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Cross-sectional Study

Routine surgeries during the COVID-19 pandemic: A French nationwide cohort study

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ABSTRACT

Background: The COVID-19 pandemic inevitably had consequences on routine surgical procedures. The objective was to quantify changes to five surgical procedures during the COVID-19 pandemic namely cataract surgery, hip and knee arthoplasties, coronary revascularization by angioplasty and definitive cardiac stimulation.

Materials and method: All hospitalizations with at least one act of each surgery between January 1, 2019, and June 30, 2021, were included from the database of all French residents' health-related expenses. Percentage changes between observed and expected numbers of hospital stays were calculated for each surgery in 2020 and the first half of 2021 with 95% Confidence Intervals. Expected numbers were calculated from the number in 2019 by applying an average annual change between 2015 and 2019. The type of intervention (primary operation or reoperation/revision) and/or the emergency status were also considered.

Results: A total of 2,153,857 hospitalizations for cataract surgery (0.6% revision), 398,213 for hip arthroplasty (10.9% revision and 26.9% in emergency), 276,607 for knee arthroplasty (8.2% revision), 471,318 for coronary angioplasty (48.7% in emergency) and 178,441 for cardiac stimulation (27.6% revision) were included. Activity was lower than expected in 2020 (cataract surgery: −21.9% [−22.5;−21.4]; hip arthroplasty: −13.4% [−14.8;−12.0]; knee arthroplasty: −24.6% [−26.1;−23.0]; coronary angioplasty: −11.2% [−12.7;−9.7]) without any catch–up in the first half of 2021 (cataract surgery: −5.0% [−5.8;−4.3]; hip arthroplasty: −9.9% [−11.6;−8.2]; knee arthroplasty: −22.0% [−24.0;−20.1]; coronary angioplasty: −12,1% [−13.9;−10.4]). Revisions and non-elective interventions also decreased but to a lesser magnitude. Cardiac stimulation activity was almost in line with expectations (−2.6% [−4.9; −0.3]/+0.6 [−2.2; +3.4]).

Conclusion: This study shows that there was a marked decrease in four routine surgeries compared to expectations through to at least the first half of 2021, despite the gradual national rollout of the vaccine.

1. Introduction

The pandemic known as COVID-19 emerged in France in early 2020 and drastic restrictions were imposed, with major limitations on all non-essential travel outside the home in order to prevent health infrastructures from becoming overwhelmed. Three national lockdowns were announced during the different waves of the epidemic: the first from March 16 to May 10, 2020 with a progressive lifting of restrictions until June, the second from October 30 to December 15, 2020 and the third from April 3 to May 3, 2021 with a progressive lifting of restrictions until the end of May.

The pandemic inevitably had an impact on hospital care provided to surgical patients. On the one hand, the organization of hospital healthcare was profoundly altered, with resources reallocated to the care of COVID-19 patients: pre-hospital emergency departments, intensive care units and anesthesia departments were particularly affected. On the other hand, patients may have experienced difficulties accessing healthcare and/or may have modified their use in a context of general anxiety and fear [1,2].

Individual centers in various countries saw a reduction in acute admissions (acute coronary syndrome ACS, stroke, acute gastrointestinal disorders or trauma) during the first pandemic wave [3–9]. Nevertheless, information is still lacking on its effect on surgery (elective or non-elective) at nationwide level, not only during the first lockdown

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period but, and above all, thereafter. In high-income countries, cataract surgery, hip and knee arthroplasties (for trauma and arthrosis), angioplasty (to treat coronary artery disease) and definitive cardiac stimulation (to treat certain rhythm and conduction disorders) represent a large portion of routine healthcare activity and have increased constantly over time. They accounted for more than one million hospital admissions in 2019 in France [10,11].

We conducted a nationwide study to determine the consequences of the COVID-19 pandemic on routine targeted surgeries. The aim was to quantify changes in these five procedures in 2020 and in 2021 (up to June) compared to 2019, taking into account their annual evolution and the type of operation (primary or reoperation/revision), as well as their emergency status, if applicable.

2. Methods

We conducted an observational national study using the medico-administrative databases of the French National Health Insurance over the period 2019–2021.

2.1. Data sources

We used data from the French National Health Data System (SNDS). This database covers the entire French population (67 million inhabitants) and includes all their health-related expenses. In this database, an anonymous unique personal identifier links information from the national hospital discharge database (PMSI) and the national health insurance claims database (DCIR):

- The PMSI database contains details of all private and public hospitalizations for either inpatient stays or outpatient care since 2006. Data on surgical discharge diagnoses (via ICD-10 codes) and surgical procedures provided during hospital stays (via a French Common Classification of Medical Procedures (Classification Commune des Actes Médicaux [CCAM]) are captured.
- The DCIR contains sociodemographic information such as sex, age and other information on health expenses

The SNDS has already been used to conduct large-scale pharmacoepidemiologic studies that have been published in international scientific journals, including studies on the COVID-19 pandemic [1,2,12–17].

The research group has permanent regulatory access to the data from the French National Health Data System (French decree No. 2016–1871 of December 26, 2016 on personal data processing known as the National Health Data System, and articles Art. R. 1461–13 and 14 of the Public Health Code). No informed consent was required because the data are anonymized. This study followed the Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) reporting guideline.

2.2. Study population

All hospitalizations for at least one of cataract surgery, hip arthroplasty, knee arthroplasty, coronary angioplasty revascularization and definitive cardiac stimulation between January 1, 2019, and June 30, 2021 were included in separate cohorts. Each surgery was defined by specific procedures codes. The details of all procedure codes used can be found in the Supplementary Material.

We excluded certain hospitalizations due to personal identifier problems in the SNDS data, such as some foreign residents, twins and people with data missing for age and sex; they represent less than 1% of the initial cohorts.

2.3. Outcomes

The main outcome was the observed and expected numbers of hospital stays for each act of surgery for the year 2020 and the first half of 2021, with the aim of ensuring completeness of the PMSI data.

The following were also considered:

- primary operation/reoperation (revision) except for coronary angioplasty (or transcutaneous intraluminal dilatation) where it was not possible to differentiate primary revascularization from new revascularization
- emergency status for two of the five surgeries: presence during the stay of at least one of the discharge diagnoses coded according to ICD10 as follows:
  - o an ACS, a cardiac arrest or a cardiogenic shock for coronary angioplasty;
  - o a fracture-type trauma for hip arthroplasty.

Detailed definitions including ICD-10 codes, are presented in the Supplementary Material.

2.4. Statistical analyses

All analyses were descriptive.

Observed and expected numbers of hospital stays were compared for each surgery and according to the type of operation and/or its emergency status, if applicable. For comparison, a percentage change was calculated as the difference between the observed and expected numbers divided by the expected number with a 95% confidence interval. The comparison was also made per fortnight, distinguishing national lockdowns and summer periods.

The number of expected stays in 2020 was calculated from the number of stays in 2019 by applying the average annual change observed between 2015 and 2019 for each surgery. The expected number in the first half of 2021 was calculated from the number of stays in the first half of 2019 by applying twice the annual average plus the squared average. Detailed average annual changes are presented in the Supplementary Material.

Analyses were performed using SAS, version 9.4 (SAS Institute Inc).

The work has been reported in line with the STROCSS criteria [18].

