rural	700	(27.5)	470	(27.8)	103	(27.1)	127	(26.9)
Missing values	239		177		27		35	
Fdep15	2537		1690		380		467	
Median [IQR]	0.22	[-0.72;1.09]	0.23	[-0.70;1.09]	0.11	[-0.89;1.11]	0.22	[-0.72;1.09]
Missing values	245		178		27		40	
APL MG 2018	2537		1689		380		468	
Median [IQR]	4.3	[3.4;4.9]	4.3	[3.4;4.9]	4.2	[3.3;4.9]	4.4	[3.5;5.0]
Missing values	245		179		27		39	
Residence-to-cathlab distance (km)	2541		1692		379		470	
Median [IQR]	29	[10;54]	28	[10;54]	29	[10;52]	32	[12;58]
Missing values	241		176		28		37	
Patient clinical characteristics								
Coronary artery disease or STEMI history	2782		1868		407		507	
No	2031	(73.0)	1342	(71.8)	317	(77.9)	372	(73.4)
Yes	530	(19.1)	365	(19.5)	69	(16.9)	96	(18.9)
Unknown	221	(7.9)	161	(8.6)	21	(5.2)	39	(7.7)
Diabetes mellitus	2782		1868		407		507	
No	2119	(76.2)	1400	(74.9)	318	(78.1)	401	(79.1)
Yes	414	(12.9)	290	(15.5)	59	(14.5)	65	(12.8)
Unknown	249	(9.0)	178	(9.5)	30	(7.4)	41	(8.1)
Dyslipidemia	2782		1868		407		507	
No	1708	(61.4)	1133	(60.7)	249	(61.2)	326	(64.3)
Yes	887	(31.9)	601	(32.2)	135	(33.2)	151	(29.8)
Unknown	187	(6.7)	134	(7.2)	23	(5.7)	30	(5.9)
Active smoking	2782		1868		407		507	
No	1194	(42.9)	787	(42.1)	183	(45.0)	224	(44.2)
Yes	1163	(41.8)	785	(42.0)	164	(40.3)	214	(42.2)
Unknown	425	(15.3)	296	(15.8)	60	(14.7)	69	(13.6)
Peripheral arterial disease	2782		1868		407		507	
No	2245	(80.7)	1487	(79.6)	339	(83.3)	419	(82.6)
Yes	70	(2.5)	40	(2.1)	16	(3.9)	14	(2.8)
Unknown	467	(16.8)	341	(18.3)	52	(12.8)	74	(14.6)
Obesity	2782		1868		407		507	
No	1801	(64.7)	1229	(65.8)	252	(61.9)	320	(63.1)
Yes	513	(18.4)	332	(17.8)	87	(21.4)	94	(18.5)
Unknown	468	(16.8)	307	(16.4)	68	(16.7)	93	(18.3)
Familial history of coronary artery disease	2782		1868		407		507	
No	2070	(74.4)	1367	(73.2)	308	(75.7)	395	(77.9)
Yes	455	(16.4)	317	(17.0)	64	(15.7)	74	(14.6)
Unknown	257	(9.2)	184	(9.9)	35	(8.6)	38	(7.5)
Chronic renal failure	2782		1868		407		507	
No	2264	(81.4)	1493	(79.9)	344	(84.5)	427	(84.2)
Yes	47	(1.7)	31	(1.7)	10	(2.5)	6	(1.2)
Unknown	471	(16.9)	344	(18.4)	53	(13.0)	74	(14.6)
Arterial hypertension	2782		1868		407		507	
No	1278	(45.9)	866	(46.4)	168	(41.3)	244	(48.1)
Yes	1356	(48.7)	897	(48.0)	220	(54.1)	239	(47.1)
Unknown	148	(5.3)	105	(5.6)	19	(4.7)	24	(4.7)
Structural characteristics of care								
Calls to emergency services activity (intensity of daily number of calls)	2782		1868		407		507	
Not high	440	(15.8)	303	(16.2)	63	(15.5)	74	(14.6)
Moderate	1093	(39.3)	744	(39.8)	143	(35.1)	206	(40.6)
High	642	(23.1)	399	(21.4)	127	(31.2)	116	(22.9)
Not concerned (no calls to emergency services)	607	(21.8)	422	(22.6)	74	(18.2)	111	(21.9)
Care during on-call activity	2712		1821		395		496	

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Monday-Friday [8h-18h30]	1116	(41.2)	741	(40.7)	164	(41.5)	211	(42.5)
Monday-Friday [18h30-20h]	133	(4.9)	90	(4.9)	21	(5.3)	22	(4.4)
Week-end and holiday [8h-20h]	547	(20.2)	368	(20.2)	68	(17.2)	111	(22.4)
Night [20h-8h]	916	(33.8)	622	(34.2)	142	(35.9)	152	(30.6)
Missing values	70		47		12		11	
EU hospital status	2782		1868		407		507	
University hospital	71	(2.6)	48	(2.6)	7	(1.7)	16	(3.2)
General hospital	839	(30.2)	564	(30.2)	114	(28)	161	(31.8)
Private hospital	275	(9.9)	187	(10)	39	(9.6)	49	(9.7)
Not concerned (not managed by EU)	1597	(57.4)	1069	(57.2)	247	(60.7)	281	(55.4)
Cathlab hospital status	2782		1868		407		507	
University hospital	624	(22.4)	417	(22.3)	96	(23.6)	111	(21.9)
General hospital	1015	(36.5)	661	(35.4)	154	(37.8)	200	(39.4)
Private hospital	975	(35.0)	666	(35.7)	136	(33.4)	173	(34.1)
Not concerned (not managed by cathlab)	168	(6.0)	124	(6.6)	21	(5.2)	23	(4.5)
FMC-to-cathlab distance (km)	2555		1703		379		473	
Median [IQR]	21	[0;50]	21	[0;50]	21	[4;48]	24	[0;52]
Missing values	227		165		28		34	

APL MG 2018=potential accessibility indicator to general practitioners; EU=emergency unit; FDep15=deprivation index; FMC=first medical contact; STEMI=segment elevation myocardial infarction.

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Supplementary material 4.

Results of the final model estimating the association between reorganisations and use of care effects on care management times: p-value of the type III global fixed effects test - Stroke cohort (N=4603)

Variable	p-value
Hospital reorganisations	
Plan Blanc	0.372
Separate Covid/non-Covid patients pathway	0.830
Decrease in non-Covid patients management and admission capacities	0.532
Specific access to imaging for Covid patients	0.658
Deprogramming of non-urgent procedures or hospitalisations	0.752
Use of care	
Calls to emergency services	0.360
Interaction period x calls to emergency services	0.039
FMC	0.034
Interaction period x FMC	0.807

Results of multivariate linear regression mixed model; variable to be explained: Y = log (EU admission-to-imaging time); results adjusted on period, age, gender, urbanicity, FDep15, APL MG 18, residence-EU distance, presence of stroke unit, MRI 24 hours a day, presence of interventional neuroradiology unit, care during on-call activity, mode of transport, calls to emergency services activity, mRS less than 1 before stroke, NIHSS at entry, previous stroke or transient ischaemic attack

APL MG 2018=potential accessibility indicator to general practitioners; EU=emergency unit; FDep15=deprivation index; FMC=first medical contact; MRI=magnetic resonance imaging; mRS=modified Rankin Scale; NIHSS=National Institute of Health Stroke Score; *Plan Blanc*=emergency plan to cope with a sudden increase of activity.

Created by the authors

Results of the final model estimating the association between reorganisations and use of care effects on care management times: estimation of regression coefficients - Stroke cohort (N=4603)

Variable	Modalities		β	p-value
Intercept			4.767	<0.001
Hospital reorganisations				
Plan Blanc	yes (ref : no)		-0.061	0.372
Separate Covid/non-Covid patients pathway	yes (ref : no)		0.013	0.830
Decrease in non-Covid patients management and admission capacities	yes (ref : no)		-0.044	0.532
Specific access to imaging for Covid patients	yes (ref : no)		0.024	0.658
Deprogramming of non-urgent procedures or hospitalisations	yes (ref : no)		0.021	0.752
Use of care				
Calls to emergency services	yes (ref : no)		-0.137	0.087
Interaction period x calls to emergency services	*pre-wave*	*no*	-	.
	pre-wave	*yes*	-	.
	per-wave	*no*	-	.
	per-wave	*yes*	0.013	0.850
	post-wave	*no*	-	.
	post-wave	*yes*	0.210	0.014
FMC	MICU (ref : EU)		-0.369	0.027
interaction period x FMC	*pre-wave*	*EU*	-	.
	pre-wave	*MICU*	-	.
	per-wave	*EU*	-	.
	per-wave	*MICU*	0.138	0.536
	post-wave	*EU*	-	.
	post-wave	*MICU*	0.008	0.968

Results of multivariate linear regression mixed model; variable to be explained: Y = log (EU admission-to-imaging time); results adjusted on period, age, gender, urbanicity, FDep15, APL MG 18, residence-EU distance, presence of stroke unit, MRI 24 hours a day, presence of interventional neuroradiology unit, care during on-call activity, mode of transport, calls to emergency services activity, mRS less than 1 before stroke, NIHSS at entry, previous stroke or transient ischaemic attack

APL MG 2018=potential accessibility indicator to general practitioners; EU=emergency unit; FDep15=deprivation index; FMC=first medical contact; MICU=mobile intensive care units; MRI=magnetic resonance imaging; mRS=modified Rankin Scale; NIHSS=National Institute of Health Stroke Score; *Plan Blanc*=emergency plan to cope with a sudden increase of activity.

Created by the authors

Results of the final model estimating the association between reorganisations and use of care effects on care management times: p-value of the type III global fixed effects test - STEMI cohort (N=1843)

Variable	p-value
Hospital reorganisations	
Increase in the telephone reception capacities	0.273
Restriction of helicopter transport for Covid patients	0.637
Plan blanc	0.077
Systematic covid testing	0.013
Separate Covid/non-Covid patients pathway	0.395
Decrease in non-Covid patients management and admission capacities	0.135
Coronary angiography room dedicated to Covid patients in cathlabs	0.907
Deprogramming of non-urgent procedures or hospitalisations	0.134
Decrease in bed capacity for non-Covid patients	0.557
Use of care	
FMC	<0.001
Interaction period x FMC	0.492
Symptoms-to-care time (10 min step)	<0.001
Interaction period x symptoms-to-care time	0.206

Results of a multivariate linear regression mixed model; variable to be explained: Y=log (FMC-to-procedure time); results adjusted on period, age, gender, urbanicity, FDep15, APL MG 18, residence-to-cathlab distance, cathlab hospital status, care during on-call activity, mode of transport, calls to emergency services activity, FMC-to-cathlab distance, diabetes mellitus, coronary artery disease or STEMI history).

APL MG 2018=potential accessibility indicator to general practitioners; EU=emergency unit; FDep15=deprivation index; FMC=first medical contact; *Plan Blanc*=emergency plan to cope with a sudden increase of activity; STEMI=segment elevation myocardial infarction.

Created by the authors

Results of the final model estimating the association between reorganisations and use of care effects on care management times: estimation of regression coefficients - STEMI cohort (N=1843)

Variable	**Modalities**		**β**	**p-value**
Intercept			4.475	<0.001
Hospital reorganisations				
Increase in the telephone reception capacities	yes (ref : no)		0.072	0.273
Restriction of helicopter transport for Covid patients	yes (ref : no)		0.034	0.637
Plan blanc	yes (ref : no)		-0.212	0.077
Systematic covid testing	yes (ref : no)		0.343	0.013
Separate Covid/non-Covid patients pathway	yes (ref : no)		-0.092	0.395
Decrease in non-Covid patients management and admission capacities	yes (ref : no)		-0.222	0.135
Coronary angiography room dedicated to Covid patients in cathlabs	yes (ref : no)		-0.010	0.907
Deprogramming of non-urgent procedures or hospitalisations	yes (ref : no)		0.131	0.134
Decrease in bed capacity for non-Covid patients	yes (ref : no)		-0.043	0.557
Use of care				
FMC	EU without cathlab (ref)		-	.
	MICU		-1.061	<0.001
	EU with cathlab		-0.326	<0.001
interaction period x FMC	*pre-wave*	*EU without cathlab*	-	
	pre-wave	*MICU*	-	
	pre-wave	*EU with cathlab*	-	
	per-wave	*EU without cathlab*	-	
	per-wave	*MICU*	-0.094	0.419
	per-wave	*EU with cathlab*	0.102	0.505
	post-wave	*EU without cathlab*	-	
	post-wave	*MICU*	0.075	0.514
	post-wave	*EU with cathlab*	0.221	0.14
Symptoms-to-care time (10 min step)			0.002	0.016
Interaction period x symptoms-to-care time	*pre-wave (ref)*		-	
	per-wave		0.003	0.137
	post-wave		0.002	0.209

Results of a multivariate linear regression mixed model; variable to be explained: Y=log (FMC-to-procedure time); results adjusted on period, age, gender, urbanicity, FDep15, APL MG 18, residence-to-cathlab distance, cathlab hospital status, care during on-call activity, mode of transport, calls to emergency services activity, FMC-to-cathlab distance, diabetes mellitus, coronary artery disease or STEMI history).

APL MG 2018=potential accessibility indicator to general practitioners; EU=emergency unit; FDep15=deprivation index; FMC=first medical contact; MICU=mobile intensive care units; *Plan Blanc*=emergency plan to cope with a sudden increase of activity; STEMI=segment elevation myocardial infarction.

