Since January 2020 Elsevier has created a COVID-19 resource centre with free information in English and Mandarin on the novel coronavirus COVID-19. The COVID-19 resource centre is hosted on Elsevier Connect, the company's public news and information website.

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CLINICAL RESEARCH

Myocardial infarction throughout 1 year of the COVID-19 pandemic: French nationwide study of hospitalization rates, prognosis and 90-day mortality rates☆

Les infarctus du myocarde pendant un an de pandémie de COVID-19 : étude nationale française des taux d'hospitalisation, du pronostic et de la mortalité à 90 jours

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KEYWORDS
Myocardial infarction;
COVID-19;

Summary
Background. — Studies reported a decrease in hospital admissions for myocardial infarction (MI) in early 2020 as a result of the coronavirus disease 2019 (COVID-19) crisis, mainly restricted to the beginning of the pandemic.

Abbreviations: CI, confidence interval; CMU-C, Couverture Maladie Universelle Complementaire (free universal health cover); COVID-19, coronavirus disease 2019; IRR, incidence rate ratio; MI, myocardial infarction; NSTEMI, non-ST-segment elevation myocardial infarction; OR, odds ratio; SAPSII, simplified acute physiology score; SARS-CoV-2, severe acute respiratory syndrome coronavirus 2; SNDS, Système National des Données de Santé (French National Health Data System); STEMI, ST-segment elevation myocardial infarction.

☆ Tweet: 6% decrease in hospital admissions for myocardial infarction in France in 2020, particularly at the beginning of the year, and for NSTEMI, women and older people. Limited effect on the acute and 3-month prognosis of MI patients who were hospitalized.

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Lockdown;
Hospitalization;
Mortality

Aims. — To describe national trends in hospital admissions for MI in 2020, and to compare patient characteristics, in-hospital prognosis and 90-day mortality between patients who had an MI in 2020 and those admitted in 2017—2019.
Methods. — All patients hospitalized for MI in France from 2017 to 2020 were selected from the national hospital discharge database. Analyses compared temporal trends in MI admissions, in-hospital cardiac complications and mortality rates in 2020 versus 2017—2019.
Results. — In 2020, 94,747 patients were hospitalized for MI, corresponding to a 6% decrease in MI admissions compared with 2017—19. This decrease was larger during the first lockdown (—24%; $P < 0.0001$) than during the second lockdown (—8%; $P < 0.0001$). Reductions in MI admissions were more pronounced and longer among patients with non-ST-segment elevation MI, older people and women. An increase in ST-segment elevation MI admissions was observed between lockdowns (+4%; $P = 0.0005$). Globally, and after adjustment for age, sex and calendar year, in-hospital and 90-day post-discharge mortality rates did not differ in 2020 versus 2017—19: incidence rate ratio $(IRR)_{adj\ in\text{-}hospital}$ 1.03, 95% confidence interval (CI) (0.98—1.08); $IRR_{adj\ 90\text{-}day\ post\text{-}discharge}$ 1.06, 95% CI (0.98—1.13).
Conclusions. — In 2020, a significant decrease in MI admissions was observed, and was marked at the beginning of the year. This highlights the need to disseminate public information on the importance of maintaining care and regular medical follow-up. The effect of the COVID-19 crisis on acute and 3-month outcomes of patients hospitalized for MI appears limited. Nevertheless, monitoring of chronic MI complications and the impact on non-hospitalized patients should continue.

MOTS CLÉS
Infarctus du myocarde ;
COVID-19 ;
Confinement ;
Hospitalisation ;
Mortalité

Résumé
Contexte. — Plusieurs études ont signalé une diminution des admissions pour infarctus du myocarde (IDM) à l'hôpital au début de l'année 2020, due à la crise de la COVID-19, mais elles étaient principalement restreintes au début de la pandémie.
Objectifs. — Décrire les tendances nationales des admissions pour IDM à l'hôpital en 2020 et comparer les caractéristiques, le pronostic hospitalier et la mortalité à 90 jours des patients admis en 2020, à ceux des patients admis en 2017—19.
Méthodes. — Tous les patients hospitalisés pour IDM en France entre 2017 et 2020 ont été inclus à partir de la base de donnée hospitalière nationale (PMSI-MCO). Les analyses ont comparé les tendances temporelles d'admissions pour IDM, les taux de complications cardiaques hospitalières et la mortalité en 2020 versus 2017—19.
Résultats. — En 2020, 94 747 patients ont été hospitalisés pour IDM, correspondant à une diminution de 6 % des admissions pour IDM par rapport à 2017—19. Cette diminution était plus importante durant le premier confinement (—24 %; $P < 0{,}0001$) que pendant le deuxième (—8 %; $P < 0{,}0001$). Les diminutions d'hospitalisation pour IDM étaient plus élevées et ont persisté plus longtemps pour les NSTEMI, pour les personnes âgées et pour les femmes. Une augmentation des hospitalisations pour STEMI a été observée entre les confinements (+4 %; $P = 0{,}0005$). Globalement et après ajustement sur l'âge, le sexe et l'effet temporel, les taux de mortalité hospitalière et dans les 90 jours qui suivaient la sortie d'hospitalisation ne différaient pas entre 2020 et 2017—19: $IRR_{aj\ hosp}$ 1,03, IC95 % [0,98—1,08]; $IRR_{aj\ 90\ jours\ post\ sortie}$ 1,06, IC95 % [0,98—1,13].
Conclusions. — En 2020, une diminution significative des hospitalisations pour IDM a été observée et était importante au début de l'année. Cela souligne la nécessité de diffuser des informations publiques sur l'importance du maintien des soins et du suivi médical régulier. L'impact de la crise du COVID-19 sur les complications aiguës et le pronostic à 3 mois des patients admis apparaît limité. Néanmoins, la surveillance des complications chroniques de l'IDM et de l'impact sur les personnes non hospitalisées devra être poursuivie.