The study is registered with an unique identifying number "researchregistry7541" on the website Research Registry under the link https://www.researchregistry.com/browse-the-registry#home/registrationdetails/61e04e165acf3a001f9d7c2d/

3. Results

3.1. Populations included

The study covered the period from 2019 until the first half of 2021, including a total of 2,153,857 hospitalizations for cataract surgery (0.6% artificial lens revisions and 99.4% artificial lens primary operations alone), 398,213 for hip arthroplasty (10.9% of which were prosthetic revisions and 26.9% of which were urgent), 276,607 for knee arthroplasty (8.2% of which were prosthetic revisions), 471,318 for coronary angioplasty (48.7% of which were urgent), and 178,441 for definitive cardiac stimulation (27.6% of which were revisions). Fig. 1.

3.2. Observed and expected numbers of stays for all types of operation (primary operation alone/at least one revision)

Surgical activity was lower overall than expected for all of 2020 and the first half of 2021 (although to a lesser extent than 2020):

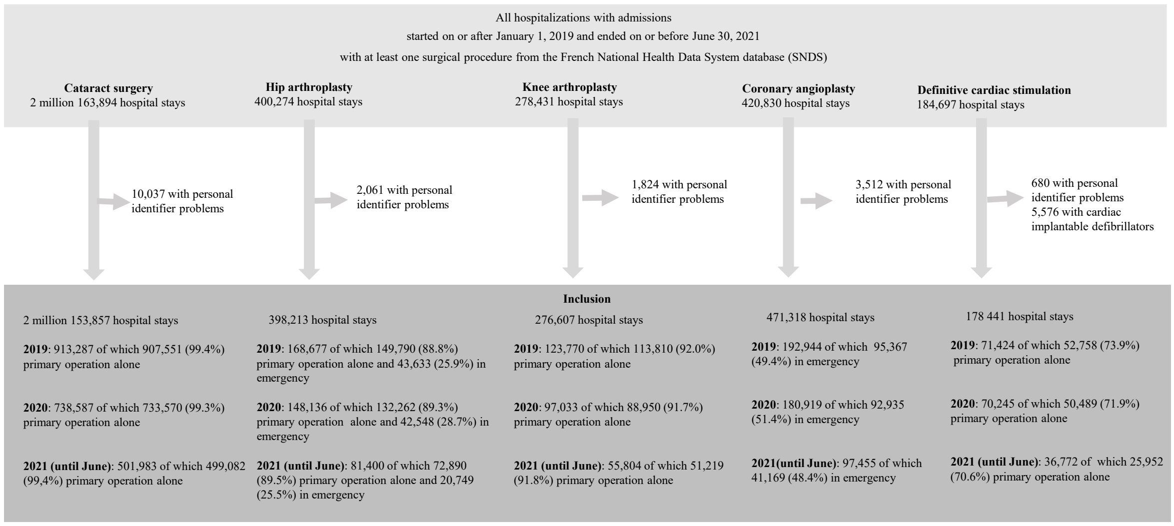

Fig. 1. Flow chart of study populations.

- cataract surgery was down sharply (−21.9% [−22.5; −21.4]) in 2020 and down moderately (−5.0% [−5.8; −4.3]) in the first half of 2021;
- hip arthroplasty was down −13.4% [−14.8; −12.0] in 2020 and −9.9% [−11.6; −8.2] in the first half of 2021;
- knee arthroplasty was down sharply, with marked decreases of −24.6% [−26.1; −23.0] in 2020 and −22.0% [−24.0; −20.1] in the first half of 2021;
- coronary angioplasty was down −11.2% [−12.7; −9.7] in 2020 and −12,1% [−13.9; −10.4] in the first half of 2021. Tables 1 and 2

The drop in the observed number of stays compared to the expected number was most marked during the first lockdown period, from week of March 16 to that of June 21, 2020 (approximately −74% [−74.7; −73.1] for cataract surgery and knee arthroplasty, −50.9% [−52.0; −49.8] for hip arthroplasty and −28.5% [−30.0; −27.0] for coronary angioplasty). The summer period of 2020 saw a moderate catch-up phenomen (between +7.8% and +14.3%, except for coronary angioplasty with −0.8% [−3.1; +1.4]). The second lockdown (from October 30 to December 15, 2020) saw decreases of approximately −10% [−11.8; −7.8] for cataract surgery, hip arthroplasty and coronary angioplasty and −23.0% [−25.0; −21.0] for knee arthroplasty. The decline in surgical activity during the third lockdown (from week of April 3 to that of May 30, 2021) worsened compared to the previous lockdown (between −12.9% [−15.0; −10.9] and −16.6% [−18.5; −14.7] for cataract surgery, hip arthroplasty and coronary angioplasty and 30.5% [−32.5; −28.5] for knee arthroplasty). Table 3.

3.3. Observed and expected numbers of stays for revision surgeries

The majority of revision surgeries were also affected by the decline. Cataract surgery (−14.1% [−21.6; −6.6]), hip arthroplasty (−16.1% [−20.0; −12.3]) and knee arthroplasty (−22.9% [−28.7; −17.1]) were down sharply in 2020 compared to expectations. The decline was still observed in the first half of 2021 (hip arthroplasty: −13.0% [−17.7; −8.3], knee arthroplasty: −21.2% [−28.1; −14.4]) except for cataract surgery (−7.6% [−17.0; +1.8]). Tables 1 and 2 The temporal trends were comparable to those observed with all types of operation, although to a lesser overall amplitude during the lockdowns and without any catch-up effect during the summer period. Table 3.

3.4. Observed and expected numbers of stays for emergency surgeries

Emergency hospitalizations (fractures requiring hip arthroplasty and

Table 1
Hospitalizations for cataract surgery, hip arthroplasty, knee arthroplasty, coronary angioplasty and definitive cardiac stimulation - Number of observed hospital stays in 2019 and 2020 and expected hospital stays in 2020.

	2019, N (%)	2020, N (%)	2020 expected[a], N	Percentage change, % [95% CI]
Cataract surgery				
All types of operation	913,287	738,587	946,027	-21.9 [-22.5; -21.4]
Primary operation alone	907,551 (99.4)	733,570 (99.3)	940,199	-22.0 [-22.6; -21.4]
At least one revision	5,736 (0.6)	5,017 (0.7)	5,841	-14.1 [-21.6; -6.6]
Hip arthroplasty				
All types of operation	168,677	148,136	171,012	-13.4 [-14.8; -12.0]
Primary operation alone	149,790 (88.8)	132,262 (89.3)	152,075	-13.0 [-14.5; -11.6]
At least one revision	18,887 (11.2)	15,874 (10.7)	18,923	-16.1 [-20.0; -12.3]
In emergency (trauma)	43,633 (25.9)	42,548 (28.7)	44,450	-4.3 [-7.3; -1.2]
Knee arthroplasty				
All types of operation	123,770	97,033	128,656	-24.6 [-26.1; -23.0]
Primary operation alone	113,810 (92.0)	88,950 (91.7)	118,176	-24.7 [-26.3; -23.1]
At least one revision	9,960 (8.0)	8,083 (8.3)	10,481	-22.9 [-28.7; -17.1]
Coronary angioplasty				
All types of operation	192,944	180,919	203,704	-11.2 [-12.7; -9.7]
In emergency (ACS, cardiogenic shock, cardiac, arrest)	95,367 (49.4)	92,935 (51.4)	98,529	-5.7 [-7.8; -3.6]
Definitive cardiac stimulation				
All types of operation	71,424	70,245	72,126	-2.6 [-4.9; -0.3]
Primary operation alone	52,758 (73.9)	50,489 (71.9)	53,245	-5.2 [-7.7; -2.6]
At least one revision	18,666 (26.1)	19,756 (28.1)	18,849	+4.8 [+0.1; +9.6]

ACS: Acute Coronary Syndrome.
[a] The expected number was calculated from the number in 2019 by applying the average annual change observed between 2015 and 2019 for each surgery. Detailed average annual changes are presented in the Supplemental Material.