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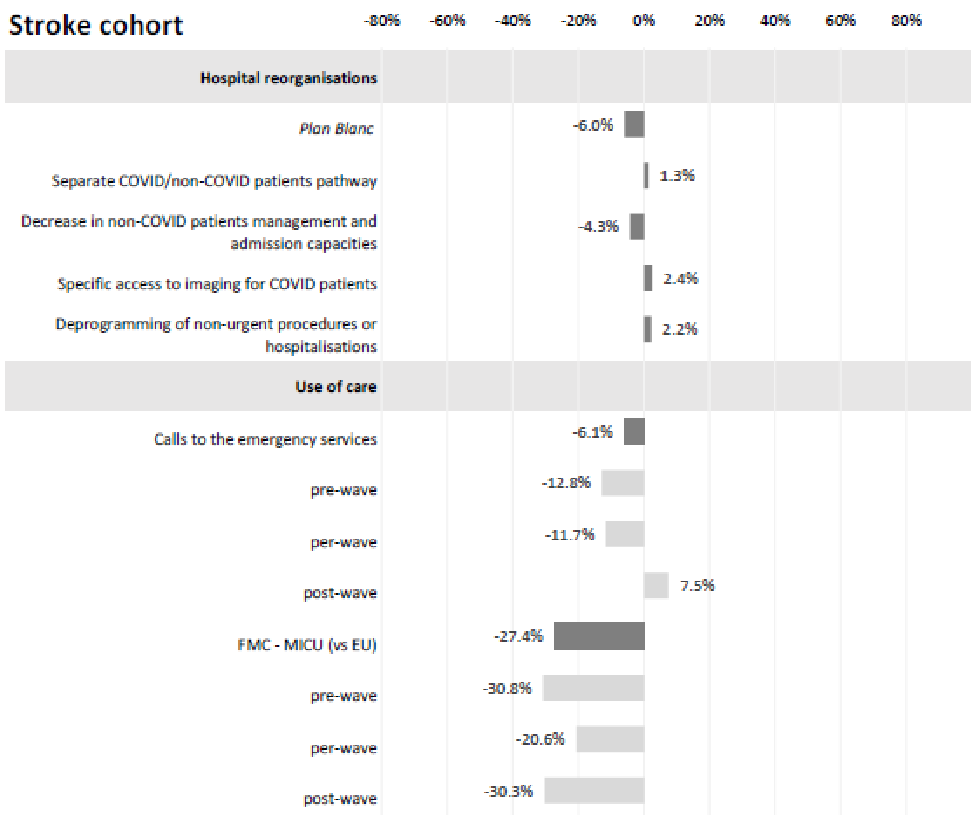
Stroke cohort
-80%
-60%
-40%
-20%
0%
20%
40%
60%
80%
Hospital reorganisations
Plan Blanc
-6.0%
Separate COVID/non-COVID patients pathway
1.3%
Decrease in non-COVID patients management and admission capacities
-4.3%
Specific access to imaging for COVID patients
2.4%
Deprogramming of non-urgent procedures or hospitalisations
2.2%
Use of care
Calls to the emergency services
-6.1%
pre-wave
-12.8%
per-wave
-11.7%
post-wave
7.5%
FMC - MICU (vs EU)
-27.4%
pre-wave
-30.8%
per-wave
-20.6%
post-wave
-30.3%

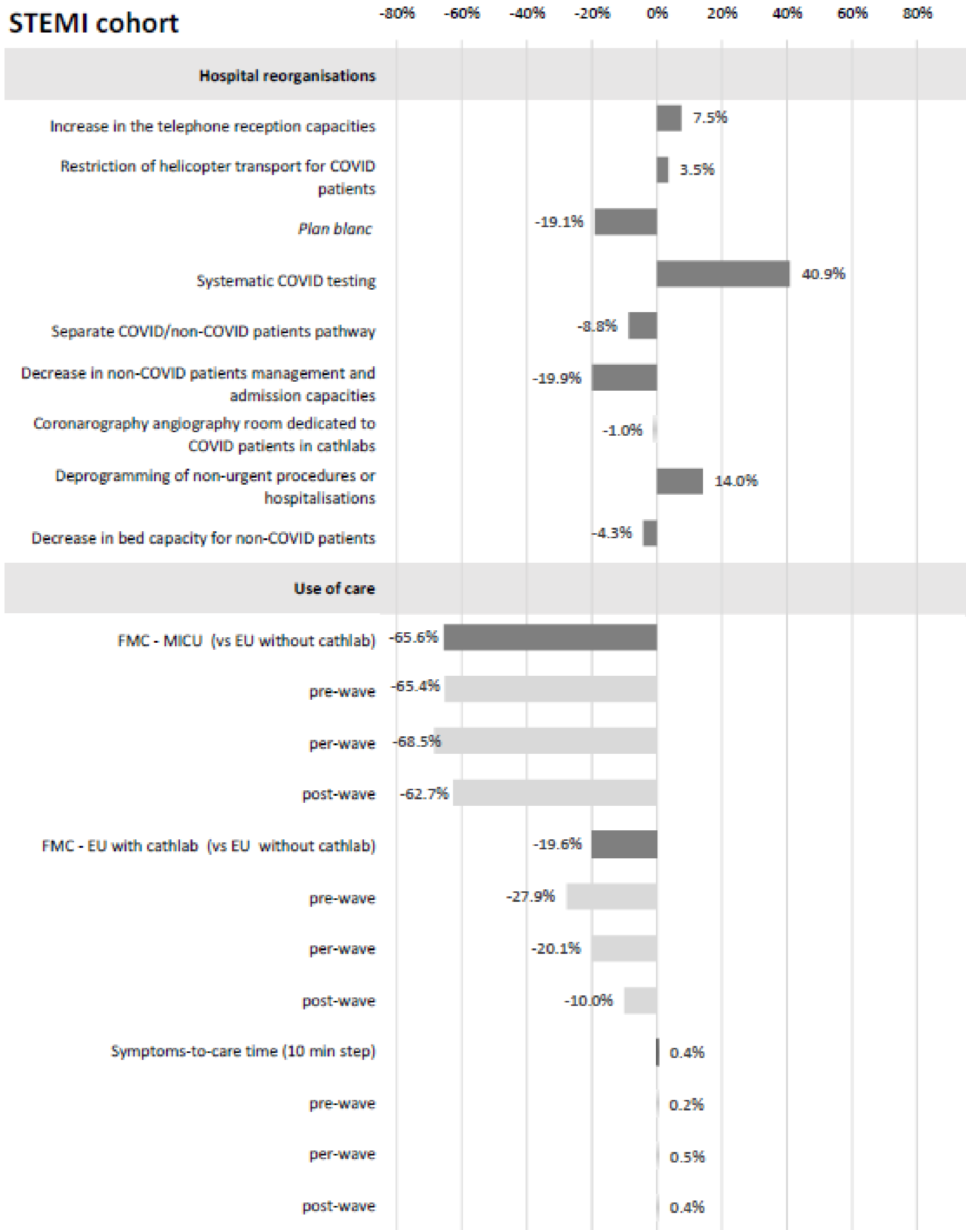
STEMI cohort
-80%
-60%
-40%
-20%
0%
20%
40%
60%
80%
Hospital reorganisations
Increase in the telephone reception capacities
7.5%
Restriction of helicopter transport for COVID patients
3.5%
Plan blanc
-19.1%
Systematic COVID testing
40.9%
Separate COVID/non-COVID patients pathway
-8.8%
Decrease in non-COVID patients management and admission capacities
-19.9%
Coronarography angiography room dedicated to COVID patients in cathlabs
-1.0%
Deprogramming of non-urgent procedures or hospitalisations
14.0%
Decrease in bed capacity for non-COVID patients
-4.3%
Use of care
FMC - MICU (vs EU without cathlab)
-65.6%
pre-wave
-65.4%
per-wave
-68.5%
post-wave
-62.7%
FMC - EU with cathlab (vs EU without cathlab)
-19.6%
pre-wave
-27.9%
per-wave
-20.1%
post-wave
-10.0%
Symptoms-to-care time (10 min step)
0.4%
pre-wave
0.2%
per-wave
0.5%
post-wave
0.4%

Figure. Stroke and STEMI cohorts. Variation percentages of the estimations of the reorganisations and use of care effects on care management times

A: Stroke cohort (N=4603) – Percentage change in overall effects; results of multivariate linear regression mixed models; variable to be explained: Y = log (EU admission-to-imaging time); results adjusted on period, age, gender, urbanicity of residence, FDep15, APL MG 18, residence-EU distance, presence of stroke unit, MRI 24 hours a day, presence of interventional neuroradiology unit, care during on-call activity, mode of transport, calls to emergency services activity, mRS less than 1 before stroke, NIHSS at entry, previous stroke or transient ischaemic attack.

B: STEMI cohort (N=1843) – Percentage change in overall effects; results of multivariate linear regression mixed models; variable to be explained: Y=log (FMC-to-procedure time); results adjusted on period, age, gender, urbanicity of residence, FDep15, APL MG 18, residence-to-cathlab distance, cathlab hospital status, care during on-call activity, mode of transport, calls to emergency services activity, FMC-to-cathlab distance, diabetes mellitus, coronary artery disease or STEMI history).

Light grey: interaction with the Covid period, Dark grey: raw results without interaction with the Covid period

Plan Blanc=emergency plan to cope with a sudden increase of activity

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STROBE Statement—Checklist of items that should be included in reports of cohort studies

	Item No	Recommendation	Page No
Title and abstract	1	(*a*) Indicate the study's design with a commonly used term in the title or the abstract	ok
		(*b*) Provide in the abstract an informative and balanced summary of what was done and what was found	ok, page 1
Introduction			
Background/rationale	2	Explain the scientific background and rationale for the investigation being reported	ok, page 4
Objectives	3	State specific objectives, including any prespecified hypotheses	ok, page 4
Methods			
Study design	4	Present key elements of study design early in the paper	ok, page 4
Setting	5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection	ok, pages 4, 5
Participants	6	(*a*) *Cohort study*—Give the eligibility criteria, and the sources and methods of selection of participants. Describe methods of follow-up	ok, pages 4, 5
		(*b*) *Cohort study*—For matched studies, give matching criteria and number of exposed and unexposed	NA
Variables	7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable	ok, pages 5, 6, 7
Data sources/ measurement	8*	For each variable of interest, give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group	ok, pages 5, 6
Bias	9	Describe any efforts to address potential sources of bias	ok, page 7
Study size	10	Explain how the study size was arrived at	ok, page 5
Quantitative variables	11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why	ok, page 7
Statistical methods	12	(*a*) Describe all statistical methods, including those used to control for confounding	ok, page 7
		(*b*) Describe any methods used to examine subgroups and interactions	ok, page 7
		(*c*) Explain how missing data were addressed	ok, page 7
		(*d*) *Cohort study*—If applicable, explain how loss to follow-up was addressed	NA
		(*e*) Describe any sensitivity analyses	ok, page 7
Results			
Participants	13*	(a) Report numbers of individuals at each stage of study—eg numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed	ok, page 7
		(b) Give reasons for non-participation at each stage	NA
		(c) Consider use of a flow diagram	NA
Descriptive data	14*	(a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders	ok, page 7, suppl mat.
		(b) Indicate number of participants with missing data for each variable of interest	ok, pages 9, 10

		(c) *Cohort study*—Summarise follow-up time (eg, average and total amount)	NA
Outcome data	15*	*Cohort study*—Report numbers of outcome events or summary measures over time	ok, page 11
Main results	16	(*a*) Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (eg, 95% confidence interval). Make clear which confounders were adjusted for and why they were included	ok, page 11
		(*b*) Report category boundaries when continuous variables were categorized	ok, pages 9, 10
		(*c*) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period	NA
Other analyses	17	Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses	ok, page 11
Discussion			
Key results	18	Summarise key results with reference to study objectives	ok, pages 11, 12
Limitations	19	Discuss limitations of the study, taking into account sources of potential bias or imprecision. Discuss both direction and magnitude of any potential bias	ok, pages 13, 14
Interpretation	20	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence	ok, pages 12
Generalisability	21	Discuss the generalisability (external validity) of the study results	ok, pages 14
Other information			
Funding	22	Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based	ok, page 15

NA= not applicable

BMJ Open

Effects of healthcare system transformations spurred by the coronavirus disease 2019 pandemic on management of stroke and STEMI: A registry-based cohort study in France

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Effects of healthcare system transformations spurred by the coronavirus disease 2019 pandemic on management of stroke and STEMI: A registry-based cohort study in France

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ABSTRACT

Objective: To assess the impact of changes in use of care and implementation of hospital reorganisations spurred by the coronavirus disease 2019 (COVID-19) pandemic (first wave) on the acute management times of stroke and ST-segment elevation myocardial infarction (STEMI) patients.

Design: Two cohorts of STEMI and stroke patients in the Aquitaine Cardio-Neuro-Vascular (CNV) registry.

Setting: Six emergency medical services, 30 emergency units, 14 hospitalisation units, and 11 cathlabs in the Aquitaine region.

Participants: This study involved 9218 patients (6436 stroke and 2782 STEMI patients) in the CNV registry from January 2019 to August 2020.

Method: Hospital reorganisations, retrieved in a scoping review, were collected from heads of hospital departments. Other data were from the CNV registry. Associations between reorganisations, use of care, and care management times were analysed using multivariate linear regression mixed models. Interaction terms between use-of-care variables and period (pre-, per-, and post-wave) were introduced.

Main outcome measures: STEMI cohort, first medical contact-to-procedure time; stroke cohort, emergency unit admission-to-imaging time.

Results: Per-wave period management times deteriorated for stroke but were maintained for STEMI. Per-wave changes in use of care did not affect STEMI management. No association was found between reorganisations and stroke management times. In the STEMI cohort, the implementation of systematic testing at admission was associated with a 41% increase in care management time (exp = 1.409, 95%CI 1.075-1.848, p = 0.013). Implementation of *Plan Blanc*, which concentrated resources in emergency activities, was associated with a 19% decrease in management time (exp = 0.801, 95%CI 0.639-1.023, p = 0.077).

Conclusions: The pandemic did not markedly alter the functioning of the emergency network. Although stroke patient management deteriorated, the resilience of the STEMI pathway was linked to its stronger structuring. Transversal reorganisations, aiming at concentrating resources on emergency care, contributed to maintenance of the quality of care.

STRENGTHS AND LIMITATIONS OF THIS STUDY

- The study analysed two large high-quality data cohorts comprising almost 10000 stroke and STEMI patients, managed in a large panel of care structures throughout the Aquitaine region, over a period of several months before and after the first wave.
- We evaluated reorganisations implemented by care structures in the management of stroke and STEMI patients to cope with the COVID-19 pandemic.
- The explanatory analyses yielded robust results due to the large amount of data collected (clinical characteristics, socio-geographical factors, acute care management pathway data), enabling integration of confounding factors identified by the directed acyclic graph method.
- The exclusion of patients who did not enter the healthcare system prevented quantification of avoidance of the health care system, which is thought to have been more frequent during the COVID-19 pandemic.
- Data were restricted to the Aquitaine region, which was less affected by the first wave of the pandemic; this hampers the geographical generalisability of results on the effects of reorganisations focused on emergency units, which were more sensitive to patient influx.