Background

The coronavirus disease 2019 (COVID-19) pandemic has affected the management of other diseases [1—3], including myocardial infarction (MI). Several studies have pointed to a significant decrease in MI hospitalizations at the beginning of the COVID-19 pandemic, in early 2020 [4—9].

In France, among 67 million inhabitants, more than 2,600,000 confirmed cases of COVID-19 were reported in 2020, and nearly 260,000 patients were hospitalized [10]. The first cases were confirmed on 24 January 2020 [11]; the pandemic then spread rapidly, with two waves in 2020 (peaking in March and October), interrupted by a short-lived improvement during the summer. A first nationwide lockdown was implemented in France from 17 March 2020 (week 12) until 11 May 2020 (week 20), and a second from 30 October 2020 (during week 44) until 15 May 2020 (during week 51).

In early 2020, the COVID-19 pandemic significantly affected the French healthcare system, including both in- and out-of-hospital care, which led to the cancelling of scheduled non-emergency care and the saturation of some services. In addition, the fear of infection and the government restrictions imposed during the lockdown may have had an impact on the management of MI. In France, reductions of > 20% in emergency department admissions for MI and > 30% in hospital admissions for MI were reported during the first lockdown [12—14]. In this context, it is essential to extend this monitoring by assessing MI admissions rates at the end of 2020, as well as the impact of the COVID-19 pandemic over 2020 in its entirety, to examine a possible mid-term effect of the drop in MI admissions, and to determine readmission and mortality rates at 3 months. To date, few studies have assessed the impact of the COVID-19 pandemic at a nationwide level [5,15], and extended the observation period to after the first lockdown [16,17].

The aim of this study was to estimate the nationwide time trends in hospital admissions for MI, and the clinical profile, management, acute cardiac complications, in-hospital mortality rates and 90-day readmission and all-cause mortality rates among in-patients who had an MI in 2020, overall and by lockdown period.

Methods

Data source

This study was performed using the French National Health Data System (Système National des Données de Santé [SNDS]), which contains comprehensive data on health insurance claims and hospital discharges for the entire French population (around 67,000,000 inhabitants) [18]. The SNDS is a medicoadministrative tool, comprising several databases linked by a unique patient identifier. The system contains demographic data, as well as exhaustive data on all medical reimbursements for all individuals with universal medical coverage. The SNDS includes the National Hospital Discharge Database (Programme de Médicalisation des Systèmes d'Information, PMSI), which collects all data on admissions to public and private hospitals, including the primary reason for the hospital stay (main diagnosis), hospital deaths and information about some procedures. In 2020, an accelerated reporting system was implemented to make the hospital data available more rapidly. The SNDS also records long-term disease status and socioeconomic proxies. Patients with long-term disease status, which is requested by the general practitioner, are entitled to 100% reimbursement of all healthcare expenditure related to that particular disease. The Couverture Maladie Universelle Complémentaire (CMU-C) system is a complementary health insurance scheme that provides free access to healthcare, but is only available to those with low income (below the poverty line), and before retirement. Registration for CMU-C reflects a low socioeconomic level, and can be used as a proxy for patients aged < 65 years. Finally, the SNDS includes the date of death of all individuals.

Study population

Patients hospitalized for MI in France in the years 2017—2020 and residing in metropolitan France or the overseas departments (Martinique, Guadeloupe, Guyane, La Réunion or Mayotte) were selected. The years were divided into five periods: weeks 1—11 (before lockdown); weeks 12—19 (first lockdown); weeks 20—43 (interim lockdown); weeks 44—50 (second lockdown); and weeks 51—52 (after lockdown). MI was defined by codes I21 to I23 of the International Classification of Diseases, Tenth Revision (ICD-10), which were recorded in the SNDS as the main diagnosis for the entire stay in hospital or one of the medical units. The distribution of MI codes is available in Table A.1. For each patient, we selected the first hospitalization for MI that occurred in each year.

Data collected

Patient characteristics included age, sex, CMU-C status [18], Charlson Comorbidity Index score [19], co-morbidities and type of MI, namely ST-segment elevation MI (STEMI) or non-STEMI (NSTEMI). MI complications (including cardiogenic shock, cardiac rupture, cardiac thrombosis, rhythm and conduction disorders and heart failure) were identified by the associated diagnoses for the MI hospital stay (Appendix A). The hospital diagnosis of COVID-19 was based on the identification of severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) through a biological test (polymerase chain reaction, antigen or serologic) or based on a computed tomography scan. In-hospital mortality was estimated for all patients by mode of discharge from hospital. However, 90-day mortality was estimated among patients affiliated to the general health insurance scheme (health insurance covering around 76% of the French population), a subpopulation with a rapid and exhaustive completion of out-of-hospital vital status and date of death. Ninety-day post-discharge mortality was defined as all-cause mortality occurring within 90 days of MI hospital discharge. In- and out-of-hospital mortality was defined as all-cause mortality occurring in hospital or within 90 days of MI hospital discharge.