Table 2
Hospitalizations for cataract surgery, hip arthroplasty, knee arthroplasty, coronary angioplasty and definitive cardiac stimulation - Number of observed hospital stays in the first half of 2019 and 2021 and expected hospital stays in the first half of 2021.

	2019, N (%)	2021, N (%)	2021 expected[a], N	Percentage change, % [95% CI]
Cataract surgery				
All types of operation	492,504	501,983	528,448	-5.0 [-5.8; -4.3]
Primary operation alone	489,475 (99.4)	499,082 (99.4)	523,325	-5.0 [-5.8; -4.2]
At least one revision	3,029 (0.6)	2,901 (0.6)	3,141	-7.6 [-17.0; +1.8]
Hip arthroplasty				
All types of operation	87,908	81,400	89,125	-9.9 [-11.6; -8.2]
Primary operation alone	78,165 (88.9)	72,890 (89.5)	80,568	-9,5 [-11.3; -7.7]
At least one revision	9,743 (11.1)	8,510 (10.5)	9,780	-13.0 [-17.7; -8.3]
In emergency (trauma)	21,546 (24.5)	20,749 (25.5)	22,360	-7.2 [-10.7; -3.7]
Knee arthroplasty				
All types of operation	66,176	55,804	71,504	-22.0 [-24.0; -20.1]
Primary operation alone	60,920 (92.1)	51,219 (91.8)	65,684	-22.0 [-23.9; -20.1]
At least one revision	5,256 (7.9)	4,585 (8.2)	5,820	-21,2 [-28.1; -14.4]
Coronary angioplasty				
All types of operation	99,509	97,455	110,917	-12,1 [-13.9; -10.4]
In emergency (ACS, cardiogenic shock, cardiac arrest)	48,903 (49.1)	47,169 (48.4)	52,200	-9.6 [-12.0; -7.3]
Definitive cardiac stimulation				
All types of operation	35,856	36,772	36,564	+0.6 [-2.2; +3.4]
Primary operation alone	26,352 (73.5)	25,952 (70.6)	26,841	-3.3 [-6.4; -0.22]
At least one revision	9,504 (26.5)	10,820 (29.4)	9,702	+11.5 [+5.6; +17.5]

ACS: Acute Coronary Syndrome.
[a] The expected number in the first half of 2021 was calculated from the number in the first half of 2019 by applying twice the annual average plus the squared average. Detailed average annual changes are presented in the Supplemental Material.

ACS requiring coronary angioplasty) were also down compared with expectations in 2020 (respectively, −4.3% [−7.3; −1.2] and −5.7% [−7.8; −3.6]). Table 1. In the first half of 2021, the decline worsened (respectively, −7.2% [−10.7; −3.7] and −9.6% [−12.0; −7.3]) without any catch-up effect during the summer period. Tables 2 and 3.

3.5. *Special case of definitive cardiac stimulation*

Only definitive cardiac stimulation activity was almost comparable to expectations (−2.6% [−4.9; −0.3] over the year 2020 and + 0.6% [−2.2; +3.4] over the first half of 2021). The decrease in 2020 mainly occurred during the first lockdown (−20.0% [−22.4; −17.6]). The revision showed a positive balance over the year 2020 as a whole and the first half of 2021 (respectively +4.8% [+0.1; +9.6] and +11.5 [+5.6; +17.5]). Tables 1 and 2.

The change in observed and expected hospital stays per fornight by primary operation/revision and, if applicable, by emergency status is depicted in Fig. 2, parts A to K for cataract surgery, hip and knee arthroplasties, coronary angioplasty and definitive cardiac stimulation in 2020 and in the first half of 2021.

4. Discussion

In France, five routine surgical procedures were strongly impacted by the COVID-19 epidemic compared to expected levels: from −11% for coronary angioplasty to −25% for knee arthroplasty in 2020, and from −5% for cataract surgery to −22% for knee arthroplasty in the first half of 2021. This decrease reflects the potential cancellation or postponement of more than 350,000 operations. Despite the gradual national rollout of the vaccine, activity did not return to normal in the first half of 2021.

The observed decrease was greater during the first spring lockdown in 2020 than during the other lockdowns, probably because the restrictions were tighter and because no catch-up phenomenon was observed after this lockdown period. Three studies (one from US health insurance representatives and the others from UK national health databases) show a similar decrease during the first lockdown period: up to −43% for coronary angioplasty, −91% for cataract surgery and −44% for cardiac stimulation compared to the same period in previous years [19–21].

Numerous factors may explain the overall reduction in these routine surgeries in our study. The first factor is the emotion and fear of being infected with COVID-19 in hospital, which prevented many patients from seeking care. The second factor is the deployment of a national plan for healthcare facilities (called the “White Plan”), involving the postponement of elective medical consultations and interventions to reallocate staff and resources to COVID-19 medical units (anesthesiologists, nurses, mechanical ventilators and curares, conversion of operating room and surgical intensive care units in COVID-19 units). The third factor is caregiver fatigue, and potential changes to clinical practice: conservative approaches might have been favored to prevent hospital-acquired COVID-19 infections among surgical candidates.

Our study shows a reduction in the frequency of urgent surgical procedures, a frequency which has not yet returned to its pre-pandemic baseline (fractures requiring hip arthroplasty: −4.3% in 2020 and -7.2% in the first half of 2021 - ACS requiring angioplasty: −5.7% in 2020 and -9.6% in the first half of 2021). Other studies estimating the volume of cancelled activity in public and private hospitals have also shown a decrease in surgical emergencies during the first lockdown in 2020 compared to the same period in previous years (between −13.4% and −20.9%) [22–25]. Revisions were less impacted than all other types of operation in our study, perhaps due to the non-elective situations they treat. Arthroplasty revisions in emergency situations are recommended for loosening with periprosthetic fractures of the implant or infections following the primary procedure. After definitive cardiac stimulation, infections or failures of one of the components of the permanent pacemaker require emergent operations. Cardiac stimulation was the surgery in our study that was least affected by the health consequences of the pandemic, particularly revisions, perhaps because of better hospital management requiring specific supervision.

The reductions observed in emergency situations might have several explanations. First, fear might have discouraged access to emergency departments in cases of mild symptoms, such as chest pain or breathlessness. Second, the insistence on isolation at home might have discouraged patients from seeking consultations with their general practitioners or undergoing examinations such as X-rays. Third, restrictive measures might have had an impact on people’s way of life, leading to a change in social behavior and hence less road traffic and fewer daily activities (work, sports), all potentially resulting in fewer acute events. Some studies provide evidence of a reduction in emergency hospital admissions for injuries/falls or cardiac accidents during the first pandemic wave (between −20% and −44% compared to the same period in 2019) [26–30]. Unfortunately, underdiagnosis and late or missed treatments could be deleterious to ACS patients or those with femoral neck fractures, potentially life-threatening conditions whose outcome is closely linked to prompt recognition and treatment. Mesnier et al., using the Fire Department database, revealed that the incidence of

Table 3
Percentage change in 2020 and in the first half of 2021 between observed and expected hospital stays according to type of operation for cataract surgery, hip arthroplasty, knee arthroplasty, coronary angioplasty and definitive cardiac stimulation.