INTRODUCTION

Governments worldwide responded to the COVID-19 pandemic with unprecedented policies that affected healthcare systems, and that were designed to slow the growth rate of the infection.(1–3) France was one of the most affected countries in the early months of the pandemic.(4) From March to May 2020, French authorities implemented a nationwide lockdown and a series of policies to curb the surge of patients requiring critical care. The French health care system was at that time almost entirely devoted to the fight against severe acute respiratory syndrome coronavirus-2 (SARS-CoV-2).

These profound changes were likely to have had a negative impact on the delivery of medical and surgical services. Use of care was altered;(5) all countries that implemented policies to prevent the spread of SARS-CoV-2 experienced a marked decrease in the number of patients entering emergency rooms for reasons other than COVID-19, revealing a tendency to delay or even forego care.(6–9)

Concerns rose about the quality of management of acute conditions other than COVID-19, particularly stroke and ST-segment elevation myocardial infarction (STEMI), the most highly time-sensitive conditions.(10,11) Management pathways for these two diseases have long been established, based initially on the patient's use of the emergency medical service (EMS) system in the event of an extreme emergency, followed by relays between emergency structures and specialised technical platforms (cathlabs, stroke units). These care pathways depend on collaboration among various professionals in pre- and intra-hospital areas. These pre-defined pathways may have been undermined by the organisational and societal upheavals associated with the COVID-19 pandemic. Indeed, international literature agrees that the COVID-19 pandemic substantially decreased the rate of stroke and STEMI admissions and the number of procedures, and increased the interval from symptom onset to hospital treatment; these latest appearing driven predominantly by delays in use of care and transfers.(12)

However, results on the effect of the COVID-19 pandemic on the intra-hospital quality of care of these two diseases are diverse.(13–16) We hypothesised that this may be due to the organisational environment of hospitals and the timing and type of re-organisations implemented to cope with the COVID-19 pandemic. Beyond national directives, each hospital had authority over its reorganisation, according to local capacity. To date, no study has quantified the effect of the COVID-19 pandemic on the delivery of stroke and STEMI care.

Since 2012, the Aquitaine region (southwestern France, 3 million inhabitants) has implemented a regional registry of cardio-neuro-vascular pathologies (CNV Registry), enabling analysis of the care pathway of STEMI and stroke patients in Aquitaine hospitals. Therefore, there is a unique opportunity to study changes in care management in the region over time.(17)

We assessed the impact of changes in use of care and health reorganisation spurred by the first wave of the COVID-19 pandemic on care management times of STEMI and stroke patients hospitalised in the Aquitaine region. We also analysed the use and quality of care provided to these patients during the COVID-19 pandemic.

METHODS

Study design and population

This study was based on two retrospective cohorts of stroke and STEMI patients. We performed ad hoc evaluation of the reorganisations implemented by healthcare structures in the Aquitaine region during the first wave of the COVID-19 pandemic.

The two cohorts comprised adult patients, living in metropolitan France, and admitted to a care structure involved in the CNV registry with recent stroke or STEMI, from January 1st 2019 to August 31 2020.(17) The STEMI cohort comprised recent STEMI patients < 24 h from symptom onset, managed in 6 EMSs, 30 emergency units (EUs), and 11 cathlabs in Aquitaine. The stroke cohort comprised recent ischaemic or haemorrhagic stroke patients diagnosed by brain imaging with validation by a neurovascular physician (exclusion of transient ischaemic attacks), managed in 5 of the 6 EMSs and 14 (including 7 stroke units) of the 20 hospitals caring for > 30 strokes per year in Aquitaine. The CNV registry has been approved by the French authority on data protection and meets the regulatory requirements for patient information (file 2216283).

Data collection

Stroke and STEMI cohorts

Data were collected from each care structure at each step of the care pathway:

1) In EMSs, data entered in electronic care records were extracted from the hospital information system.

2) In EUs, data were entered prospectively by physicians in dedicated paper or electronic care records and extracted or collected retrospectively by clinical research assistants.

3) In cathlabs or stroke hospitalisation units, data were entered prospectively by physicians, and then extracted.

Data of the two cohorts were consolidated and incorporated into one data warehouse, allowing the reconstruction of the STEMI or stroke management pathway.

The CNV registry collects information on:

1) Patient socio-demographic characteristics: age, gender, place of residence.

2) Patient clinical characteristics: medical history, cardiovascular risk factors, stroke clinical severity (modified Rankin Scale [mRS] and National Institute of Health Stroke Score [NIHSS]), and stroke type (ischaemic/haemorrhagic).

3) Use of care (Table 1): calls to emergency services, first medical contact (FMC), and symptom-to-care time.

4) Acute care management quality (Table 1): Intervals between key management steps (stroke, EU admission-to-imaging time; STEMI, FMC-to-procedure time), pre-hospital and hospital pathways, mode of transport to the EU, orientation to stroke unit or cathlab and treatment (stroke, first imaging type, intravenous thrombolysis [IVT] in ischaemic stroke, mechanical thrombectomy in ischaemic stroke; STEMI, fibrinolysis, percutaneous coronary intervention [PCI], coronary angiography alone).

5) Structural characteristics of care: Care during on-call activity, calls to emergency services during care, administrative status of the hospital and FMC-to-cathlab distance. For the stroke cohort, availability of magnetic resonance imaging (MRI) 24 hours a day, stroke unit and interventional neuroradiology unit.

Place of residence was used to calculate distances between residence and care structures and three geographical indices: Urbanicity, deprivation index (Fdep15), potential accessibility to general practitioners (APL MG 2018) (Table 1).(18–20)

Table 1. Definition of use of care variables, acute care management quality variables and geographical indexes

Variables	Definition
Use of care	
Calls to emergency services	Patient call to emergency services after the onset of symptoms
FMC	First medical team to take care of the patient: - in the stroke cohort, two categories of FMC: 1) MICU in case of call to, 2) EU in case of no call to emergency services; - in the STEMI cohort, three categories of FMC: 1) MICU, 2) EU with cathlab, 3) EU without cathlab.
Symptoms-to-care time	Delay in minutes between symptoms onset and start of management by the healthcare system, either call to emergency services or EU admission in case of no call to emergency services
Acute care management quality	
EU admission-to-imaging time	Delay in minutes between EU admission and start of the first imaging (MRI or CT scan)
FMC-to-procedure time	Delay in minutes between FMC and the start of the treatment procedure (coronary angiography or PCI)
IVT in ischaemic stroke	Two variables: 1) IVT in all ischaemic stroke patients, 2) IVT in "IVT alert" patients *ie.* patients with symptoms-to-EU admission time less than 4 hours.
Geographical indexes	
Urbanicity	Urban defined as commune or group of communes with a continuous built-up area with at least 2000 inhabitants
FDep15	Validated social level index calculated from four variables attributed to each commune: median household income, proportion of baccalaureate, proportion of workers in the active population and unemployment rate
APL MG 2018	Index calculated from the supply of general practitioners, the demand for care and the distance between the place of residence and the supply of care

APL MG 2018=potential accessibility indicator to general practitioners; CT=computerized tomography scan; EU=emergency unit; FDep15=deprivation index; FMC=first medical contact; IVT=intravenous thrombolysis; MICU=mobile intensive care units; MRI=magnetic resonance imaging; PCI=Percutaneous Coronary Intervention; STEMI=segment elevation myocardial infarction.
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<u>Reorganisations implemented in healthcare structures</u>

A scoping review was conducted in compliance with the PRISMA recommendations (21) to evaluate the structural reorganisations implemented in care structures related to acute management of stroke and STEMI patients, to deal with the first wave of the COVID-19 pandemic (Supplementary Material 1).(22) The retrieved reorganisations were classified according to care structure: in EMSs ("increase in the telephone reception capacities", "restriction of helicopter transport for COVID patients"), EUs ("systematic COVID testing", "separate COVID/non-COVID patients pathway", "decrease in non-COVID patients management and admission capacities", *Plan Blanc* [emergency plan to cope with a sudden increase of activity]) and stroke or STEMI hospitalisation units ("coronary angiography room dedicated to COVID patients in cathlabs", "deprogramming of non-urgent procedures or hospitalisations", "decrease in bed capacity for non-COVID patients", "specific access to imaging for COVID patients"). The retrieved reorganisations were compiled into a questionnaire addressed to the care-structure heads who were asked to indicate, for each reorganisation, whether it had been implemented and, if so, its dates of implementation and of termination.

Care management times

The primary endpoints were the FMC-to-procedure time and EU admission-to-imaging time for the STEMI and stroke cohorts, respectively.

Statistical analysis

Analyses were performed separately for each cohort. Three periods were defined according to the dates of implementation of the first hospital reorganisations and termination of national lockdown: pre-wave (January 1, 2019, to February 9, 2020), per-wave (February 10, to May 10, 2020), and post-wave (May 11, to August 31, 2020). Use-of-care and acute-care management quality variables were compared among the three periods (Khi2 test or Fisher exact test for qualitative variables, and Kruskal–Wallis test for quantitative variables. P-values were corrected by the false discovery rate [FDR] method to account for the multiplicity of tests).

The associations between reorganisations (STEMI, nine variables; stroke, five variables), use of care (STEMI, two variables; stroke, two variables), and care management times (introduced as continuous variables after logarithmic transformation) were analysed using a multivariate linear regression mixed model (two random effects on hospital and health territory). Interaction terms between the use-of-care variables and period (pre-, per-, and post-wave) were introduced. The confounding variables were identified by means of a directed acyclic graph (DAG) (Supplementary Material 2).

The relationships between reorganisations or use of care and care management times were quantified (β) by the contrast method (statistical significance $P < 0.05$) and the exponentials of the betas ($\exp(\beta)$); their 95% confidence intervals and percentage changes ($1 - \exp(\beta)$) were calculated.

For the stroke cohort, a sensitivity analysis was carried out by adding the variable symptoms-to-care time to the model. This variable was not introduced in principal analysis because it presented more than 20% missing data. Statistical analysis was conducted using SAS 9.4.

Patient and public involvement statement

As members of the CNV registry scientific boards, patient representatives were involved in study conception, implementation, and dissemination; they validated data collection and analysis, and results diffusion. Dissemination of results was conducted on the CNV registry website, to the scientific boards, and to care-structure physicians.

This study is reported in accordance with the STROBE guidelines and is registered with ClinicalTrials.gov (NCT04979208).

RESULTS

Study sample (Supplementary Material 3)

The study sample comprised 9218 patients: 6008 pre-wave, 1487 per-wave, and 1723 post-wave. The mean number of included patients was stable during the pre- and post-wave periods (weekly mean number [SD] of inclusions: 32 [6] STEMIs pre-wave, 32 [5] STEMIs post-wave; 83 [8] strokes pre-wave, 75 [7] strokes post-wave). At the beginning of the per-wave period (weeks 7 to 15), inclusions of stroke (lowest weekly number, 56) and STEMI (lowest weekly number, 22) patients decreased, followed by a slow increase that continued into the post-wave period.

A total of 6436 stroke patients (5669 [88.1%] with ischaemic stroke and 767 [17.9%] with haemorrhagic stroke) was managed in 5 EMSs, 14 EUs, and 14 hospitalisation units (7 stroke units); the 2782 STEMI patients were managed in 6 EMSs, 30 EUs, and 11 cathlabs. The median age was younger in the stroke cohort during the per- and post-wave compared to the pre-wave periods (77 and 76 years vs. 79 years) and the median age of STEMI patients was similar in the three periods. In the STEMI cohort, a lower proportion of women (24.1% *vs*. 27.6% and 26.6%) and a higher proportion of patients with hypertension history (54.1% *vs*. 48.0% and 47.1%) were observed during the per-wave period compared to the pre- and post-wave periods. In the stroke cohort, the frequency of severe strokes was lower in the per- and post-wave periods (56.2% and 57.3%, respectively, of stroke patients with NIHSS < 7) than in the pre-wave period (52.8%).

Reorganisations implemented in care structures (figure 1)

Reorganisations began in early February 2020. In the middle of the per-wave period, 83% of EMSs, 90% of EUs, 93% of stroke hospitalisation units, and 64% of cathlabs had implemented at least one reorganisation. The two most frequently implemented reorganisations were "increase in the telephone reception capacities" (implemented in all EMSs) and "separate COVID/non-COVID patients pathways" (implemented by 93% of EUs; n = 13 for stroke, n = 28 for STEMI). Half of the EUs implemented *Plan Blanc*. Most reorganisations implemented during the per-wave period were maintained in the post-wave period.

Use of care and acute care management quality in the pre-, per-, and post-wave periods (Tables 2, 3)

Use of care

In the per-wave compared to the pre-wave periods, calls to emergency services (stroke, 65.5% *vs*. 61.5%; STEMI, 81.8% *vs*. 77.4%) and the median symptom-to-care interval (stroke, 139 min *vs*. 121 min; STEMI, 84 min *vs*. 76 min) increased in both cohorts. These values returned to their previous levels during the post-wave period, except for calls to emergency services for stroke, which remained high.

Care management quality

The stroke median EU admission-to-imaging time increased (91 min *vs*. 83 min) and the STEMI median FMC-to-procedure time decreased (95 min *vs*. 100 min) in the per-wave compared to the pre-wave period. The management time remained high for stroke (88 min) and increased for STEMI (102 min) in the post-wave period.

In the stroke cohort, the proportion of IVT decreased during the per-wave compared to the pre- and post-wave periods (all ischaemic strokes, 14.6% *vs*. 19.4% and 16.7%, p = 0.011; IVT alert patients, 31.3% *vs*. 42.4% and 38.8%, p = 0.011) and the proportion of patients with an optimal pathway (calls to emergency services/mobile intensive care units [MICU] transport/EU) was larger during the per-wave period (59.5%) compared to the pre- (57.3%) and post-wave (58.3%, p = 0.040) periods.