Statistical analysis

Patient characteristics and acute care management were compared between 2017—2019 and 2020 using the χ^2 test for

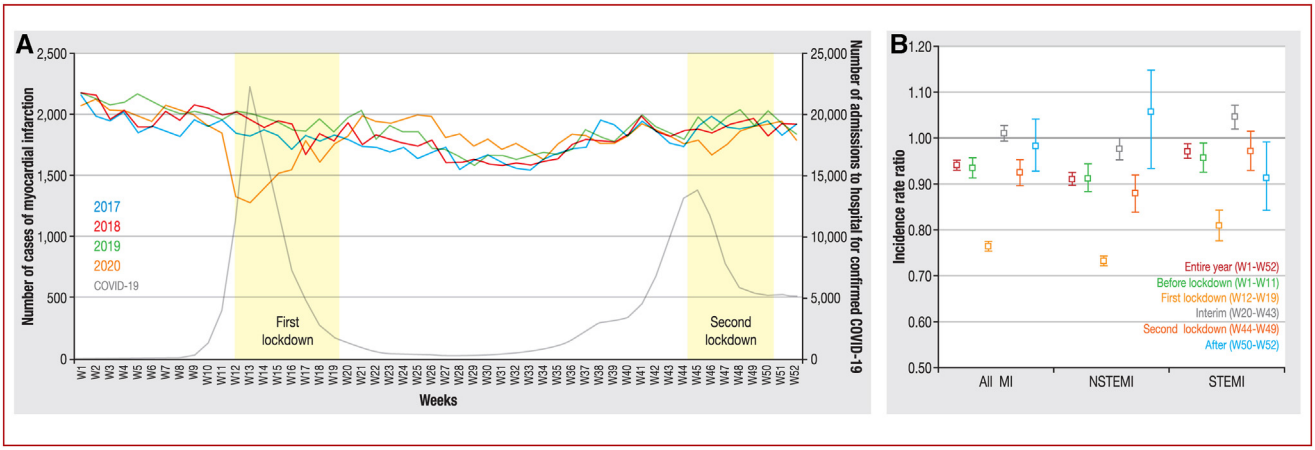

Figure 1. A. Weekly number of patients hospitalized for myocardial infarction (MI) from 2017 to 2020 (n_{2017} = 94,297; n_{2018} = 96,090; n_{2019} = 98,677; n_{2020} = 94,747). B. Incidence rate ratios of patients hospitalized for all MI, ST-segment elevation MI (STEMI) and non-STEMI (NSTEMI) from 2017—2019 and in 2020. Incidence rate ratios are adjusted for calendar years. COVID-19: coronavirus disease 2019; W: week.

categorical variables and the Wilcoxon-Mann-Whitney test for quantitative variables. Characteristics were described according to the five time periods. For each period, Poisson regression models were used to assess changes between 2017—2019 and 2020:

- in the rates of patients hospitalized for MI, using the log of the census population size of each year as the denominator (population estimates were provided by the French National Institute of Statistics and Economic Studies [INSEE]);
- in mortality rates (in-hospital, 3-day in-hospital, 90-day post-discharge and in- and out-of-hospital mortality) using the log of the number of patients hospitalized for MI each year as the denominator.

These models were adjusted for calendar year (time trend in the number of patients with MI in France, independent of COVID-19). Mortality models were adjusted for calendar year, sex and age. Stratified analyses by sex, age, region (corresponding to the first level of the Nomenclature of Territorial Units for Statistics (NUTS1) [20] and type of MI (STEMI and NSTEMI) were conducted, and interactions were tested.

To compare patient characteristics (Charlson Comorbidity Index score $\geq$ 2), hospital management (admission to a resuscitation unit, admission to an intensive care unit, percutaneous coronary intervention, coronary artery bypass graft, transfer to rehabilitation units) and prognosis (MI complications, MI readmission) between the reference years 2017—2019 and 2020, odds ratios (ORs) were computed and adjusted for calendar years, sex and age.

Statistical analyses were performed with SAS Enterprise Guide software, version 7.15 (SAS Institute, Cary, NC, USA).

Patient consent—ethics approval

In line with French government regulations and the National Ethics Committee, no patient consent was required. The database used in the study contained anonymous patient information. Furthermore, full access to the SNDS is granted to the National Agency for Public Health (Santé Publique France) by French law (Code de la Santé Publique: articles L. 1461-3 I 2° and R. 1461-12 et seq.).

Results

Trends in admission rates

In 2020, 94,747 patients were hospitalized for MI at least once in France, equivalent to 1608 fewer patients on average compared with 2017—2019 (n_{2017} = 94,297; n_{2018} = 96,090; n_{2019} = 98,677) (Fig. 1A). Overall, in the year 2020, the rate of admissions for MI dropped by 6% (incidence rate ratio [IRR]$_{2020}$ 0.94, 95% confidence interval [CI] 0.93—0.95; P < 0.0001). Admissions for MI decreased before lockdown (IRR_{W1-11} 0.93, 95% CI 0.91—0.96; P < 0.0001) and during the two 2020 lockdowns (IRR_{W12-19} 0.76, 0.7—0.79 [P < 0.0001]; IRR_{W44-50} 0.92, 95% CI 0.90—0.95 [P < 0.0001]) compared with the same weeks in 2017—2019 (Fig. 1B).