		Cataract surgery (artificial lens)	Hip arthroplasty (prosthesis)	Knee arthroplasty (prosthesis)	Coronary angioplasty (stents)	Definitive cardiac stimulation (pacemaker)
All types of operation	**2020 (January to December)**	**-21.9 [-22.5; -21.4]**	**-13.4 [-14.8; -12.0]**	**-24.6 [-26.1; -23.0]**	**-11.2 [-12.7; -9.7]**	**-2.6 [-4.9; -0.3]**
	2021 (January to June)	**-5.0 [-4.3; -5.8]**	**-9.9 [-11.6; -8.2]**	**-22.0 [-24.0; -20.1]**	**-12,1 [-13.9; -10.4]**	**+0.6 [-2.2; +3.4]**
	First lockdown period[a]	-73.5 [-73.8; -73.2]	-50.9 [-52.0; -49.8]	-73.9 [-74.7; -73.1]	-28.5 [-30.0; -27.0]	-20.0 [-22.4; -17.6]
	Summer period[b]	+7.8 [+6.7; +9.0]	+14.3 [+11.7; +16.9]	+9.6 [+6.2; +13.1]	-0.8 [-3.1; +1.4]	+9,3 [+5.7; +12.8]
	Second lockdown period[c]	-10.8 [-11.6; -10.0]	-10.0 [-11.8; -8.1]	-23.0 [-25.0; -21.0]	-9.8 [-11.8; -7.8]	-2,5 [-5.8; +0.8]
	Third lockdown period[d]	-14.7 [-15.6;-13.8]	-16.6 [-18.5; -14.7]	-30.5 [-32.5; -28.5]	-12.9 [-15.0; -10.9]	-1.1 [-4.4; +2.3]
Restriction to emergency status	**2020 (January to December)**		**-4.3 [-7.3; -1.2]**		**-5.7 [-7.8; -3.6]**	
	2021 (January to June)		**-7.2 [-10.7; -3.7]**		**-9.6 [-12.0; -7.3]**	
	First lockdown period[a]		-9.5 [-12.3; -6.7]		-14.2 [-16.0; -11.8]	
	Summer period[b]		-4.0 [-7.4; -0.6]		+3.6 [+0.2; +6.9]	
	Second lockdown period[c]		-5.8 [-9.1; -2.6]		-6.9 [-9.6; -4.3]	
	Third lockdown period[d]		-6.1 [-9.4; -2.7]		-9.1 [-11.9; -6.2]	
Restriction to at least one revision	**2020 (January to December)**	**-14.1 [-21.6; -6.6]**	**-16.1 [-20.0; -12.3]**	**-22.9 [-28.7; -17.1]**		**+4.8 [+0.1; +9.6]**
	2021 (January to June)	**-7.6 [-17.0; +1.8]**	**-13.0 [-17.7; -8.3]**	**-21,2 [-28.1; -14.4]**		**+11.5 [+5.6; +17.5]**
	First lockdown period[a]	-55.2 [-60.5; -49.9]	-45.6 [-48.9; -42.3]	-59.2 [-63.3; -55.1]		-17.4 [-21.3; -13.6]
	Summer period[b]	+6.0 [-7.0; +19.0]	-2.9 [-9.2; +3.3]	-7.3 [-17.0; +2.4]		+26.9 [+20.0; +33.9]
	Second lockdown period[c]	-4.6 [-15.5; +6.3]	-10.4 [-16.0; -4.9]	-14.2 [-22.6; -5.8]		+4.5 [-1.2; +10.2]
	Third lockdown period[dd]	-11.3 [-22.2; -0.5]	-18.7 [-24.0; -13.4]	-26.9 [-34.3; -19.4]		+7.9 [+2.3; +13.5]

Data are reported as a percentage of (n observed-n expected)/n expected with 95% confidence interval [95% CI].
[a] From week of March 16 to that of June 21, 2020.
[b] From week of July 1 to that of August 31, 2020.
[c] From week of October 30 to that of December 15, 2021.
[d] From week of April 3 to that of May 30, 2021.

non-traumatic out-of-hospital cardiac arrest per million inhabitants in the Paris area doubled between March and April 2020 compared to previous weeks, and that two thirds of this increase were not directly related to COVID deaths [31].

4.1. Strengths and limitations

The key strength of our study is its use of the PMSI database, which is mandatory for all hospitals and clinics; its information on hospital stays is accurate and precise because such data are used to allocate budgets to the hospital sector. In addition, for each patient identified by a personal card, a specific code for each reimbursed heathcare act is entered, thus avoiding recall or recording bias.

Furthermore, this is the first study to cover a recent period for an entire population: it provides a pragmatic and comprehensive picture of surgical activity during the COVID-19 pandemic. We were able to quantify whether there has been a change for each surgery over an 18-month period covering three epidemic waves including the start of the national COVID-19 vaccination campaign until the first half of 2021. Only five nationwide studies have investigated the impact of COVID-19 on surgical procedures during the 2020 pandemic and mainly during the first wave [22–25,32,33]. Finally, our study includes several surgical procedures in different patient populations, some of which have not yet been studied on a national scale, such as namely pacemaker placement and reoperation.

Our study has some limitations.

First, we did not study whether there were geographical disparities in surgeries, especially in areas where the virus spread sharply. The first wave in France mainly concerned four of the country's 13 regions, while all regions were concerned by the following two waves. In addition, we were not able to conduct specific analyses of routine surgeries among COVID-19 patients. However, this was not the objective of our study, which was to quantify the impact of the pandemic on routine surgical procedures in the whole population.

The second limitation is the lack of formal clinical validation of the diagnosis. However, the causes of hospitalization in emergency situations are available, accurate and precise thanks to the pricing of surgical procedures that use implantable medical devices, namely artificial lens implants, hip or knee prosthetic implants, coronary stenting and pacemakers, which reduces coding errors [12,17]. In addition, the quality of the diagnostic codes from these data is regularly checked against patients' medical records.

5. Conclusion

This study is the first to provide information on routine surgical activity during the COVID-19 pandemic for an entire country. The results demonstrate a rapid and profound change in the overall number of certain ophthalmological, cardiac and orthopedic interventions through to at least the first half of 2021, with no catch-up outside the lockdown periods and despite the gradual national rollout of the vaccine in 2021. Non-use of hospital care or difficulties in access for patients are unlikely