Table 2. Comparison of use of care and acute care management quality characteristics between the pre, per, post-wave periods - Stroke cohort (N=6436)

	Global (N=6436)		Pre-wave (N=4140)		Per-wave (N=1080)		Post-wave (N=1216)		p-value corrected (FDR)	
	n	(%)	n	(%)	n	(%)	n	(%)		
Use of care										
Calls to emergency services	6430		4135		1079		1216		0.083	*
No	2399	(37.3)	1590	(38.5)	372	(34.5)	437	(35.9)		
Yes	4031	(62.7)	2545	(61.5)	707	(65.5)	779	(64.1)		
Missing values	*6*		*5*		*1*		*0*			
FMC	6436		4140		1080		1216		0.332	*
EU	6278	(97.5)	4040	(97.6)	1059	(98.1)	1179	(9.0)		
MICU	158	(2.5)	100	(2.4)	21	(1.9)	37	(3.0)		
Symptoms-to-care time (min)	3157		1991		556		610		0.232	**
Median [IQR]	126	[38;401]	121	[38;384]	139	[46;488]	125	[38;392]		
Missing values	*3279*		*2149*		*524*		*606*			
Acute care management quality										
EU admission-to-imaging time (min)	4819		3014		889		916		0.332	**
Median [IQR]	86	[47;194]	83	[45;201]	91	[51;175]	88	[52;191]		
Missing values	*1617*		*1126*		*191*		*300*			
Pre-hospital pathway type	6430		4135		1079		1216		0.040	*
Optimal pathway: calls to emergency services/MICU transport/EU	3719	(57.8)	2368	(57.3)	642	(59.5)	709	(58.3)		
Calls to emergency services /non-MICU transport/EU	312	(4.9)	177	(4.3)	65	(6.0)	70	(5.8)		
EU direct entry	2399	(37.3)	1590	(38.5)	372	(34.5)	437	(35.9)		
Missing values	*6*		*5*		*1*		*0*			
Mode of transport to the EU	6436		4140		1080		1216		0.812	*
Personal transport	732	(11.4)	475	(11.5)	117	(10.8)	140	(11.5)		
Non-MICU transport	4495	(69.8)	2902	(70.1)	758	(70.2)	835	(68.7)		
MICU transport	222	(3.4)	149	(3.6)	34	(3.1)	39	(3.2)		
Unknown	987	(15.3)	614	(14.8)	171	(15.8)	202	(16.6)		
Transfer to a stroke unit	6436		4140		1080		1216		0.923	*
No	752	(11.7)	484	(11.7)	123	(11.4)	145	(11.9)		
Yes	5684	(88.3)	3656	(88.3)	957	(88.6)	1071	(88.1)		
First imaging type	6041		3870		1019		1152		0.332	***
MRI	3782	(62.6)	2395	(61.9)	650	(63.8)	737	(64.0)		
CT scan	2245	(37.2)	1463	(37.8)	369	(36.2)	413	(35.9)		
None	14	(0.2)	12	(0.3)	0	(0.0)	2	(0.2)		
Missing values	*395*		*270*		*61*		*64*			
IVT (all ischaemic strokes)	5660		3616		938		1106		0.011	*
No	4635	(81.9)	2913	(80.6)	801	(85.4)	921	(83.3)		
Yes	1025	(18.1)	703	(19.4)	137	(14.6)	185	(16.7)		
Missing values	*9*		*1*		*3*		*5*			
Exclusion	*767*		*523*		*139*		*105*			
IVT in 'Thrombolysis alert' patients (ischaemic stroke)	1758		1100		310		348		0.011	*
No	1060	(60.3)	634	(57.6)	213	(68.7)	213	(61.2)		
Yes	698	(39.7)	466	(42.4)	97	(31.3)	135	(38.8)		
Missing values	*2*		*1*		*0*		*1*			
Exclusion	*4676*		*3039*		*770*		*867*			
Mechanical thrombectomy (all ischaemic stroke)	5620		3585		938		1097		0.332	*
No	4998	(88.9)	3170	(88.4)	842	(89.8)	986	(89.9)		
Yes	622	(11.1)	415	(11.6)	96	(10.2)	111	(10.1)		
Missing values	*49*		*32*		*3*		*14*			
Exclusion	*767*		*523*		*139*		*105*			

Test realized=Khi2 test (*), Kruskal-Wallis test (**), Fisher exact test (***); CT scan=computerized tomography scan; EU=emergency unit; FDR=correction of p-value by False Discovery Rate method; FMC=first medical contact; IVT=intravenous thrombolysis; MICU=mobile intensive care units; MRI=magnetic resonance imaging.
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Table 3. Comparison of use of care and acute care management quality characteristics between the pre, per, post-wave periods - STEMI cohort (N=2782)

	Global (N=2782)		Pre-wave (N=1868)		Per-wave (N=407)		Post-wave (N=507)		p-value corrected (FDR)
	n	(%)	n	(%)	n	(%)	n	(%)	
Use of care									
Calls to emergency services	2782		1868		407		507		0.704 *
No	607	(21.8)	422	(22.6)	74	(18.2)	111	(21.9)	
Yes	2175	(78.2)	1446	(77.4)	333	(81.8)	396	(78.1)	
FMC	2782		1868		407		507		0.704 *
MICU	1597	(57.4)	1069	(57.2)	247	(60.7)	281	(55.4)	
EU with cathlab	458	(16.5)	321	(17.2)	51	(12.5)	86	(17.0)	
EU without cathlab	727	(26.1)	478	(25.6)	109	(26.8)	140	(27.6)	
Symptoms-to-care time (min)	2360		1581		349		430		0.799 **
Median [IQR]	77	[30;206]	76	[30;212]	84	[31;202]	75	[30;178]	
Missing values	*422*		*287*		*58*		*77*		
Acute care management quality									
FMC-to-procedure time (min)	2364		1577		353		434		0.799 **
Median [IQR]	99	[71;157]	100	[71;158]	95	[69;152]	102	[71;153]	
Missing values	*418*		*291*		*54*		*73*		
Pathway type	2742		1841		400		501		0.799 *
Optimal pathway: calls to emergency services/ MICU transport/direct referral to cathlab	1557	(56.8)	1042	(56.6)	240	(60.0)	275	(54.9)	
Calls to emergency services /EU/direct referral to cathlab	550	(20.1)	356	(19.3)	82	(20.5)	112	(22.4)	
No call to emergency services /EU/direct referral to cathlab	591	(21.6)	412	(22.4)	72	(18.0)	107	(21.4)	
Calls to emergency services /EU/no direct referral to cathlab	28	(1.0)	20	(1.1)	4	(1.0)	4	(0.8)	
No call to emergency services /EU/no direct referral to cathlab	16	(0.6)	11	(0.6)	2	(0.5)	3	(0.6)	
Missing values	*40*		*27*		*7*		*6*		
Mode of transport to the first hospital	2782		1868		407		507		0.722 *
Personal transport	444	(16.0)	311	(16.6)	55	(13.5)	78	(15.4)	
Non- MICU transport	558	(20.1)	372	(19.9)	77	(18.9)	109	(21.5)	
MICU transport (road)	1523	(54.7)	1010	(54.1)	243	(59.7)	270	(53.3)	
MICU transport (helicopter)	123	(4.4)	84	(4.5)	11	(2.7)	28	(5.5)	
Unknown	134	(4.8)	91	(4.9)	21	(5.2)	22	(4.3)	
Direct referral to cathlab	2782		1868		407		507		0.799 *
No	84	(3.0)	58	(3.1)	13	(3.2)	13	(2.6)	
Yes	2698	(97.0)	1810	(96.9)	394	(96.8)	494	(97.4)	
Fibrinolysis	2560		1724		366		470		0.799 *
No	2428	(94.8)	1633	(94.7)	345	(94.3)	450	(95.7)	
Yes	132	(5.2)	91	(5.3)	21	(5.7)	20	(4.3)	
Missing values	*222*		*144*		*41*		*37*		
PCI	2364		1577		353		434		0.799 *
No	330	(14.0)	211	(13.4)	50	(14.2)	69	(15.9)	
Yes	2034	(86.0)	1366	(86.6)	303	(85.8)	365	(84.1)	
Missing values	*418*		*291*		*54*		*73*		
Fibrinolysis or PCI	2359		1576		349		434		0.704 *
No	292	(12.4)	190	(12.1)	38	(10.9)	64	(14.7)	
Yes	2067	(87.6)	1386	(87.9)	311	(89.1)	370	(85.3)	
Missing values	*423*		*292*		*58*		*73*		

Test realized=Khi2 test (*), Kruskal-Wallis test (**), Fisher exact test (***); EU=emergency unit; FDR=correction of p-value by False Discovery Rate method; FMC=first medical contact; MICU=mobile intensive care units; PCI=Percutaneous Coronary Intervention.
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Associations between use of care, reorganisations, and care management times (Figure 2, Supplementary Material 4)

Stroke cohort model (4603 patients)

The final model showed no statistically significant association between reorganisations and EU admission-to-imaging time. FMC by MICU transport was associated with a significant decrease of 27% in the EU admission-to-imaging time (expβ = 0.726, 95%CI 0.548-0.961, p = 0.034), with no interaction with COVID-19 period (p = 0.807). The association between calls to emergency services and EU admission-to-imaging time was not significant (expβ = 0.939, 95%CI 0.793-1.112, p = 0.360) during the study period but differed according to COVID-19 period (significant interaction with the COVID-19 period, p = 0.039). Calls to emergency services were associated with an 8% increase in admission-to-imaging time during the post-wave compared to the pre- and per-wave periods. Sensitivity analysis of 2458 patients confirmed the absence of an association between reorganisations or use-of-care changes during the COVID-19 pandemic and care management times.

STEMI cohort model (1843 patients)

Systematic COVID-19 testing was associated with a 41% increase (expβ = 1.409, 95%CI 1.075-1.848, p = 0.013) in the FMC-to-procedure time. The implementation of *Plan Blanc* was associated with a 19% decrease (expβ = 0.801, 95%CI 0.639-1.023, p = 0.077) in the FMC-to-procedure time. Compared to FMC "EU without cathlab", FMC "MICU transport pathway" was associated with a 66% decrease (expβ = 0.344, 95%CI 0.266-0.445, p < 0.001) in the FMC-to-procedure time and FMC "EU with cathlab" with a 20% decrease (expβ = 0.804, 95%CI 0.674-0.958, p < 0.001). The interaction with the COVID period was not significant (p = 0.492). Finally, each 10 min increase in symptom-to-care time increased the FMC-to-procedure time by 0.36% (expβ = 1.004, 95%CI 1.002-1.005, p < 0.001), and there was no effect of COVID-19 period (p = 0.206).

DISCUSSION

We evaluated the global impact of the health system transformations spurred by the first wave of the COVID-19 pandemic on use of care by, and the acute management of, stroke and STEMI patients.

Beginning in the per-wave period, most hospitals in Aquitaine adapted to the COVID-19 pandemic. Most of the reorganisations were maintained several months after the end of the national lockdown. Stroke management times deteriorated during the pandemic, but this was not directly related to the reorganisations implemented. By contrast, STEMI patients' quality of care was maintained during the first wave of the COVID-19 pandemic, to which *Plan Blanc*, by concentrating resources in emergency activities, contributed. Implementation of systematic COVID-19 screening at admission was associated with an increase in STEMI patient management time. In the STEMI and stroke cohorts, more frequent calls to emergency services and longer times to access the healthcare system were observed during the per-wave compared to the pre-wave period.

The contrasting changes in STEMI and stroke management times during the per-wave period may be explained by the different structures and performances of the related networks in France. The STEMI network is structured as a dedicated pathway. By contrast, the stroke network is more recent and not fully structured. Highly structured patient-centred clinical pathways improve the quality of care of chronic or acute conditions with predictable trajectories.(23–27) Moreover, guidelines on stroke and STEMI patient management and national stroke and STEMI improvement programs recommend the implementation of structured pathways that include close collaborations between healthcare professionals as well as patient orientation to specialised technical platforms (cathlabs, stroke units) and to the EMS system.(28,29).

The results suggest the absence of a change in the functioning of the emergency pathway during the pandemic. Indeed, calls to the emergency services by STEMI patients and orientation to the optimal pathway using MICU were associated with decreased stroke and STEMI management times. Therefore, the management of these two highly time-sensitive pathologies was not disrupted during the pandemic.

Plan Blanc, which enhanced the quality of care of COVID-19 patients, improved that of STEMI patients by decreasing management times. In the stroke cohort, *Plan Blanc* non-significantly decreased management times. The different results may be explained by use of different primary endpoints in the two cohorts. In the STEMI cohort, the FMC-to-procedure time, which accounted for coordination of care among multiple actors pre- and in-hospital, was sufficiently extensive to detect an effect. In the stroke cohort, the EU admission-to-imaging time, which focused on the beginning of in-hospital care, involved so little a part of the patient pathway that it had difficulty in detecting an effect. Most reorganisations implemented in EUs or hospitalisation units had little effect on STEMI and stroke care management times.

Only the “systematic COVID testing” reorganisation increased the STEMI management time. This effect was marked in patients arriving late after symptom onset. In these patients, whose symptoms were often atypical and included respiratory signs suggestive of COVID-19, management was delayed until availability of screening results. STEMI patients arriving very early were regarded as requiring extreme emergency management before screening. The “systematic COVID testing” reorganisation was not included in the stroke cohort model, but the only hospital in the stroke cohort that implemented it exhibited results similar to the STEMI cohort.

The increased time to contact the healthcare system during the COVID-19 pandemic is consistent with prior reports from France and elsewhere.(6,13,30) Mesnier *et al.*, in a French cohort of 1167 STEMI patients, found that symptom onset to hospital admission times were stable from 4 weeks before to 4 weeks after lockdown implementation. However, comparison of that work and ours is hampered by differences in management times and study periods.(7)

By calling the emergency services more frequently, patients followed the national recommendations, which were widely publicised in the French media during the COVID-19 pandemic. Although a global decrease in STEMI and stroke patient admissions during the per-wave period has been reported, the average figures over the period(31) suggest an initial decrease at the beginning of the per-wave period and a progressive increase thereafter. This findings, mirrored by other surveys at the regional or national level in France, are based on analysis of changes in hospital admissions during the per-wave period.(32,33) Stroke patients were younger, and had less severe strokes during the per-wave compared to the pre-wave period. Although several studies, including one meta-analysis, reported more severe and older patients during the first wave of the pandemic, others reported findings consistent with ours.(31,34–38) Wallace *et al*. suggested this to be a consequence of regional variation in virus spread and the fear of contracting COVID-19 in hospital. Alternatively, most studies included patients with transient ischaemic attacks; these were excluded in this work. Patients with resolving and less-severe symptoms were more likely to avoid hospital admission for fear of contracting COVID-19 in hospital. Lastly, information on the origin of hospitalised patients (home, nursing homes, other hospitals) would have been useful but was not available in the databases.