During the first lockdown, the decrease was significant for both STEMI and NSTEMI, but was systematically of a higher magnitude for NSTEMI. Weekly IRRs showed that the decrease reached up to 40% for all types of MI (week 13), 49% for NSTEMI (week 12) and 36% for STEMI (week 13). The NSTEMI decrease was significant from week 10 to week 20 (Fig. A.1—A.3). During the first lockdown, the decrease in MI admissions did not differ between men and women (24% vs 27%, $P_{interaction}$ = 0.50). Instead, the decrease in MI admissions increased progressively with age (P for trend < 0.0001) for both men and women (Fig. 2). Analysis by type of MI showed that the decrease in STEMI admissions was significantly higher among women than among men ($P_{interaction}$ < 0.0001). Regarding age, whereas STEMI admissions decreased linearly with age, the decrease in NSTEMI admissions was greater among those aged $\geq$ 85 years (Fig. 2). During the first lockdown, a decrease in MI admissions was found in all regions except Bretagne and the overseas departments, and was maximal in Bourgogne-Franche-Comté (—39%; P < 0.0001) (Fig. A.4).

During the interim lockdown period, whereas the rate of admissions for NSTEMI was reduced (IRR_{W20-43} 0.98, 95%

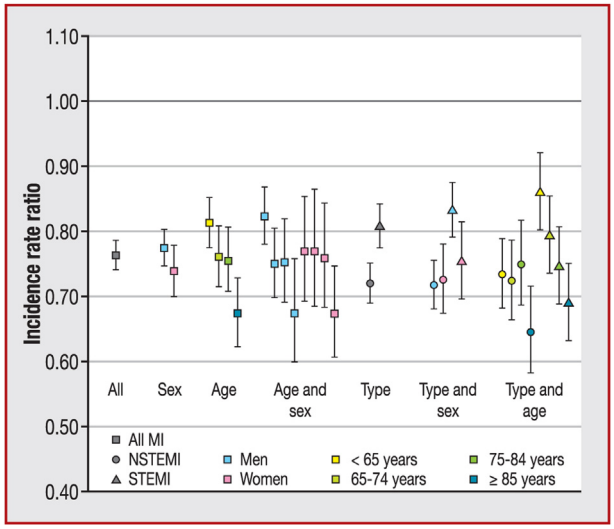

Figure 2. Incidence rate ratio (IRR) of patients hospitalized for myocardial infarction (MI) during the first lockdown (weeks 12—19) in 2020 compared with the same period in 2017—2019, according to type of MI, sex and age. IRRs are adjusted for calendar years. NSTEMI: non-ST-segment elevation MI; STEMI: ST-segment elevation MI.

CI 0.95—1.00; $P = 0.04$), the rate of admissions for STEMI increased, and was higher than in the years 2017—2019 (IRR_{W20-43} 1.04, 95% CI 1.02—1.07; $P = 0.0005$) (Fig. 1B). This excess of STEMI admissions was more pronounced for young men (Fig. A.5). At a regional level, a global excess of MI admissions was significant for people living in Auvergne-Rhône-Alpes and Corse (Fig. A.4).

During the second 2020 lockdown, the decrease in admissions was significant only for NSTEMI (IRR_{W44-50} 0.88, 95% CI 0.84—0.92; $P < 0.0001$) (Fig. 1B), for people living in Auvergne-Rhône-Alpes, Provence-Alpes-Côte d'Azur and Guyane (Fig. A.4) and, in particular, for women and the elderly (Fig. A.6).

Patient characteristics

The characteristics of the patients according to the 2020 lockdowns, and compared with the same periods in the reference years, are shown in Table 1. Almost one-third of patients hospitalized for MI were women, and the mean age ranged from 67.9 to 69.0 years across the five study periods and reference years. The proportion of socioeconomically disadvantaged patients receiving CMU-C was higher in the five study periods of 2020 than in the reference years (among those aged < 65 years). In general, despite a few statistically significant differences, there were no clinically meaningful differences in patient characteristics for the five periods of 2020 compared with the corresponding periods in the reference years (Table 1). However, patients admitted to resuscitation units (6% of those hospitalized for MI) during the first lockdown and the interim period tended to be less severely ill than those admitted during the same periods in 2017—2019, as shown by the significantly lower simplified acute physiology score (SAPSII) during the first lockdown (50.0 vs. 45.4; $P < 0.0001$) and the interim period (50.2 vs. 47.5; $P < 0.0001$). Furthermore, patients admitted to resuscitation units during the first lockdown tended to be younger than those admitted during the same periods in 2017—2019 (65.1 vs. 66.7 years; $P = 0.001$) (Table 2).

Hospital management and prognosis

The average length of stay was shorter during the five study periods in 2020 compared with 2017—2019 ($P < 0.0001$) (Table 2; Fig. A.7). Overall and during the first lockdown, the rates of cardiac complications, admissions to resuscitation units, admissions to intensive care units, percutaneous coronary interventions and coronary artery bypass grafts did not differ between 2020 and the reference years after adjusting for age, sex and time effect (Fig. 3). In 2020, in-hospital deaths occurred in 21,722 patients (5.7%), with 11,438 in the first 3 days of hospitalization. The in-hospital case fatality rate ranged from 5.2% to 6.1%, and the early (i.e. first 3 days) in-hospital case fatality rate ranged from 2.8% to 3.2% (Table 2). Among patients with MI discharged alive from hospital in 2020, 90-day post-discharge mortality rates ranged from 3.4% to 4.6% (Table 3). No difference was observed compared with the reference years, after adjusting for time effect, age and sex, over the whole year ($IRR_{adj\ 2020\ in\text{-}hospital}$ 1.03, 95% CI 0.98—1.08 [$P = 0.19$]; $IRR_{adj\ 2020\ 90\text{-}day\ post\text{-}discharge}$ 1.06, 95% CI 0.98—1.13; $P = 0.14$) or over each study period (Fig. 4). Weekly IRRs for mortality for the reference years and 2020 are detailed in Fig. A.8—A.10.