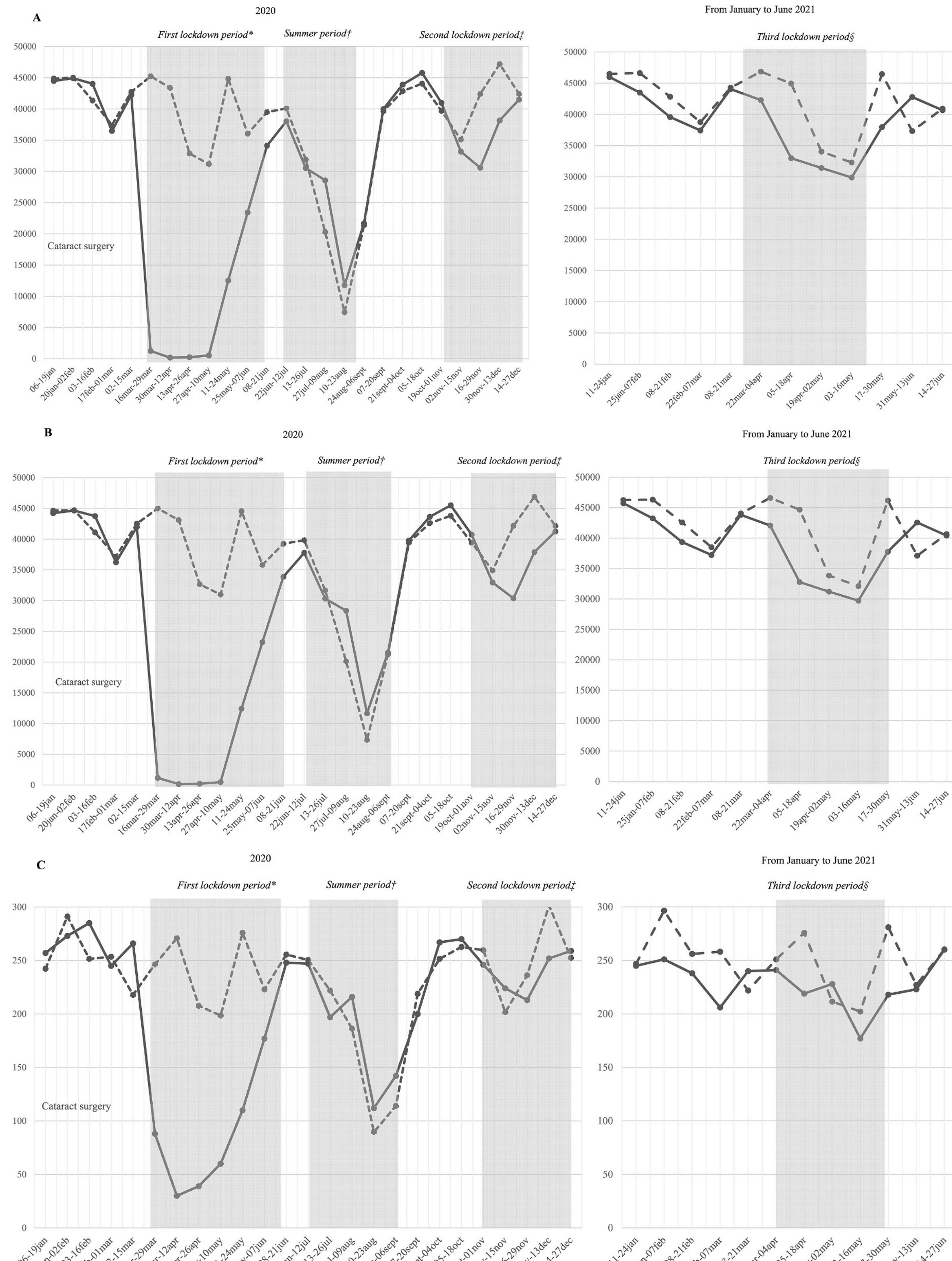

Fig. 2. Number of observed and expected hospital stays per fornight in 2020 and in the first half of 2021.
A: All types of operation - cataract surgery **B**: Primary operation - cataract surgery **C**: Revision - cataract surgery **D**: All types of operation - hip and knee arthroplasties **E**: Primary operation - hip and knee arthroplasties **F**: Revision - hip and knee arthroplasties **G**: Emergency hip arthroplasty **H**: All types of operation - cardiac surgery (coronary angioplasty and definitive cardiac stimulation) **I**: Primary operation - definitive cardiac stimulation **J**: Revision - definitive cardiac stimulation **K**: Emergency coronary angioplasty — Observed - - Expected *From week of March 16 to that of June 21, 2020 †From week of July 1 to that of August 31, 2020 ‡From week of October 30 to that of December 15, 2020 §From week of April 3 to that of May 30, 2021.

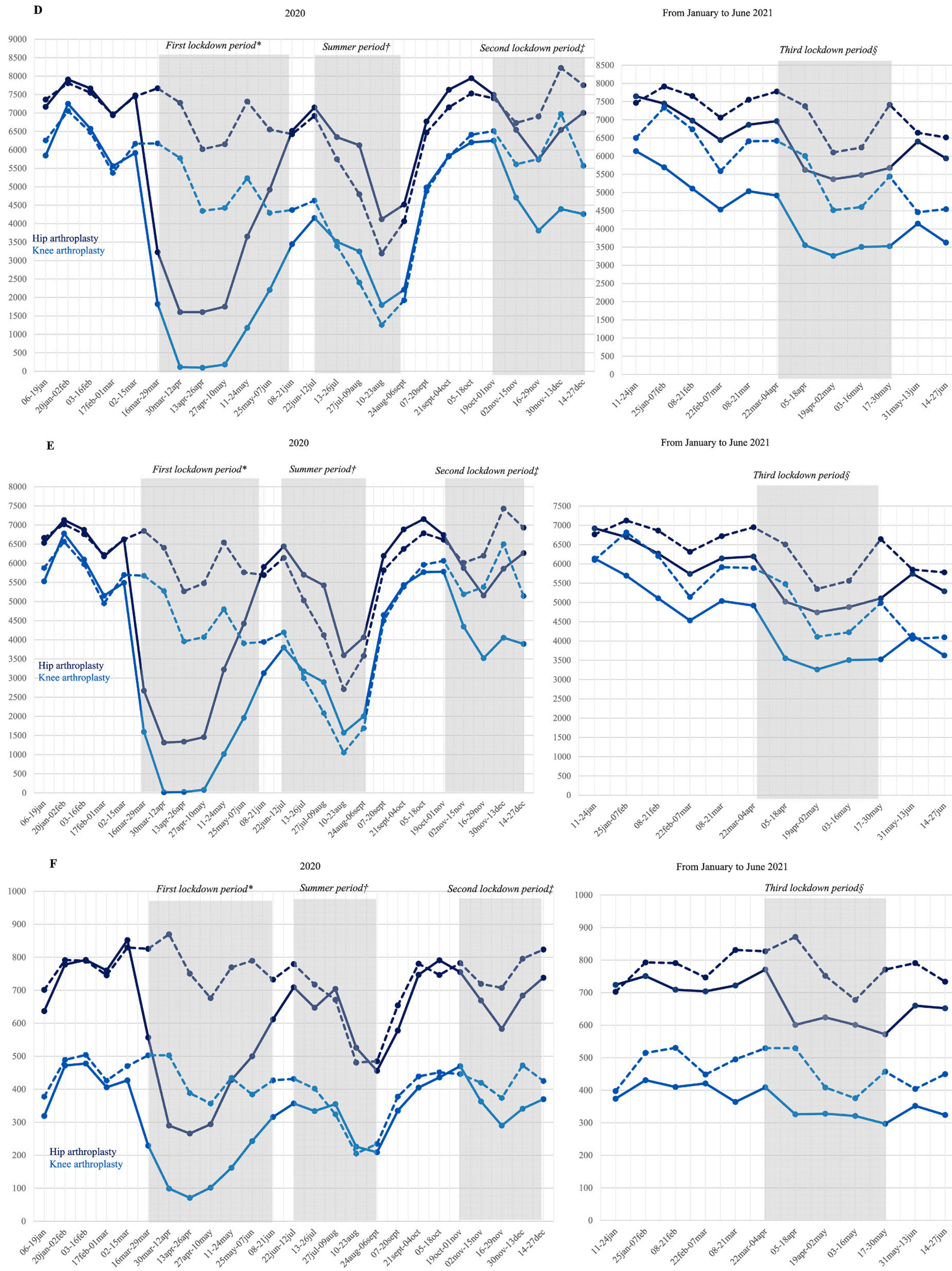

Fig. 2. (*continued*).

to be the only reasons, especially in non-elective situations. The long-term effects of widespread delays and their influence on resources may not become apparent for some time. The COVID-19 pandemic poses great challenges to health systems worldwide, and our data suggest the need to optimize surgical patient care in a pandemic setting and to identify ways to improve the available capacity of surgical activity. Understanding the underlying reasons for the altered patterns and the impact on patient outcomes within the context of a global pandemic will be crucial for guiding optimal treatments in the future.