Prior studies investigating the association between the COVID-19 pandemic and the quality of stroke and STEMI management reported diverse results.(13–16) Our data suggest that these discordant results are a result of the variety of policies implemented and the heterogeneity of hospital organisations. To our knowledge, no study has analysed at a regional level the effect of reorganisations implemented by hospitals to deal with the COVID-19 pandemic. Those extant simply provide feedback on reorganisations at a local level.(11,39,40)

We analysed two high-quality databases with a large number of stroke and STEMI patients managed in numerous healthcare institutions in Aquitaine. This broad geographical scope, which ensured diverse clinical and management characteristics, and the historical depth of the data are major strengths of this study.

The sample was representative of stroke and STEMI patients managed in hospitals. However, patients who did not enter the healthcare system because they had died or did not benefit from hospital care, were not included. This precluded quantification of avoidance of the healthcare system, which is thought to have been more frequent during the COVID-19 pandemic and may have generated selection bias. Moreover, the STEMI cohort included patients who experienced STEMI within 24 h of admission. The proportion of STEMI patients presenting > 24 h after symptom onset increased during the COVID-19 pandemic, and these individuals had more so called “mechanical complications” and a higher mortality rate.(41) Exclusion of these patients may have generated selection bias, leading to a risk of underestimation of the increased delay to use of care.

We conducted a systematic evaluation of hospital reorganisations implemented in response to the COVID-19 pandemic. However, we cannot exclude the possibility of errors in the responses of the healthcare professionals, particularly concerning the dates on which reorganisations were implemented or terminated, due to memory bias. It was not feasible to interview several individuals and cross-check the responses.

Explanatory analyses by the DAG method yielded several confounding factors. The large amount of data enabled integration of a variety of confounders—clinical and sociogeographic factors, acute care management pathways, and hospital activity. In the stroke cohort, 20% of the symptom-to-FMC data were missing, so we excluded this variable from the main model to increase the statistical power. The lack of a reason for these missing data precluded their analysis by the multiple imputation method. A sensitivity analysis with symptom-to-FMC time as an explanatory variable did not alter the results, confirming their robustness.

The primary endpoints were the care management times, which are major prognostic issues in the management of stroke and STEMI and sensitive to intrahospital organisational changes. They were used as continuous variables to maximise the statistical power. Use of the proportion of patients managed within the recommended time frame as an endpoint would have had marked operational implications. However, this was not possible for statistical reasons (3.3% of patients underwent the first imaging within 20 min, the target time).

A major methodological issue was per-wave period, which was defined according to implementation of healthcare reorganisations in response to the COVID-19 pandemic. Therefore, the per-wave period began simultaneously with the first hospital reorganisations, and ended at the end of the lockdown, which corresponded to restoration of normal hospital activity and a reduction in the number of reorganisations. The post-wave period was an important component of our analysis of changes in patient management. However, the follow-up ended at the end of August, to produce not too late results. The inclusion of summer is unlikely to have generated bias because no summer variation in stroke and STEMI inclusion or management delay has been reported.

This study was restricted to Aquitaine, one of the regions least affected by the first wave of the pandemic.(6) We hypothesised that the "decrease in non-COVID patients management and admission capacities", which did not affect STEMI and stroke patient management times, would have degraded the management of non-COVID-19 conditions in regions with many EUs. Indeed, the impact of EU reorganisations may be sensitive to patient influx. Moreover, the effects of global and structural reorganisations such as *Plan Blanc* should not differ geographically. Because use of care did not differ according to pandemic intensity, our results are unlikely to apply only to Aquitaine.(33) It would be interesting to repeat the study in another region of France or in another country more affected by the pandemic to test the external validity of the results.

Stroke and STEMI are managed by means of defined pathways. Our results may be extrapolated to similar conditions requiring urgent management in a coordinated pathway, such as respiratory distress or life-threatening bleeding.

Perspectives

This study is the first step of a three-step analysis of the effect of the COVID-19 pandemic on stroke and STEMI patient management. Other issues are the clinical and social health inequalities in stroke and STEMI patient management induced or reinforced by the COVID-19 pandemic, and the impact of the COVID-19 pandemic on the long-term mortality and morbidity of stroke and STEMI patients.

Conclusions

There was no alteration of emergency pathway structure during the COVID-19 pandemic, but stroke patient management deteriorated. The resilience of the STEMI pathway was due to its stronger structuring. Also, transversal reorganisations, aimed at concentrating resources within the emergency care network, such as *Plan Blanc*, contributed to maintaining the quality of care of stroke and STEMI patients. Our results can be extrapolated to other time-sensitive conditions that require coordination of EMSs and benefit from a defined pathway.

- **Figure Legend/Caption**

Figure 1. Weekly cumulated number of care structures having implemented reorganisations, by reorganisation category– Minimum and maximum number and proportion of care structures having implemented reorganisation, by reorganisation category and by period (pre, per, post-wave)
EMS=emergency medical service; EU=emergency unit; *Plan Blanc*=emergency plan to cope with a sudden increase of activity

Figure 2. Stroke and STEMI cohorts. Estimation of the reorganisations and use of care effects (95% confidence interval) on care management times.
Stroke cohort (N=4603) – Estimated overall effects expressed as exp(β) with 95% CI; results of multivariate linear regression mixed models; variable to be explained: Y = log (EU admission-to-imaging time); results adjusted on period, age, gender, urbanicity of residence, FDep15, APL MG 18, residence-EU distance, presence of stroke unit, MRI 24 hours a day, presence of interventional neuroradiology unit, care during on-call activity, mode of transport, calls to emergency services activity, mRS less than 1 before stroke, NIHSS at entry, previous stroke or transient ischaemic attack.
STEMI cohort (N=1843) – Estimated overall effects expressed as exp(β) with 95% CI; results of multivariate linear regression mixed models; variable to be explained: Y=log (FMC-to-procedure time); results adjusted on period, age, gender, urbanicity of residence, FDep15, APL MG 18, residence-to-cathlab distance, cathlab hospital status, care during on-call activity, mode of transport, calls to emergency services activity, FMC-to-cathlab distance, diabetes mellitus, coronary artery disease or STEMI history).
Light grey: interaction with the COVID period, Dark grey: raw results without interaction with the COVID period
APL MG 2018=potential accessibility to general practitioners; EU=emergency unit; FDep15=deprivation index; FMC=first medical contact; MICU=mobile intensive care units; MRI=magnetic resonance imaging; mRS=modified Rankin Scale; NIHSS=National Institute of Health Stroke Score; *Plan Blanc*=emergency plan to cope with a sudden increase of activity; STEMI=segment elevation myocardial infarction.

- **Data sharing statement**

Deidentified participant data will be available upon reasonable request. Proposals may be submitted to the corresponding author. Data requestors will need to sign a data access agreement

- **Patient consent for publication**

Not applicable.

- **Ethics statements**

According to French authority on data protection "Commission Nationale Informatique et Libertés", in the category of studies not involving humans based on secondary use of health data, the CNV registry met regulatory requirements for patient information and do not require a patient consent form.
Ethics approval
Not applicable

- **Authors' contributions**

EL, FSa, SD and FSe were responsible for the study concept and design. EL, FF, FSa conducted the literature review and MB, QL the scoping review. EL and FSe had full access to all of the data and takes responsibility for their integrity and accuracy. SD, SMH performed the statistical analysis. FSa, EL, SD, FF, FSe, LC, PC, FR, IS, CP interpreted the data. EL, FSa, FF and SD wrote the manuscript. FSe, LC, PC, FR, IS and CP critically reviewed the manuscript.

- **Competing interests statement**

The authors declare that they have no competing interests with this study.

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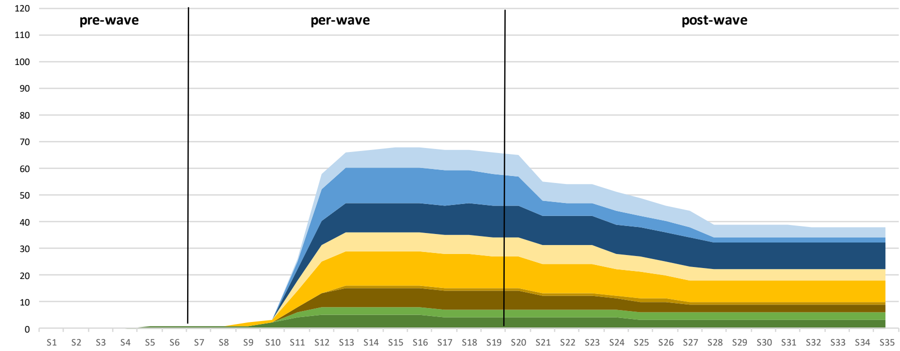
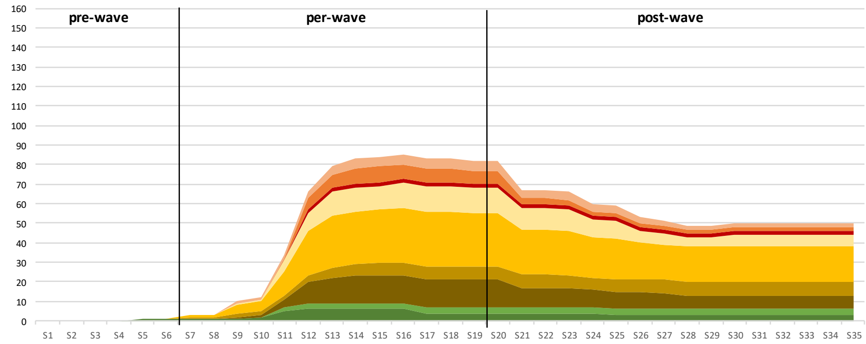
Stroke cohort



reorganisation categories*	pre-wave min	(%)	max	(%)	per-wave min	(%)	max	(%)	post-wave min	(%)	max	(%)
EMS (N=5)												
Increase in the telephone reception capacities	0	(0.0)	1	(20.0)	1	(20.0)	5	(100.0)	3	(60.0)	4	(80.0)
Restriction of helicopter transport for COVID patients	0	(0.0)	0	(0.0)	0	(0.0)	3	(60.0)	3	(60.0)	3	(60.0)
Emergency unit (N=14)												
Plan Blanc	0	(0.0)	0	(0.0)	0	(0.0)	7	(50.0)	3	(21.4)	7	(50.0)
Systematic COVID testing	0	(0.0)	0	(0.0)	0	(0.0)	1	(7.1)	1	(7.1)	1	(7.1)
Separate COVID/non-COVID patients pathway	0	(0.0)	0	(0.0)	0	(0.0)	13	(92.9)	8	(57.1)	12	(85.7)
Decrease in non-COVID patients management and admission capacities	0	(0.0)	0	(0.0)	0	(0.0)	7	(50.0)	4	(28.6)	7	(50.0)
Hospitalisation unit (N=14)												
Specific access to imaging for COVID patients	0	(0.0)	0	(0.0)	0	(0.0)	12	(85.7)	10	(71.4)	12	(85.7)
Deprogramming of non-urgent procedures or hospitalisations	0	(0.0)	0	(0.0)	0	(0.0)	13	(92.9)	2	(14.3)	11	(78.6)
Decrease in bed capacity for non-COVID patients	0	(0.0)	0	(0.0)	0	(0.0)	8	(57.1)	4	(28.6)	8	(57.1)

* minimal and maximal number of structures having implemented each reorganisation among the three periods - (%) : percentage calculated on total number of structures concerned

STEMI cohort



reorganisation categories*	pre-wave min	(%)	max	(%)	per-wave min	(%)	max	(%)	post-wave min	(%)	max	(%)
EMS (N=6)												
Increase in the telephone reception capacities	0	(0.0)	1	(16.7)	1	(16.7)	6	(100.0)	3	(50.0)	4	(66.7)
Restriction of helicopter transport for COVID patients	0	(0.0)	0	(0.0)	0	(0.0)	3	(50.0)	3	(50.0)	3	(50.0)
Emergency unit (n=30)												
Plan Blanc	0	(0.0)	0	(0.0)	0	(0.0)	14	(46.7)	7	(23.3)	14	(46.7)
Systematic COVID testing	0	(0.0)	0	(0.0)	1	(3.3)	7	(23.3)	6	(20.0)	7	(23.3)
Separate COVID/non-COVID patients pathway	0	(0.0)	0	(0.0)	1	(3.3)	28	(93.3)	18	(60.0)	27	(90.0)
Decrease in non-COVID patients management and admission capacities	0	(0.0)	0	(0.0)	0	(0.0)	13	(43.3)	5	(16.7)	13	(43.3)
Cathlabs (n=11)												
Coronary angiography room dedicated to COVID patients in cathlabs	0	(0.0)	0	(0.0)	0	(0.0)	2	(18.2)	2	(18.2)	2	(18.2)
Deprogramming of non-urgent procedures or hospitalisations	0	(0.0)	0	(0.0)	0	(0.0)	8	(72.7)	2	(18.2)	7	(63.6)
Decrease in bed capacity for non-COVID patients	0	(0.0)	0	(0.0)	0	(0.0)	5	(45.5)	2	(18.2)	5	(45.5)

* minimal and maximal number of structures having implemented each reorganisation among the three periods - (%) : percentage calculated on total number of structures concerned

Figure 1. Weekly cumulated number of care structures having implemented reorganisations, by reorganisation category– Minimum and maximum number and proportion of care structures having implemented reorganisation, by reorganisation category and by period (pre, per, post-wave)

EMS=emergency medical service; EU=emergency unit; *Plan Blanc*=emergency plan to cope with a sudden increase of activity