Between weeks 44 and 49 (second lockdown), 0.25% (99 patients) of MIs in 2017—2019 versus 0.35% (44 patients) in 2020 were complicated by a cardiac rupture or ventricular septal defect, corresponding to a two-fold increase in risk after adjusting for age, sex and time effect (OR_{adj} 2.14, 95% CI 1.14—3.99; $P = 0.02$). The risk of in-hospital mortality was increased compared with previous years during the weeks of the second lockdown ($IRR_{adj\ in\text{-}hospital}$ 1.15, 95% CI 1.01—1.32; $P = 0.03$). In NSTEMI, there was a higher risk of cardiac rupture (OR_{adj} 5.93, 95% CI 1.37—25.73; $P = 0.02$) and of rhythm and conduction disorders (OR_{adj} 1.18, 95% CI 1.04—1.33; $P = 0.01$) during the second lockdown than during the same periods in 2017—2019. In the analysis stratified by MI type, mortality rates did not differ significantly between 2020 and the reference years, including over the second lockdown period (Fig. A.11—14).

In 2020, among patients with MI discharged home, the all-cause readmission rates within 90 days after discharge ranged from 27.5% to 33.5%, and were significantly lower before the first lockdown, during the first lockdown and during the interim period compared with the same periods in the reference years (Table 3, Fig. 4).

Discussion

This French nationwide study is the first to investigate MI admission rates over the year 2020, and to examine nationwide trends in readmissions and all-cause mortality in the 90 days following MI hospitalization. There was a significant decrease in hospitalization for MI observed in France, as in many countries, during the first wave of the COVID-19 pandemic in early 2020 [4—9,12,14]. The overall effects over the year on MI admissions and on the acute and 90-day outcomes of patients hospitalized for MI were limited.

Table 1 Characteristics of patients hospitalized for myocardial infarction from 2017 to 2020 (crude comparison).

	W1—11 (before lockdown)			W12—19 (first lockdown)			W20—43 (interim lockdown)			W44—50 (second lockdown)			W51—52 (after lockdown)		
	2017—19	2020	P[a]	2017—19	2020	P[a]	2017—19	2020	P[a]	2017—19	2020	P[a]	2017—19	2020	P[a]
N	66,404	22,061		45,103	12,232		126,060	44,041		40,123	12,661		11,374	3752	
Women (%)	32.0	31.8	0.45	31.4	31.2	0.61	32.3	32.2	0.76	32.6	31.8	0.07	31.6	29.7	0.03
Mean age ± SD (years)	68.9 ± 14.5	68.7 ± 14.2	0.03	68.3 ± 14.5	67.9 ± 14.1	0.005	68.5 ± 14.5	68.4 ± 14.2	0.20	68.9 ± 14.3	68.4 ± 14.2	0.0002	69.0 ± 14.4	68.5 ± 14.2	0.06
CMU-C (%)[b]	8.7	9.7	0.003	8.3	10.3	< 0.0001	8.7	10.9	< 0.0001	8.9	11.6	< 0.0001	9.2	12.4	0.0003
CCI score (%)[c]															
0—1	48.6	47.7	0.05	49.6	48.2	0.03	50.0	49.1	< 0.0001	49.8	49.2	0.36	49.7	50.3	0.33
2—3	34.7	35.1		34.5	35.3		33.7	35.1		34.2	34.8		33.9	34.3	
4+	16.7	17.2		15.9	16.5		16.3	15.8		16.0	16.0		16.4	15.4	
Co-morbidities (%)[c,d]															
COVID-19	-	0.1		-	2.5		-	0.7		-	2.9		-	1.9	
Acute coronary syndrome	26.5	31.0	< 0.0001	28.2	28.6	0.48	27.4	27.6	0.31	27.0	26.5	0.24	26.0	27.3	0.13
Ischaemic heart disease	45.9	46.8	0.02	44.6	44.2	0.47	44.1	43.4	0.02	43.8	42.5	0.01	43.2	43.3	0.98
Stroke	4.4	4.5	0.37	4.5	4.2	0.22	4.4	4.3	0.27	4.5	4.4	0.79	4.4	4.5	0.80
Heart failure	12.6	12.5	0.81	11.5	10.8	0.02	11.2	10.7	0.002	11.2	10.4	0.01	11.7	9.8	0.002
Atrial fibrillation and flutter	10.7	10.6	0.80	10.0	9.6	0.17	10.2	10.1	0.62	10.2	9.7	0.09	10.3	9.2	0.05
Rhythm and conduction disorders	17.2	17.4	0.61	16.2	16.0	0.53	16.4	16.4	0.68	16.4	15.8	0.13	16.9	16.0	0.20
Valvulopathy	6.5	6.5	0.93	6.1	5.9	0.51	6.1	5.9	0.11	6.0	5.7	0.20	6.3	5.9	0.34
Venous thromboembolism	2.6	2.9	0.02	2.6	2.7	0.33	2.6	2.9	0.001	2.7	2.8	0.48	2.8	2.4	0.20
Any circulatory diseases	65.0	65.1	0.78	63.4	62.4	0.05	63.4	62.7	0.01	63.3	61.6	0.001	63.6	62.2	0.13
STEMI (%)	50.4	48.1	< 0.0001	50.7	50.6	0.94	50.1	48.8	< 0.0001	49.9	49.0	0.09	50.2	48.1	0.03

CCI: Charlson Comorbidity Index; CMU-C: Couverture Maladie Universelle Complémentaire; COVID-19: coronavirus disease 2019; SD: standard deviation; STEMI: ST-segment elevation myocardial infarction; W: weeks.