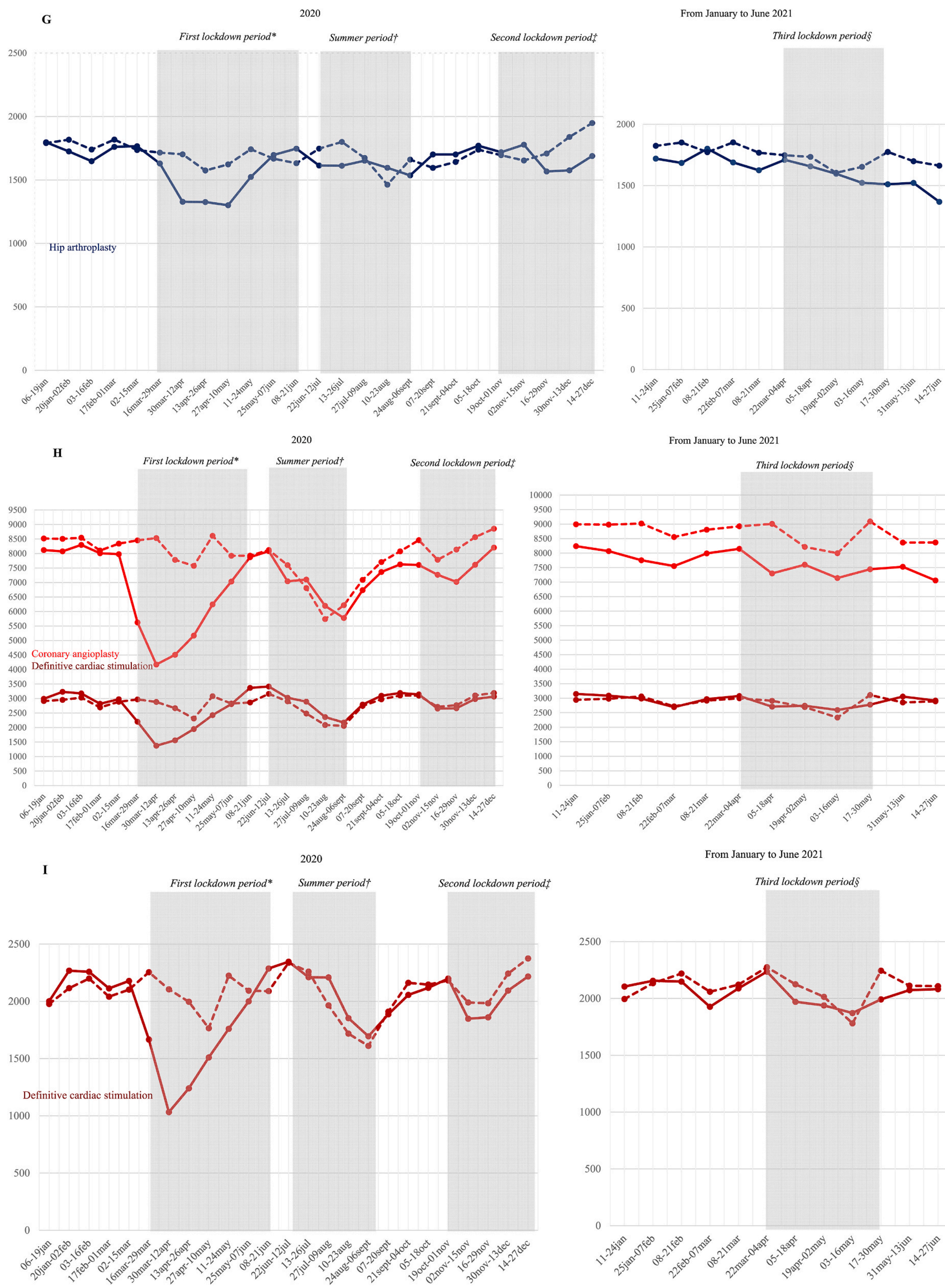

Fig. 2. (*continued*).

Sources of funding

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Ethical approval

Not applicable.

The National Health Data System (SNDS) is a set of strictly anonymous databases, comprising all mandatory national health insurance