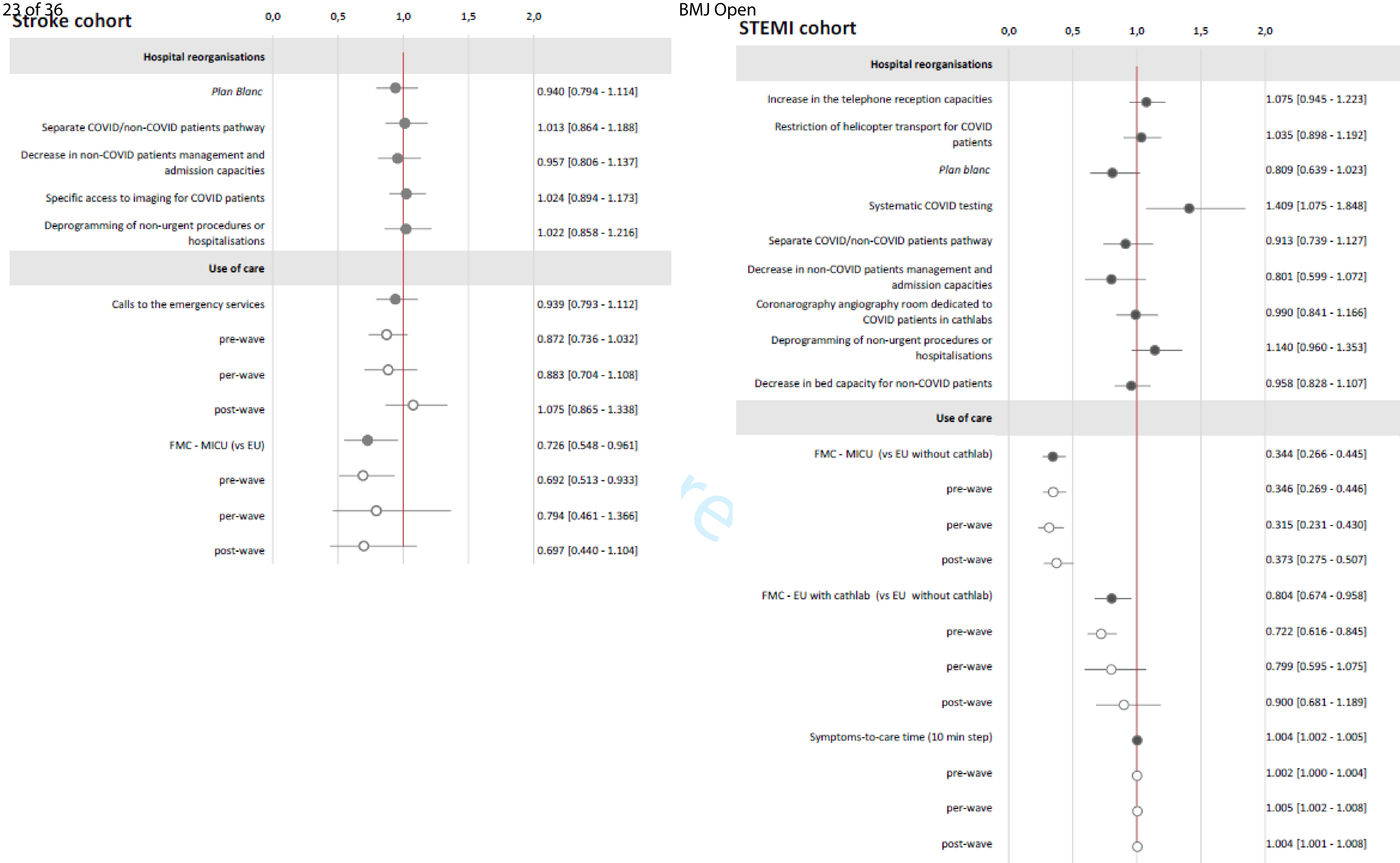

Stroke cohort
0,0
0,5
1,0
1,5
2,0
Hospital reorganisations
Plan Blanc
0.940 [0.794 - 1.114]
Separate COVID/non-COVID patients pathway
1.013 [0.864 - 1.188]
Decrease in non-COVID patients management and admission capacities
0.957 [0.806 - 1.137]
Specific access to imaging for COVID patients
1.024 [0.894 - 1.173]
Deprogramming of non-urgent procedures or hospitalisations
1.022 [0.858 - 1.216]
Use of care
Calls to the emergency services
0.939 [0.793 - 1.112]
pre-wave
0.872 [0.736 - 1.032]
per-wave
0.883 [0.704 - 1.108]
post-wave
1.075 [0.865 - 1.338]
FMC - MICU (vs EU)
0.726 [0.548 - 0.961]
pre-wave
0.692 [0.513 - 0.933]
per-wave
0.794 [0.461 - 1.366]
post-wave
0.697 [0.440 - 1.104]
STEMI cohort
0,0
0,5
1,0
1,5
2,0
Hospital reorganisations
Increase in the telephone reception capacities
1.075 [0.945 - 1.223]
Restriction of helicopter transport for COVID patients
1.035 [0.898 - 1.192]
Plan blanc
0.809 [0.639 - 1.023]
Systematic COVID testing
1.409 [1.075 - 1.848]
Separate COVID/non-COVID patients pathway
0.913 [0.739 - 1.127]
Decrease in non-COVID patients management and admission capacities
0.801 [0.599 - 1.072]
Coronarography angiography room dedicated to COVID patients in cathlabs
0.990 [0.841 - 1.166]
Deprogramming of non-urgent procedures or hospitalisations
1.140 [0.960 - 1.353]
Decrease in bed capacity for non-COVID patients
0.958 [0.828 - 1.107]
Use of care
FMC - MICU (vs EU without cathlab)
0.344 [0.266 - 0.445]
pre-wave
0.346 [0.269 - 0.446]
per-wave
0.315 [0.231 - 0.430]
post-wave
0.373 [0.275 - 0.507]
FMC - EU with cathlab (vs EU without cathlab)
0.804 [0.674 - 0.958]
pre-wave
0.722 [0.616 - 0.845]
per-wave
0.799 [0.595 - 1.075]
post-wave
0.900 [0.681 - 1.189]
Symptoms-to-care time (10 min step)
1.004 [1.002 - 1.005]
pre-wave
1.002 [1.000 - 1.004]
per-wave
1.005 [1.002 - 1.008]
post-wave
1.004 [1.001 - 1.008]

Figure 2. Stroke and STEMI cohorts. Estimation of the reorganisations and use of care effects (95% confidence interval) on care management times.

Stroke cohort (N=4603) – Estimated overall effects expressed as exp(β) with 95% CI; results of multivariate linear regression mixed models; variable to be explained: Y = log (EU admission-to-imaging time); results adjusted on period, age, gender, urbanicity of residence, FDep15, APL MG 18, residence-EU distance, presence of stroke unit, MRI 24 hours a day, presence of interventional neuroradiology unit, care during on-call activity, mode of transport, calls to emergency services activity, mRS less than 1 before stroke, NIHSS at entry, previous stroke or transient ischaemic attack.
STEMI cohort (N=1843) – Estimated overall effects expressed as exp(β) with 95% CI; results of multivariate linear regression mixed models; variable to be explained: Y=log (FMC-to-procedure time); results adjusted on period, age, gender, urbanicity of residence, FDep15, APL MG 18, residence-to-cathlab distance, cathlab hospital status, care during on-call activity, mode of transport, calls to emergency services activity, FMC-to-cathlab distance, diabetes mellitus, coronary artery disease or STEMI history).
Light grey: interaction with the COVID period, Dark grey: raw results without interaction with the COVID period
APL MG 2018=potential accessibility to general practitioners; EU=emergency unit; FDep15=deprivation index; FMC=first medical contact; MICU=mobile intensive care units; MRI=magnetic resonance imaging; mRS=modified Rankin Scale; NIHSS=National Institute of Health Stroke Score; *Plan Blanc*=emergency plan to cope with a sudden increase of activity; STEMI=segment elevation myocardial infarction.

Supplementary material 1.

Method of the scoping review

The method of the scoping review was conducted to retrieve the structural reorganisations implemented in care structures to deal with the first wave of the COVID-19 pandemic in the acute management of stroke or STEMI.
Two categories of information sources were systematically explored:

- **Written English or French-language documents**

All written English or French-language documents published between January and December 2020 were retrieved without geographical limitation:

- scientific articles analysing the impact of the first wave of Covid-19 pandemic on stroke and STEMI management;
- government reports, professional stroke or STEMI guidelines providing guidance on the management of stroke and STEMI patients during the COVID-19 pandemic;
- published feedback on hospital management of stroke and STEMI patients during the first wave of the COVID-19 pandemic.

The following sources were consulted:

- computerised bibliographic database “Pubmed” and “Scopus” with the following algorithm TITLE-ABS-KEY (Pathway OR organisation OR use of care) AND (COVID-19 OR SARS-CoV-2) AND (stroke OR STEMI) AND (effect OR effectiveness OR impact);
- “Google" search engine with the keywords "Organisations", "hospital unit", or "hospital", "COVID-19";
- French Health Ministry (Ministère des solidarités et de la santé) website in search of reports on organisational recommendations for hospital in the management of the Covid-19 pandemic;
- French societies of cardiology, emergency medicine, and neurology (Société Française de Neuro-Vasculaire, Société Française de Cardiologie, Société Française de Médecine d’Urgence) websites in search of clinical recommendations in the management of stroke and STEMI patients in the context of the Covid-19 pandemic.

After a pre-selection on the title and the abstract, the complete reading of the articles allowed to filter out the articles that did not describe any structural organisations. Then, organisational data was independently collected on a dedicated collection grid. If necessary, a common reading was carried out.

- **Structured telephone interviews**

In December 2020, structured telephone interviews were conducted with healthcare professionals involved in stroke or STEMI management in hospitals in the Aquitaine Region, to question them on the organisations they had to cope with during the first wave of the pandemic in stroke and STEMI patients’ management. Among the 16 approached professionals, eight (2 nurses, 2 emergency physicians, 2 cardiologists, and 2 neurologists) from 8 hospitals accepted to participate. Questions asked were: "What reorganisations were implemented during the first wave?"; "Have you been provided with facilities for this reorganisation?"; "Have you received help from professionals in other services?"; "Did you expand/reduce your capacity? ". Responses were transcribed as the interview progressed. Each verbatim was reviewed by the two interviewers in collaboration with the AVICOVID principal investigator.

Supplementary material 2.

Confounding variables introduced in the stroke and STEMI final model estimating the association between reorganizations and use of care effects on care management times

Category of variables	Stroke cohort Model	STEMI Cohort Model
Time	Period (pre, per, post-wave)	Period (pre, per, post-wave)
Socio-demographic characteristics	Age, gender	Age, gender
Geographical indexes	Urbanicity, FDep15, APL MG 2018, residence-EU distance	Urbanicity, FDep15, APL MG 2018, residence-to-cathlab distance
Clinical characteristics	mRS less than 1 before stroke, NIHSS at entry, previous stroke or transient ischaemic attack	Diabetes mellitus, history of coronary artery disease or of STEMI
Acute care management quality	Mode of transport	Mode of transport
Structural characteristics of care	call to the emergency services activity during care, care during on-call activity, presence of stroke unit, availability of MRI 24 hours a day, presence of interventional neuroradiology unit	call to the emergency services activity during care, care during on-call activity, cathlab hospital status, FMC-to-cathlab distance

APL MG 2018=potential accessibility indicator to general practitioners; EU=emergency unit; FDep15=deprivation index; FMC=first medical contact; MRI=magnetic resonance imaging; mRS=modified Rankin Scale; NIHSS=National Institute of Health Stroke Score; STEMI=segment elevation myocardial infarction.

Created by the authors

Supplementary material 3.

Description of the stroke cohort study sample (N=6436)

	Global (N=6436)		pre-wave (N=4140)		per-wave (N=1080)		post-wave (N=1216)	
	n	(%)	n	(%)	n	(%)	n	(%)
Patient socio-demographic characteristics								
Gender	6436		4140		1080		1216	
Male	3533	(54.9)	2264	(54.7)	589	(54.5)	680	(55.9)
Female	2903	(45.1)	1876	(45.3)	491	(45.5)	536	(44.1)
Age	6436		4140		1080		1216	
Median [IQR]	78	[68;87]	79	[69;87]	77	[68;86]	76	[68;85]
Urbanicity	6153		3882		1072		1199	
Urban	4451	(72.3)	2816	(72.5)	786	(73.3)	849	(70.8)
Rural	1702	(27.7)	1066	(27.5)	286	(26.7)	350	(29.2)
Missing values	283		258		8		17	
Fdep15	6145		3878		1070		1197	
Median [IQR]	0.10	[-0.96;1.14]	0.10	[-1.02;1.22]	-0.01	[-0.98;1.11]	0.08	[-0.88;1.11]
Missing values	291		262		10		19	
APL MG 2018	6171		3891		1076		1204	
Median [IQR]	4.3	[3.4;5.0]	4.3	[3.4;5.0]	4.3	[3.4;5.0]	4.2	[3.4;5.1]
Missing values	265		249		4		12	
Residence-EU distance (km)	6179		3897		1077		1205	
Median [IQR]	17	[6;32]	17	[6;33]	16	[5;28]	18	[7;34]
Missing values	*257*		*243*		*3*		*11*	
Patient clinical characteristics								
Stroke type	6436		4140		1080		1216	
Ischaemic	5669	(88.1)	3617	(87.4)	941	(87.1)	1111	(91.4)
Haemorragic	767	(11.9)	523	(12.6)	139	(12.9)	105	(8.6)
Coronary artery disease	6436		4140		1080		1216	
Absence	5877	(91.3)	3778	(91.3)	987	(91.4)	1112	(91.4)
Presence	559	(8.7)	362	(8.7)	93	(8.6)	104	(8.6)
Previous STEMI	6436		4140		1080		1216	
Absence	6057	(94.1)	3886	(93.9)	1017	(94.2)	1154	(94.9)
Presence	379	(5.9)	254	(6.1)	63	(5.8)	62	(5.1)
Previous stroke or transient ischaemic attack	6436		4140		1080		1216	
Absence	5166	(80.3)	3305	(79.8)	882	(81.7)	979	(80.5)
Presence	1270	(19.7)	835	(20.2)	198	(18.3)	237	(19.5)
Diabetes mellitus	6436		4140		1080		1216	
Absence	5198	(80.8)	3352	(81.0)	894	(82.8)	952	(78.3)
Presence	1238	(19.2)	788	(19.0)	186	(17.2)	264	(21.7)
Hypertension	6436		4140		1080		1216	
Absence	2419	(37.6)	1538	(37.1)	437	(40.5)	444	(36.5)
Presence	4017	(62.4)	2602	(62.9)	643	(59.5)	772	(63.5)
Dyslipidemia	6436		4140		1080		1216	
Absence	4618	(71.8)	2973	(71.8)	786	(72.8)	859	(70.6)
Presence	1818	(28.2)	1167	(28.2)	294	(27.2)	357	(29.4)
Smoking	6436		4140		1080		1216	
Absence	5103	(79.3)	3290	(79.5)	846	(78.3)	967	(79.5)
Presence	1333	(20.7)	850	(20.5)	234	(21.7)	249	(20.5)
Atheroma of the supra-aortic arteris	6436		4140		1080		1216	
Absence	6213	(96.5)	4015	(97.0)	1027	(95.1)	1171	(96.3)
Presence	223	(3.5)	125	(3.0)	53	(4.9)	45	(3.7)
Peripheral artery disease	6436		4140		1080		1216	
Absence	6144	(95.5)	3959	(95.6)	1023	(94.7)	1162	(95.6)
Presence	292	(4.5)	181	(4.4)	57	(5.3)	54	(4.4)
Atrial fibrillation	6436		4140		1080		1216	
Absence	5348	(83.1)	3432	(82.9)	885	(81.9)	1031	(84.8)
Presence	1088	(16.9)	708	(17.1)	195	(18.1)	185	(15.2)
Cardiac failure	6436		4140		1080		1216	
Absence	6114	(95.0)	3934	(95.0)	1021	(94.5)	1159	(95.3)
Presence	322	(5.0)	206	(5.0)	59	(5.5)	57	(4.7)
Psychiatry	6436		4140		1080		1216	
Absence	5759	(89.5)	3672	(88.7)	988	(91.5)	1099	(90.4)
Presence	677	(10.5)	468	(11.3)	92	(8.5)	117	(9.6)
mRS less than 1 before stroke	6436		4140		1080		1216	
No	961	(14.9)	660	(15.9)	153	(14.2)	148	(12.2)
Yes	3709	(57.6)	2292	(55.4)	673	(62.3)	744	(61.2)
Unknown	1766	(27.4)	1188	(28.7)	254	(23.5)	324	(26.6)
NIHSS at entry	6436		4140		1080		1216	
[0-6]	3489	(54.2)	2185	(52.8)	607	(56.2)	697	(57.3)