[a] 2017—19 versus 2020.

[b] Complementary health insurance for people with low income aged < 65 years.

[c] Among those with a unique identifier (98% of the population).

[d] Hospitalizations or long-term disease status in the 5 years preceding myocardial infarction and associated diagnosis during the myocardial infarction index hospitalization.

Table 2 Management and hospital prognosis of patients hospitalized for myocardial infarction from 2017 to 2020 (crude comparison).

	W1–11 (before lockdown)			W12–19 (first lockdown)			W20–43 (interim lockdown)			W44–50 (second lockdown)			W51–52 (after lockdown)		
	2017–19	2020	P[a]	2017–19	2020	P[a]	2017–19	2020	P[a]	2017–19	2020	P[a]	2017–19	2020	P[a]
STEMI (%)	50.4	48.1	< 0.0001	50.7	50.6	0.94	50.1	48.8	< 0.0001	49.9	49.0	0.09	50.2	48.1	0.03
Clinical management															
Mean length of stay ± SD (days)	7.4 ± 12.2	6.9 ± 11.4	< 0.0001	7.2 ± 10.6	6.6 ± 10.3	< 0.0001	6.9 ± 8.4	6.5 ± 6.6	< 0.0001	6.9 ± 8.1	6.3 ± 6.4	< 0.0001	6.7 ± 8.1	6.1 ± 6.3	< 0.0001
PCI (%)	61.9	63.6	< 0.0001	63.7	67.6	< 0.0001	63.3	64.8	< 0.0001	63.5	65.3	0.0002	62.8	63.6	0.37
CABG (%)	2.3	2.2	0.12	2.3	2.0	0.02	2.3	2.4	0.84	2.3	2.3	0.91	2.2	1.9	0.27
Admitted to ICU (%)	75.5	76.6	0.001	77.7	78.1	0.27	77.7	78.3	0.02	77.3	78.6	0.002	77.0	78.4	0.07
Admitted to resuscitation unit (%)	5.6	5.6	0.74	5.9	6.4	0.02	5.8	6.1	0.04	5.9	5.6	0.36	5.7	5.6	0.79
Mean SAPSII ± SD[b]	50.1 ± 24.6	49.7 ± 24.1	0.59	50.0 ± 24.7	45.4 ± 23.2	< 0.0001	50.2 ± 24.8	47.5 ± 24.4	< 0.0001	50.2 ± 31.5	47.9 ± 24.5	0.08	50.2 ± 24.7	50.6 ± 24.4	0.82
Mean age ± SD (years)[b]	66.8 ± 12.4	67.0 ± 12.3	0.60	66.7 ± 12.3	65.1 ± 12.1	0.001	66.3 ± 12.6	66.0 ± 11.8	0.41	67.0 ± 12.5	66.1 ± 11.7	0.10	67.1 ± 12.4	65.6 ± 12.3	0.13
Transfer to rehabilitation unit[c]	7.0	6.2	< 0.0001	6.5	6.0	0.03	7.0	6.4	< 0.0001	6.8	5.5	< 0.0001	6.5	4.9	0.0007
Prognosis: complications (%)[d]															
Cardiogenic shock	4.3	4.2	0.35	4.4	4.3	0.69	4.3	4.1	0.02	4.2	4.2	0.88	4.1	3.9	0.73
Cardiac rupture/VSD	0.3	0.3	0.79	0.3	0.5	0.001	0.3	0.3	0.41	0.2	0.3	0.06	0.4	0.4	0.92
Cardiac thrombosis	0.4	0.5	0.07	0.4	0.4	0.40	0.4	0.4	0.62	0.4	0.4	0.54	0.4	0.5	0.20
Atrial fibrillation and flutter[e]	9.2	8.5	0.004	8.5	8.5	0.93	8.7	8.6	0.37	9.0	9.1	0.77	8.9	8.8	0.87
Rhythm and conduction disorders[e]	23.0	23.3	0.32	22.5	23.5	0.04	22.9	23.2	0.36	23.0	24.0	0.04	22.7	22.9	0.82
Heart failure[e]	18.4	19.5	0.0003	18.2	20.3	< 0.0001	17.6	19.5	< 0.0001	18.0	20.6	< 0.0001	18.1	19.9	0.02
Mortality (%)															
3-day in-hospital case fatality	3.2	3.0	0.17	2.9	3.0	0.79	2.9	2.8	0.39	3.0	2.9	0.72	3.2	3.1	0.68
In-hospital case fatality	6.1	5.7	0.02	5.6	5.6	0.71	5.6	5.2	0.01	5.6	5.9	0.21	6.1	5.6	0.29

CABG: coronary artery bypass graft; ICU: intensive care unit; PCI: percutaneous coronary intervention; SAPSII: simplified acute physiology score; SD: standard deviation; STEMI: ST-segment elevation myocardial infarction; VSD: ventricular septal defect; W: weeks.

[a] 2017–19 versus 2020.

[b] Among those admitted to a resuscitation unit.

[c] Among those discharged from hospital alive.