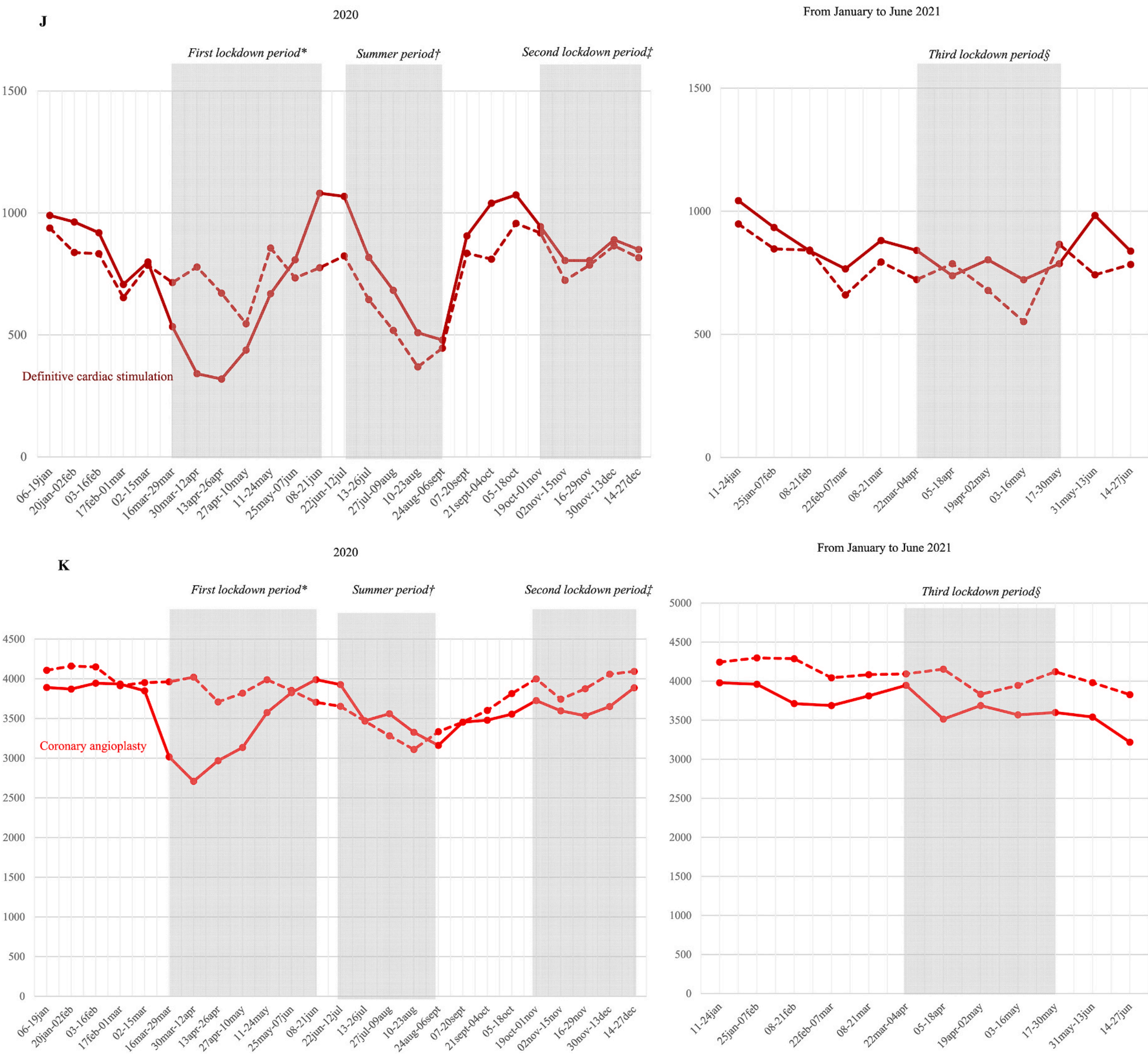

Fig. 2. (*continued*).

reimbursement data, particularly data derived from processing of health care claims (electronic or paper claims) and data from health care facilities (PMSI). No informed consent was required because data are anonymized.

EPI-PHARE has a regulatory permanent access to the data from the SNDS. This permanent access is given according the French Decree No. 2016–1871 of December 26, 2016 relating to the processing of personal data called "National Health Data System" [1] and French law articles Art. R. 1461–13 [2] and 14 [3]. This study was declared prior to initiation on the EPI-PHARE registry of studies requiring the use of the SNDS.

1. Décret n° 2016–1871 du 26 decembre 2016 relatif au traitement de données à caractère personnel dénommé « système national des données de santé » [Internet]. Available from: https://www.legifrance.gouv.fr/affichTexte.do?cidTexte=JORFTEXT000033702840&categorieLien=id
2. Code de la sante publique - Article R1461-13 [Internet]. Available from: https://www.legifrance.gouv.fr/affichCodeArticle.do?idArticle=LEGIARTI000038789574&cidTexte=LEGITEXT000006072665&dateTexte=20190708.
3. Code de la sante publique - Article R1461-14 [Internet]. Available from: https://www.legifrance.gouv.fr/affichCodeArticle.do;jsessionid=97E45CB54E32A4B721-DE72BAE0B29B0F.tplgfr43s_1?idArticle=LEGIARTI000037678676&cidTexte=LEGITEXT000006072665&dateTexte=20190708&categorieLien=id&oldAction=&nbResultRech = .

Consent

No informed consent was required because data are anonymized.

Author contribution

Conceptualization and Methodology: ED, MZ; Data extraction: CB, ED; Data analyses: ED, CB; Interpretation of the results: ED, MZ; Writing - original draft preparation: ED; Reviewing and editing: ED, MZ.

Registration of research studies

1. Name of the registry: https://www.researchregistry.com/
2. Unique Identifying number or registration ID: researchregistry7541
3. Hyperlink to your specific registration (must be publicly accessible and will be checked): https://www.researchregistry.com/browse-the-registry#home/registrationdetails/61e04e165acf3a001f9d7c2d/

Guarantor

ED, MZ.

Provenance and peer review

Not commissioned, externally peer-reviewed.

Declaration of competing interest

No conflicts of interest.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.amsu.2022.103721.