[7-16]	1128	(17.5)	749	(18.1)	184	(17)	195	(16.0)
[17-42]	761	(11.8)	522	(12.6)	110	(10.2)	129	(10.6)
Unknown	1058	(16.4)	684	(16.5)	179	(16.6)	195	(16.0)
Structural characteristics of care								
Calls to emergency services activity during care (intensity of daily number of calls)	6436		4140		1080		1216	
Not high	899	(14.0)	608	(14.7)	140	(13)	151	(12.4)
Moderate	1948	(30.3)	1268	(30.6)	264	(24.4)	416	(34.2)
High	1184	(18.4)	669	(16.2)	303	(28.1)	212	(17.4)
Not concerned (no calls to emergency services)	2405	(37.4)	1595	(38.5)	373	(34.5)	437	(35.9)
Care during on-call activity	6411		4122		1080		1209	
Monday-Friday [8h-18h30]	3351	(52.3)	2178	(52.8)	565	(52.3)	608	(50.3)
Monday-Friday [18h30-20h]	338	(5.3)	212	(5.1)	55	(5.1)	71	(5.9)
Week-end and holiday [8h-20h]	1328	(20.7)	829	(20.1)	233	(21.6)	266	(22.0)
Night [20h-8h]	1394	(21.7)	903	(21.9)	227	(21.0)	264	(21.8)
Missing values	25		18		0		7	
EU hospital status	6436		4140		1080		1216	
University hospital	2441	(37.9)	1654	(40.0)	348	(32.2)	439	(36.1)
General hospital	3879	(60.3)	2410	(58.2)	715	(66.2)	754	(62.0)
Private hospital	116	(1.8)	76	(1.8)	17	(1.6)	23	(1.9)
Availability of MRI 24 hours a day	6436		4140		1080		1216	
No	1694	(26.3)	1061	(25.6)	291	(26.9)	342	(28.1)
Yes	4742	(73.7)	3079	(74.4)	789	(73.1)	874	(71.9)
Presence of stroke unit	6436		4140		1080		1216	
No	1245	(19.3)	799	(19.3)	197	(18.2)	249	(20.5)
Yes	5191	(80.7)	3341	(80.7)	883	(81.8)	967	(79.5)
Presence of interventional neuroradiology unit	6436		4140		1080		1216	
No	3304	(51.3)	2102	(50.8)	551	(51.0)	651	(53.5)
Yes	3132	(48.7)	2038	(49.2)	529	(49.0)	565	(46.5)

APL MG 2018=potential accessibility indicator to general practitioners; EU=emergency unit; FDep15=deprivation index; MRI=magnetic resonance imaging; mRS=modified Rankin Scale; NIHSS=National Institute of Health Stroke Score; STEMI=segment elevation myocardial infarction.
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Description of the STEMI cohort study sample (N=2782)

	Global (N=2782)		Pre-wave (N=1868)		Per-wave (N=407)		Post-wave (N=507)	
	n	(%)	n	(%)	n	(%)	n	(%)
Patient socio-demographic characteristics								
Gender	2782		1868		407		507	
Male	2033	(73.1)	1352	(72.4)	309	(75.9)	372	(73.4)
Female	749	(26.9)	516	(27.6)	98	(24.1)	135	(26.6)
Age	2776		1865		405		506	
Median [IQR]	65	[55;74]	65	[55;74]	65	[55;74]	64	[54;74]
Missing values	6		3		2		1	
Urbanicity	2543		1691		380		472	
Urban	1843	(72.5)	1221	(72.2)	277	(72.9)	345	(73.1)
Rural	700	(27.5)	470	(27.8)	103	(27.1)	127	(26.9)
Missing values	239		177		27		35	
Fdep15	2537		1690		380		467	
Median [IQR]	0.22	[-0.72;1.09]	0.23	[-0.70;1.09]	0.11	[-0.89;1.11]	0.22	[-0.72;1.09]
Missing values	245		178		27		40	
APL MG 2018	2537		1689		380		468	
Median [IQR]	4.3	[3.4;4.9]	4.3	[3.4;4.9]	4.2	[3.3;4.9]	4.4	[3.5;5.0]
Missing values	245		179		27		39	
Residence-to-cathlab distance (km)	2541		1692		379		470	
Median [IQR]	29	[10;54]	28	[10;54]	29	[10;52]	32	[12;58]
Missing values	241		176		28		37	
Patient clinical characteristics								
Coronary artery disease or STEMI history	2782		1868		407		507	
No	2031	(73.0)	1342	(71.8)	317	(77.9)	372	(73.4)
Yes	530	(19.1)	365	(19.5)	69	(16.9)	96	(18.9)
Unknown	221	(7.9)	161	(8.6)	21	(5.2)	39	(7.7)
Diabetes mellitus	2782		1868		407		507	
No	2119	(76.2)	1400	(74.9)	318	(78.1)	401	(79.1)
Yes	414	(12.9)	290	(15.5)	59	(14.5)	65	(12.8)
Unknown	249	(9.0)	178	(9.5)	30	(7.4)	41	(8.1)
Dyslipidemia	2782		1868		407		507	
No	1708	(61.4)	1133	(60.7)	249	(61.2)	326	(64.3)
Yes	887	(31.9)	601	(32.2)	135	(33.2)	151	(29.8)
Unknown	187	(6.7)	134	(7.2)	23	(5.7)	30	(5.9)
Active smoking	2782		1868		407		507	
No	1194	(42.9)	787	(42.1)	183	(45.0)	224	(44.2)
Yes	1163	(41.8)	785	(42.0)	164	(40.3)	214	(42.2)
Unknown	425	(15.3)	296	(15.8)	60	(14.7)	69	(13.6)
Peripheral arterial disease	2782		1868		407		507	
No	2245	(80.7)	1487	(79.6)	339	(83.3)	419	(82.6)
Yes	70	(2.5)	40	(2.1)	16	(3.9)	14	(2.8)
Unknown	467	(16.8)	341	(18.3)	52	(12.8)	74	(14.6)
Obesity	2782		1868		407		507	
No	1801	(64.7)	1229	(65.8)	252	(61.9)	320	(63.1)
Yes	513	(18.4)	332	(17.8)	87	(21.4)	94	(18.5)
Unknown	468	(16.8)	307	(16.4)	68	(16.7)	93	(18.3)
Familial history of coronary artery disease	2782		1868		407		507	
No	2070	(74.4)	1367	(73.2)	308	(75.7)	395	(77.9)
Yes	455	(16.4)	317	(17.0)	64	(15.7)	74	(14.6)
Unknown	257	(9.2)	184	(9.9)	35	(8.6)	38	(7.5)
Chronic renal failure	2782		1868		407		507	
No	2264	(81.4)	1493	(79.9)	344	(84.5)	427	(84.2)
Yes	47	(1.7)	31	(1.7)	10	(2.5)	6	(1.2)
Unknown	471	(16.9)	344	(18.4)	53	(13.0)	74	(14.6)
Arterial hypertension	2782		1868		407		507	
No	1278	(45.9)	866	(46.4)	168	(41.3)	244	(48.1)
Yes	1356	(48.7)	897	(48.0)	220	(54.1)	239	(47.1)
Unknown	148	(5.3)	105	(5.6)	19	(4.7)	24	(4.7)
Structural characteristics of care								
Calls to emergency services activity (intensity of daily number of calls)	2782		1868		407		507	
Not high	440	(15.8)	303	(16.2)	63	(15.5)	74	(14.6)
Moderate	1093	(39.3)	744	(39.8)	143	(35.1)	206	(40.6)
High	642	(23.1)	399	(21.4)	127	(31.2)	116	(22.9)
Not concerned (no calls to emergency services)	607	(21.8)	422	(22.6)	74	(18.2)	111	(21.9)
Care during on-call activity	2712		1821		395		496	

Monday-Friday [8h-18h30]	1116	(41.2)	741	(40.7)	164	(41.5)	211	(42.5)
Monday-Friday [18h30-20h]	133	(4.9)	90	(4.9)	21	(5.3)	22	(4.4)
Week-end and holiday [8h-20h]	547	(20.2)	368	(20.2)	68	(17.2)	111	(22.4)
Night [20h-8h]	916	(33.8)	622	(34.2)	142	(35.9)	152	(30.6)
Missing values	70		47		12		11	
EU hospital status	2782		1868		407		507	
University hospital	71	(2.6)	48	(2.6)	7	(1.7)	16	(3.2)
General hospital	839	(30.2)	564	(30.2)	114	(28)	161	(31.8)
Private hospital	275	(9.9)	187	(10)	39	(9.6)	49	(9.7)
Not concerned (not managed by EU)	1597	(57.4)	1069	(57.2)	247	(60.7)	281	(55.4)
Cathlab hospital status	2782		1868		407		507	
University hospital	624	(22.4)	417	(22.3)	96	(23.6)	111	(21.9)
General hospital	1015	(36.5)	661	(35.4)	154	(37.8)	200	(39.4)
Private hospital	975	(35.0)	666	(35.7)	136	(33.4)	173	(34.1)
Not concerned (not managed by cathlab)	168	(6.0)	124	(6.6)	21	(5.2)	23	(4.5)
FMC-to-cathlab distance (km)	2555		1703		379		473	
Median [IQR]	21	[0;50]	21	[0;50]	21	[4;48]	24	[0;52]
Missing values	227		165		28		34	

APL MG 2018=potential accessibility indicator to general practitioners; EU=emergency unit; FDep15=deprivation index; FMC=first medical contact; STEMI=segment elevation myocardial infarction.
Created by the authors

Supplementary material 4.

Results of the final model estimating the association between reorganisations and use of care effects on care management times: p-value of the type III global fixed effects test - Stroke cohort (N=4603)

Variable	p-value
Hospital reorganisations	
Plan Blanc	0.372
Separate Covid/non-Covid patients pathway	0.830
Decrease in non-Covid patients management and admission capacities	0.532
Specific access to imaging for Covid patients	0.658
Deprogramming of non-urgent procedures or hospitalisations	0.752
Use of care	
Calls to emergency services	0.360
Interaction period x calls to emergency services	0.039
FMC	0.034
Interaction period x FMC	0.807

Results of multivariate linear regression mixed model; variable to be explained: Y = log (EU admission-to-imaging time); results adjusted on period, age, gender, urbanicity, FDep15, APL MG 18, residence-EU distance, presence of stroke unit, MRI 24 hours a day, presence of interventional neuroradiology unit, care during on-call activity, mode of transport, calls to emergency services activity, mRS less than 1 before stroke, NIHSS at entry, previous stroke or transient ischaemic attack

APL MG 2018=potential accessibility indicator to general practitioners; EU=emergency unit; FDep15=deprivation index; FMC=first medical contact; MRI=magnetic resonance imaging; mRS=modified Rankin Scale; NIHSS=National Institute of Health Stroke Score; *Plan Blanc*=emergency plan to cope with a sudden increase of activity.

Created by the authors

Results of the final model estimating the association between reorganisations and use of care effects on care management times: estimation of regression coefficients - Stroke cohort (N=4603)

Variable	Modalities		β	p-value
Intercept			4.767	<0.001
Hospital reorganisations				
Plan Blanc	yes (ref : no)		-0.061	0.372
Separate Covid/non-Covid patients pathway	yes (ref : no)		0.013	0.830
Decrease in non-Covid patients management and admission capacities	yes (ref : no)		-0.044	0.532
Specific access to imaging for Covid patients	yes (ref : no)		0.024	0.658
Deprogramming of non-urgent procedures or hospitalisations	yes (ref : no)		0.021	0.752
Use of care				
Calls to emergency services	yes (ref : no)		-0.137	0.087
Interaction period x calls to emergency services	*pre-wave*	*no*	-	.
	pre-wave	*yes*	-	.
	per-wave	*no*	-	.
	per-wave	*yes*	0.013	0.850
	post-wave	*no*	-	.
	post-wave	*yes*	0.210	0.014
FMC	MICU (ref : EU)		-0.369	0.027
interaction period x FMC	*pre-wave*	*EU*	-	.
	pre-wave	*MICU*	-	.
	per-wave	*EU*	-	.
	per-wave	*MICU*	0.138	0.536
	post-wave	*EU*	-	.
	post-wave	*MICU*	0.008	0.968

Results of multivariate linear regression mixed model; variable to be explained: Y = log (EU admission-to-imaging time); results adjusted on period, age, gender, urbanicity, FDep15, APL MG 18, residence-EU distance, presence of stroke unit, MRI 24 hours a day, presence of interventional neuroradiology unit, care during on-call activity, mode of transport, calls to emergency services activity, mRS less than 1 before stroke, NIHSS at entry, previous stroke or transient ischaemic attack

APL MG 2018=potential accessibility indicator to general practitioners; EU=emergency unit; FDep15=deprivation index; FMC=first medical contact; MICU=mobile intensive care units; MRI=magnetic resonance imaging; mRS=modified Rankin Scale; NIHSS=National Institute of Health Stroke Score; *Plan Blanc*=emergency plan to cope with a sudden increase of activity.