[d] Associated diagnosis during the myocardial infarction index hospitalization.

[e] Among those with no history of hospitalization for this reason.

Table 3 Ninety-day post-discharge outcomes of patients hospitalized for myocardial infarction from 2017 to 2020 (crude comparison).

	W1—11 (before lockdown)			W12—19 (first lockdown)			W20—43 (interim lockdown)			W44—50 (second lockdown)			W51—52 (after lockdown)		
	2017—19	2020	P[a]	2017—19	2020	P[a]	2017—19	2020	P[a]	2017—19	2020	P[a]	2017—19	2020	P[a]
Readmission to full hospitalization within 90 days (%)[b]															
All causes	32.0	28.3	< 0.0001	31.7	27.5	< 0.0001	30.5	28.8	< 0.0001	31.7	29.8	0.0003	33.5	29.3	< 0.0001
Any circulatory diseases	23.2	20.7	< 0.0001	23.4	19.6	< 0.0001	22,0	20.8	< 0.0001	23.1	22.2	0.07	24.3	22.3	0.03
Ischaemic heart disease	17.2	15.5	< 0.0001	18.0	14.1	< 0.0001	16.5	16,0	0.02	17.2	16.6	0.16	18.4	16.7	0.03
Heart failure	3.9	3.3	< 0.0001	3.3	3.5	0.5	3.2	2.4	0.0006	3.7	3.5	0.29	3.8	3.5	0.58
Venous thromboembolism	0.2	0.1	0.16	0.1	0.1	0.53	3.3	2.7	< 0.0001	0.1	0.2	0.66	0.2	0.07	0.18
Stroke	0.4	0.4	0.55	0.4	0.4	0.71	0.2	0.1	0.44	0.4	0.3	0.29	0.4	0.4	0.7
One-day CV hospitalization within 90 days (%)[b]	4.6	4.1	0.006	4.6	4.6	0.87	4.5	5.2	< 0.0001	4.8	6.2	< 0.0001	5.2	5.4	0.65
All-cause 90-day post-discharge mortality (%)[c]															
Among those discharged from hospital alive	3.9	4.2	0.07	3.5	3.4	0.83	3.6	3.9	0.03	4.2	4.4	0.33	4.6	4.6	0.86

CV: cardiovascular; W: week.
[a] 2017—19 versus 2020.
[b] Among those discharged home.
[c] Among those affiliated to the general insurance scheme (about 76% of the French population).