References

[1] A. Meyer, J. Drouin, M. Zureik, A. Weill, R. Dray-Spira, Colonoscopy in France during the COVID-19 pandemic, Int. J. Colorectal Dis. 36 (2021) 1073–1075, https://doi.org/10.1007/s00384-020-03816-3.
[2] S. Billioti de Gage, J. Drouin, D. Desplas, F. Cuenot, R. Dray-Spira, A. Weill, et al., Intravitreal anti-vascular endothelial growth factor use in France during the coronavirus disease 2019 pandemic, JAMA Ophthalmol 139 (2021) 240–242, https://doi.org/10.1001/jamaophthalmol.2020.5594.
[3] G.J.J. van Aert, L. van der Laan, L.J.M. Boonman-de Winter, C.A.S. Berende, H.G. W. de Groot, P. Boele van Hensbroek, et al., Effect of the COVID-19 pandemic during the first lockdown in The Netherlands on the number of trauma-related admissions, trauma severity and treatment: the results of a retrospective cohort study in a level 2 trauma centre, BMJ Open 11 (2021), e045015, https://doi.org/10.1136/bmjopen-2020-045015, 2020.
[4] A.S. Mariet, M. Giroud, E. Benzenine, J. Cottenet, A. Roussot, L.S. Aho-Glélé, et al., Hospitalizations for stroke in France during the COVID-19 pandemic before, during, and after the national lockdown, Stroke 52 (2021) 1362–1369, https://doi.org/10.1161/STROKEAHA.120.032312.
[5] H.M. Nef, A. Elsässer, H. Möllmann, M. Abdel-Hadi, T. Bauer, M. Brück, et al., Impact of the COVID-19 pandemic on cardiovascular mortality and catherization activity during the lockdown in central Germany: an observational study, Clin. Res. Cardiol. 110 (2021) 292–301, https://doi.org/10.1007/s00392-020-01780-0.
[6] H. Guadalajara, J.L. Muñoz de Nova, M. Yiasemidou, M. Recarte Rico, L.D. Juez, J. García Septiem, et al., The SARS-CoV-2 first wave impact in the acute inflammatory surgical pathologies, Sci. Rep. 11 (2021), 19645, https://doi.org/10.1038/s41598-021-98878-w.
[7] R. Montagnon, L. Rouffilange, G. Agard, P. Benner, N. Cazes, A. Renard, Impact of the COVID-19 pandemic on emergency department use: focus on patients requiring urgent revascularization, J. Emerg. Med. 60 (2021) 229–236, https://doi.org/10.1016/j.jemermed.2020.09.042.
[8] J. Tankel, A. Keinan, O. Blich, M. Koussa, B. Helou, S. Shay, et al., The decreasing incidence of acute appendicitis during COVID-19: a retrospective multi-centre study, World J. Surg. 44 (2020) 2458–2463, https://doi.org/10.1007/s00268-020-05599-8.
[9] A. Azul Freitas, R. Baptista, V. Gonçalves, C. Ferreira, J. Milner, C. Lourenço, et al., Impact of SARS-CoV-2 pandemic on ST-elevation myocardial infarction admissions and outcomes in a Portuguese primary percutaneous coronary intervention center: preliminary Data, Rev. Port. Cardiol. 40 (2021) 465–471, https://doi.org/10.1016/j.repc.2020.10.012.
[10] Agence technique de l'information sur l'hospitalisation. Médecine, Chirurgie, Obstétrique. Chiffres clés en 2019, ATIH, https://www.atih.sante.fr/sites/default/files/public/content/2554/atih_chiffres_cles_mco_2019.pdf, 2019.
[11] Agence technique de l'information sur l'hospitalisation. Médecine, Chirurgie, Obstétrique. Nombre de séjours par diagnostic ou acte, ATIH (2019). https://www.scansante.fr/opendata/pmsi-mco/ccam.
[12] E. Schapiro-Dufour, A. Tricotel, M.S. Slama, P. Ducimetiere, A. Trinh-Duc, C. Sichel, T. Le Tri, H. Galmiche, R. Dray-Spira, M. Zureik, Major ischaemic and bleeding risks following current drug-eluting stent implantation: are there differences across current drug-eluting stent types in real life? Arch. Cardiovasc. Dis. 112 (2019) 469–484, https://doi.org/10.1016/j.acvd.2019.04.007.
[13] M. Lemaitre, J. Kirchgesner, A. Rudnichi, F. Carrat, M. Zureik, F. Carbonnel, et al., Association between use of thiopurines or tumor necrosis factor Antagonists alone or in combination and risk of lymphoma in patients with inflammatory bowel disease, JAMA 318 (2017) 1679–1686, https://doi.org/10.1001/jama.2017.16071.
[14] K. Bouillon, M. Bertrand, G. Bader, J.-P. Lucot, R. Dray-Spira, M. Zureik, Association of hysteroscopic vs laparoscopic sterilization with procedural, gynecological, and medical outcomes, JAMA 319 (2018) 375–387, https://doi.org/10.1001/jama.2017.21269.
[15] A. Weill, M. Dalichampt, F. Raguideau, P. Ricordeau, P.-O. Blotiere, J. Rudant, et al., Low dose oestrogen combined oral contraception and risk of pulmonary embolism, stroke, and myocardial infarction in five million French women: cohort study, BMJ 353 (2016), i2002, https://doi.org/10.1136/bmj.i2002.
[16] S. Tubiana, P.-O. Blotiere, B. Hoen, P. Lesclous, S. Millot, J. Rudant, et al., Dental procedures, antibiotic prophylaxis, and endocarditis among people with prosthetic heart valves: nationwide population based cohort and a case crossover study, BMJ 358 (2017), j3776, https://doi.org/10.1136/bmj.j3776.
[17] S. Colas, C. Collin, P. Piriou, M. Zureik, Association between total hip replacement characteristics and 3-year prosthetic survivorship: a population-based study, JAMA Surg. 150 (2015) 979–988, https://doi.org/10.1001/jamasurg.2015.1325.
[18] G. Mathew, R. Agha, STROCSS Group, STROCSS 2021: Strengthening the reporting of cohort, cross-sectional and case-control studies in surgery, Int. J. 96 (2021), 106165, https://doi.org/10.1016/j.ijsu.2021.106165.
[19] F. Leyva, A. Zegard, O. Okafor, B. Stegemann, P. Ludman, T. Qiu, Cardiac operations and interventions during the COVID-19 pandemic: a nationwide perspective, Europace 23 (2021) 928–936, https://doi.org/10.1093/europace/euab013.
[20] C.S. Kwok, C.P. Gale, T. Kinnaird, N. Curzen, P. Ludman, E. Kontopantelis, et al., Impact of COVID-19 on percutaneous coronary intervention for ST-elevation myocardial infarction, Heart 106 (2020) 1805–1811, https://doi.org/10.1136/heartjnl-2020-317650.
[21] C.M. Whaley, M.F. Pera, J. Cantor, J. Chang, J. Velasco, H.K. Hagg, et al., Changes in health services use among commercially insured US populations during the COVID-19 pandemic, 2020, JAMA Netw. Open 3 (2020), e2024984, https://doi.org/10.1001/jamanetworkopen.2020.24984.
[22] A. Lazzati, M. Raphael Rousseau, S. Bartier, Y. Dabi, A. Challine, B. Haddad, et al., Impact of COVID-19 on Surgical Emergencies: Nationwide Analysis, vol. 5, BJS Open, 2021, https://doi.org/10.1093/bjsopen/zrab039 zrab039.
[23] T.D. Dobbs, J.A.G. Gibson, A.J. Fowler, T.E. Abbott, T. Shahid, F. Torabi, et al., Surgical activity in England and Wales during the COVID-19 pandemic: a nationwide observational cohort study, Br. J. Anaesth. 127 (2021) 196–204, https://doi.org/10.1016/j.bja.2021.05.001.
[24] K. Magnusson, J. Helgeland, M. Grøsland, K. Telle, Impact of the COVID-19 pandemic on emergency and elective hip surgeries in Norway, Acta Orthop. 92 (2021) 376–380, https://doi.org/10.1080/17453674.2021.1898782.
[25] L. Grassner, O. Petr, F.M. Warner, M. Dedeciusova, A.M. Mathis, D. Pinggera, et al., Trends and outcomes for non-elective neurosurgical procedures in Central Europe during the COVID-19 pandemic, Sci. Rep. 11 (2021) 6171, https://doi.org/10.1038/s41598-021-85526-6.
[26] E. Rennert-May, J. Leal, N.X. Thanh, E. Lang, S. Dowling, B. Manns, et al., The impact of COVID-19 on hospital admissions and emergency department visits: a population-based study, PLoS One 16 (2021), e0252441, https://doi.org/10.1371/journal.pone.0252441.
[27] M. Sokolski, P. Gajewski, R. Zymliński, J. Biegus, J.M.T. Berg, W. Bor, et al., Impact of coronavirus disease 2019 (COVID-19) outbreak on acute admissions at the emergency and cardiology departments across europe, Am. J. Med. 134 (2021) 482–489, https://doi.org/10.1016/j.amjmed.2020.08.043.
[28] J. Mesnier, Y. Cottin, P. Coste, E. Ferrari, F. Schiele, G. Lemesle, et al., Hospital admissions for acute myocardial infarction before and after lockdown according to regional prevalence of COVID-19 and patient profile in France: a registry study, Lancet Public Health 5 (2020) e536–e542, https://doi.org/10.1016/S2468-2667(20)30188-2.
[29] J.D. Moyer, A. James, C. Gakuba, M. Boutonnet, E. Angles, E. Rozenberg, et al., Impact of the SARS-COV-2 outbreak on epidemiology and management of major traumain France: a registry-based study (the COVITRAUMA study), Scand. J. Trauma Resuscitation Emerg. Med. 29 (2021) 51, https://doi.org/10.1186/s13049-021-00864-8.
[30] B.M. Sephton, P. Mahapatra, M. Shenouda, N. Ferran, K. Deierl, T. Sinnett, et al., The effect of COVID-19 on a Major Trauma Network. An analysis of mechanism of injury pattern, referral load and operative case-mix, Injury 52 (2021) 395–401, https://doi.org/10.1016/j.injury.2021.02.035.
[31] E. Marijon, N. Karam, D. Jost, D. Perrot, B. Frattini, C. Derkenne, et al., Out-of-hospital cardiac arrest during the COVID-19 pandemic in Paris, France: a population-based, observational study, Lancet Public Health 5 (2020) e437–e443, https://doi.org/10.1016/S2468-2667(20)30117-1.
[32] M. Czubak-Wrzosek, J. Czubak, D. Grzelecki, M. Tyrakowski, The effect of the COVID-19 pandemic on total hip and knee arthroplasty surgical volume in 2020 in Poland, Int. J. Environ. Res. Publ. Health 18 (2021) 8830, https://doi.org/10.3390/ijerph18168830.
[33] C.L. Barnes, X. Zhang, B.M. Stronach, D.A. Haas, The initial impact of COVID-19 on total hip and knee arthroplasty, J. Arthroplasty 36 (2021) S56–S61, https://doi.org/10.1016/j.arth.2021.01.0.