Created by the authors

Results of the final model estimating the association between reorganisations and use of care effects on care management times: p-value of the type III global fixed effects test - STEMI cohort (N=1843)

Variable	p-value
Hospital reorganisations	
Increase in the telephone reception capacities	0.273
Restriction of helicopter transport for Covid patients	0.637
Plan blanc	0.077
Systematic covid testing	0.013
Separate Covid/non-Covid patients pathway	0.395
Decrease in non-Covid patients management and admission capacities	0.135
Coronary angiography room dedicated to Covid patients in cathlabs	0.907
Deprogramming of non-urgent procedures or hospitalisations	0.134
Decrease in bed capacity for non-Covid patients	0.557
Use of care	
FMC	<0.001
Interaction period x FMC	0.492
Symptoms-to-care time (10 min step)	<0.001
Interaction period x symptoms-to-care time	0.206

Results of a multivariate linear regression mixed model; variable to be explained: Y=log (FMC-to-procedure time); results adjusted on period, age, gender, urbanicity, FDep15, APL MG 18, residence-to-cathlab distance, cathlab hospital status, care during on-call activity, mode of transport, calls to emergency services activity, FMC-to-cathlab distance, diabetes mellitus, coronary artery disease or STEMI history).

APL MG 2018=potential accessibility indicator to general practitioners; EU=emergency unit; FDep15=deprivation index; FMC=first medical contact; *Plan Blanc*=emergency plan to cope with a sudden increase of activity; STEMI=segment elevation myocardial infarction.

Created by the authors

Results of the final model estimating the association between reorganisations and use of care effects on care management times: estimation of regression coefficients - STEMI cohort (N=1843)

Variable	Modalities		β	p-value
Intercept			4.475	<0.001
Hospital reorganisations				
Increase in the telephone reception capacities	yes (ref : no)		0.072	0.273
Restriction of helicopter transport for Covid patients	yes (ref : no)		0.034	0.637
Plan blanc	yes (ref : no)		-0.212	0.077
Systematic covid testing	yes (ref : no)		0.343	0.013
Separate Covid/non-Covid patients pathway	yes (ref : no)		-0.092	0.395
Decrease in non-Covid patients management and admission capacities	yes (ref : no)		-0.222	0.135
Coronary angiography room dedicated to Covid patients in cathlabs	yes (ref : no)		-0.010	0.907
Deprogramming of non-urgent procedures or hospitalisations	yes (ref : no)		0.131	0.134
Decrease in bed capacity for non-Covid patients	yes (ref : no)		-0.043	0.557
Use of care				
FMC	EU without cathlab (ref)		-	.
	MICU		-1.061	<0.001
	EU with cathlab		-0.326	<0.001
interaction period x FMC	*pre-wave*	*EU without cathlab*	-	
	pre-wave	*MICU*	-	
	pre-wave	*EU with cathlab*	-	
	per-wave	*EU without cathlab*	-	
	per-wave	*MICU*	-0.094	0.419
	per-wave	*EU with cathlab*	0.102	0.505
	post-wave	*EU without cathlab*	-	
	post-wave	*MICU*	0.075	0.514
	post-wave	*EU with cathlab*	0.221	0.14
Symptoms-to-care time (10 min step)			0.002	0.016
Interaction period x symptoms-to-care time	*pre-wave (ref)*		-	
	per-wave		0.003	0.137
	post-wave		0.002	0.209

Results of a multivariate linear regression mixed model; variable to be explained: Y=log (FMC-to-procedure time); results adjusted on period, age, gender, urbanicity, FDep15, APL MG 18, residence-to-cathlab distance, cathlab hospital status, care during on-call activity, mode of transport, calls to emergency services activity, FMC-to-cathlab distance, diabetes mellitus, coronary artery disease or STEMI history).

APL MG 2018=potential accessibility indicator to general practitioners; EU=emergency unit; FDep15=deprivation index; FMC=first medical contact; MICU=mobile intensive care units; *Plan Blanc*=emergency plan to cope with a sudden increase of activity; STEMI=segment elevation myocardial infarction.

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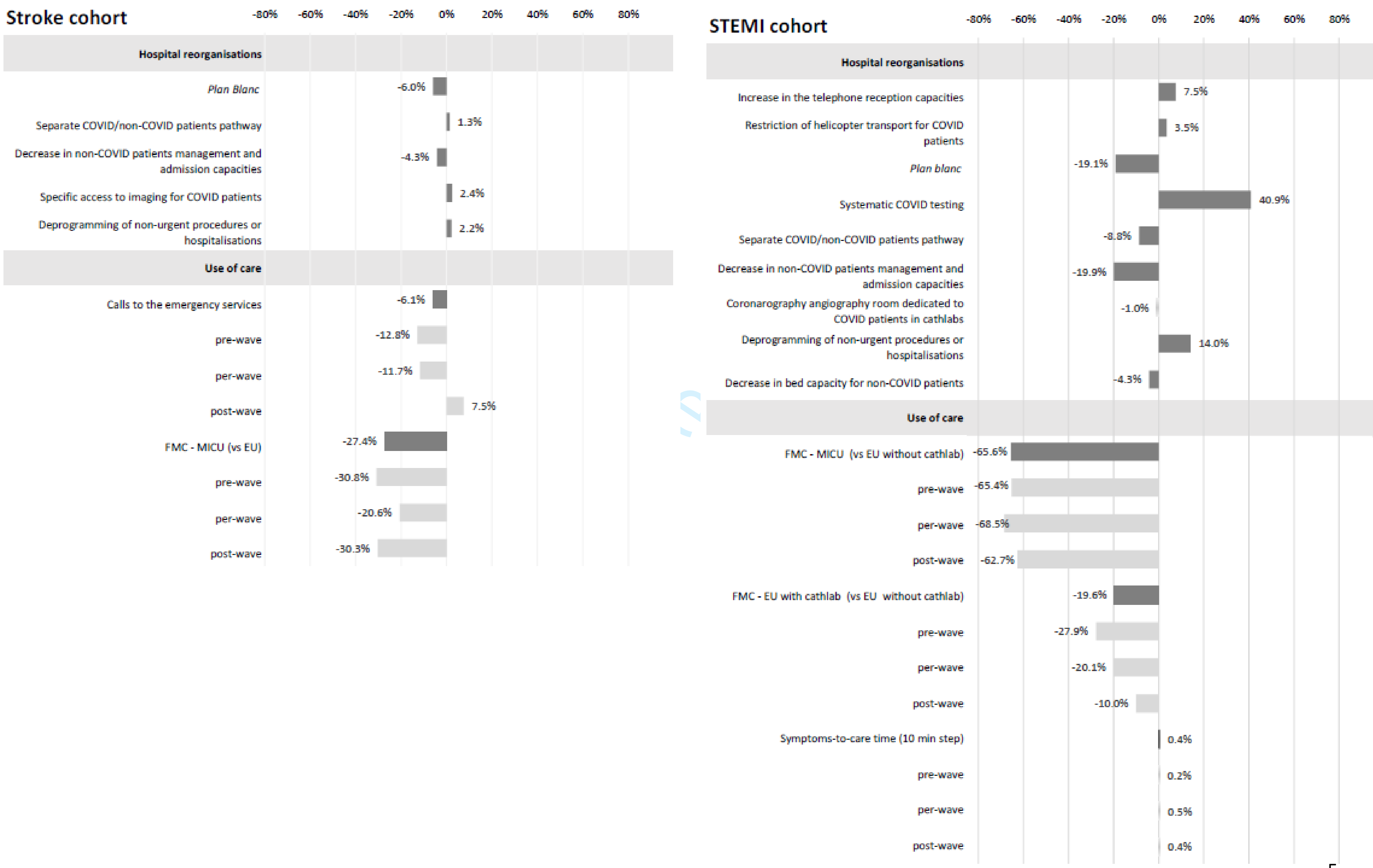
Stroke cohort
-80%
-60%
-40%
-20%
0%
20%
40%
60%
80%
Hospital reorganisations
Plan Blanc
-6.0%
Separate COVID/non-COVID patients pathway
1.3%
Decrease in non-COVID patients management and admission capacities
-4.3%
Specific access to imaging for COVID patients
2.4%
Deprogramming of non-urgent procedures or hospitalisations
2.2%
Use of care
Calls to the emergency services
-6.1%
pre-wave
-12.8%
per-wave
-11.7%
post-wave
7.5%
FMC - MICU (vs EU)
-27.4%
pre-wave
-30.8%
per-wave
-20.6%
post-wave
-30.3%
STEMI cohort
Hospital reorganisations
Increase in the telephone reception capacities
7.5%
Restriction of helicopter transport for COVID patients
3.5%
Plan blanc
-19.1%
Systematic COVID testing
40.9%
Separate COVID/non-COVID patients pathway
-8.8%
Decrease in non-COVID patients management and admission capacities
-19.9%
Coronarography angiography room dedicated to COVID patients in cathlabs
-1.0%
Deprogramming of non-urgent procedures or hospitalisations
14.0%
Decrease in bed capacity for non-COVID patients
-4.3%
Use of care
FMC - MICU (vs EU without cathlab)
-65.6%
pre-wave
-65.4%
per-wave
-68.5%
post-wave
-62.7%
FMC - EU with cathlab (vs EU without cathlab)
-19.6%
pre-wave
-27.9%
per-wave
-20.1%
post-wave
-10.0%
Symptoms-to-care time (10 min step)
0.4%
pre-wave
0.2%
per-wave
0.5%
post-wave
0.4%

Figure. Stroke and STEMI cohorts. Variation percentages of the estimations of the reorganisations and use of care effects on care management times

A: Stroke cohort (N=4603) – Percentage change in overall effects; results of multivariate linear regression mixed models; variable to be explained: Y = log (EU admission-to-imaging time); results adjusted on period, age, gender, urbanicity of residence, FDep15, APL MG 18, residence-EU distance, presence of stroke unit, MRI 24 hours a day, presence of interventional neuroradiology unit, care during on-call activity, mode of transport, calls to emergency services activity, mRS less than 1 before stroke, NIHSS at entry, previous stroke or transient ischaemic attack.

B: STEMI cohort (N=1843) – Percentage change in overall effects; results of multivariate linear regression mixed models; variable to be explained: Y=log (FMC-to-procedure time); results adjusted on period, age, gender, urbanicity of residence, FDep15, APL MG 18, residence-to-cathlab distance, cathlab hospital status, care during on-call activity, mode of transport, calls to emergency services activity, FMC-to-cathlab distance, diabetes mellitus, coronary artery disease or STEMI history).

Light grey: interaction with the Covid period, Dark grey: raw results without interaction with the Covid period

Plan Blanc=emergency plan to cope with a sudden increase of activity

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STROBE Statement—Checklist of items that should be included in reports of cohort studies

	Item No	Recommendation	Page No
Title and abstract	1	(*a*) Indicate the study's design with a commonly used term in the title or the abstract	ok
		(*b*) Provide in the abstract an informative and balanced summary of what was done and what was found	ok, page 1
Introduction			
Background/rationale	2	Explain the scientific background and rationale for the investigation being reported	ok, page 4
Objectives	3	State specific objectives, including any prespecified hypotheses	ok, page 4
Methods			
Study design	4	Present key elements of study design early in the paper	ok, page 4
Setting	5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection	ok, pages 4, 5
Participants	6	(*a*) *Cohort study*—Give the eligibility criteria, and the sources and methods of selection of participants. Describe methods of follow-up	ok, pages 4, 5
		(*b*) *Cohort study*—For matched studies, give matching criteria and number of exposed and unexposed	NA
Variables	7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable	ok, pages 5, 6, 7
Data sources/ measurement	8*	For each variable of interest, give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group	ok, pages 5, 6
Bias	9	Describe any efforts to address potential sources of bias	ok, page 7
Study size	10	Explain how the study size was arrived at	ok, page 5
Quantitative variables	11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why	ok, page 7
Statistical methods	12	(*a*) Describe all statistical methods, including those used to control for confounding	ok, page 7
		(*b*) Describe any methods used to examine subgroups and interactions	ok, page 7
		(*c*) Explain how missing data were addressed	ok, page 7
		(*d*) *Cohort study*—If applicable, explain how loss to follow-up was addressed	NA
		(*e*) Describe any sensitivity analyses	ok, page 7
Results			
Participants	13*	(a) Report numbers of individuals at each stage of study—eg numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed	ok, page 7
		(b) Give reasons for non-participation at each stage	NA
		(c) Consider use of a flow diagram	NA
Descriptive data	14*	(a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders	ok, page 7, suppl mat.
		(b) Indicate number of participants with missing data for each variable of interest	ok, pages 9, 10

		(c) *Cohort study*—Summarise follow-up time (eg, average and total amount)	NA
Outcome data	15*	*Cohort study*—Report numbers of outcome events or summary measures over time	ok, page 11
Main results	16	(*a*) Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (eg, 95% confidence interval). Make clear which confounders were adjusted for and why they were included	ok, page 11
		(*b*) Report category boundaries when continuous variables were categorized	ok, pages 9, 10
		(*c*) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period	NA
Other analyses	17	Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses	ok, page 11
Discussion			
Key results	18	Summarise key results with reference to study objectives	ok, pages 11, 12
Limitations	19	Discuss limitations of the study, taking into account sources of potential bias or imprecision. Discuss both direction and magnitude of any potential bias	ok, pages 13, 14
Interpretation	20	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence	ok, pages 12
Generalisability	21	Discuss the generalisability (external validity) of the study results	ok, pages 14
Other information			
Funding	22	Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based	ok, page 15

NA= not applicable