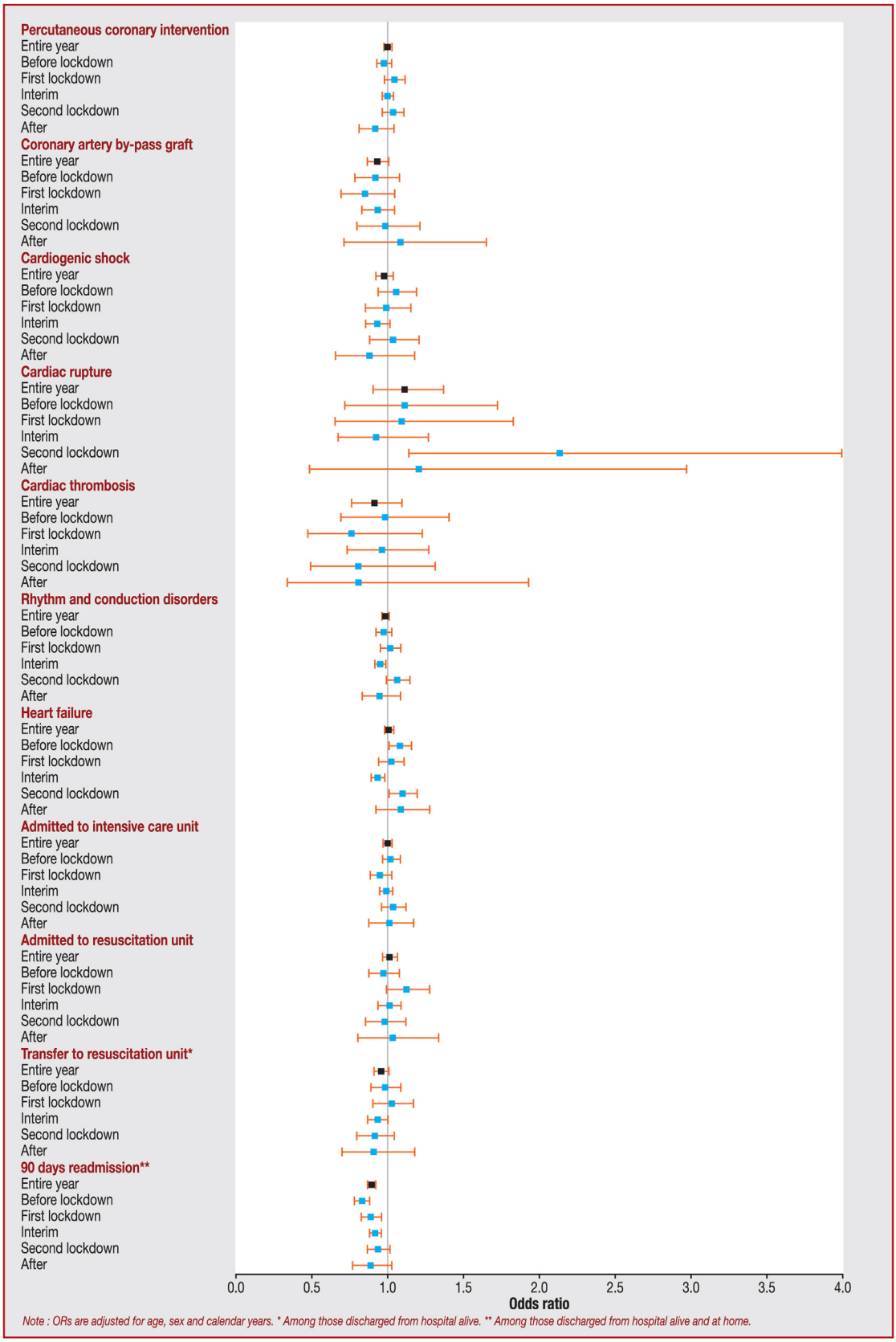

Figure 3. Prevalence odds ratios of acute hospital care, cardiac complications and readmission of patients hospitalized for myocardial infarction in 2020 compared with 2017–2019. Odds ratios are adjusted for age, sex and calendar years. [a] Among those discharged from hospital alive. [b] Among those discharged from hospital alive and at home.

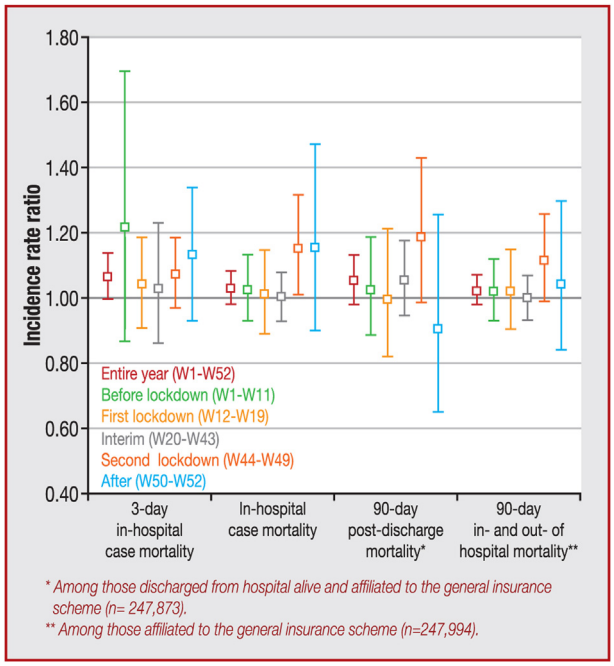

Figure 4. Incidence rate ratio (IRR) of case fatality. IRRs are adjusted for age, sex and calendar years. W: week. [a] Among those discharged from hospital alive and affiliated to the general insurance scheme ($n = 247,873$). [b] Among those affiliated to the general insurance scheme ($n = 247,994$).

A lower use of care can be assumed considering the reduction in MI hospitalizations and rehospitalizations; this may have caused an increase in coronary deaths at home and without hospitalization. In the USA, an increase in deaths caused by ischaemic heart disease and hypertensive diseases was found during the initial phase of the COVID-19 pandemic [21]. Excess all-cause mortality was observed in France during the lockdown, especially for those aged > 65 years [22], and in Paris and its suburbs, an increase in out-of-hospital cardiac arrest during the first weeks of lockdown was detected [23]. In our study, it cannot be ruled out that a proportion of the non-hospitalized MI cases died at home, without seeking healthcare. An English analysis estimated that the decline in emergency department visits for suspected cardiac disease during the COVID-19 pandemic was associated with cardiac excess mortality—between 3.1 and 8.4 per 100 emergency department visits for suspected cardiac disease [24]. In the current study, no significant increase in in-hospital mortality was observed during the lockdown among patients hospitalized for MI, which is consistent with the literature [5,9,15]. We expand on these findings by showing that 90-day post discharge mortality rates also did not increase. However, the analysis of the causes and places of death in 2020, specifically deaths due to MI at home, will be able to complement this study by including non-hospitalized patients with MI, as soon as the French data are available (death certificates), and will be taken into account when assessing the overall impact of the COVID-19 crisis on MI.

In addition, it is likely that part of the decrease in the number of hospitalized MI cases is linked to competing deaths, particularly in the elderly or multimorbid patients at risk of COVID-19 [25]. Finally, a decrease in MI incidence as a result of the decline in air pollution [26—28] cannot be excluded, but probably only explains a minor part of it [5].

This study supported a moderate decrease of 6% in MI admissions. During the first lockdown and in the weeks before, there was a significant decrease in MI admissions, of up to 40%. Among the patients who reached the hospital, cardiac complications, in-hospital mortality and 90-day post discharge mortality were not increased. MI admission rates declined in 2020 before and beyond the first lockdown, which may point to a possible impact of the pandemic, independent of the lockdown effect [4,5]. The decrease in hospitalizations affected all types of MI and all population groups, although stratified analysis indicates that it was more pronounced for NSTEMI, for older people with NSTEMI and for women with STEMI. The decrease in MI admissions concerned almost all regions of metropolitan France, regardless of the level of SARS-CoV-2 spread. As was observed for emergency department admissions for MI or stroke, some regions little affected by the first wave of COVID-19, such as Occitanie, recorded a large and significant decrease in MI hospital admissions during the first lockdown [13].

Given the extent of the decrease in MI admissions, the pandemic context may be a major hypothesis to explain this drop. The peak in hospital admissions for COVID-19 and the decrease in admissions for MI were reached concomitantly at week 13. The fear of infection by COVID-19 led patients to forego care [29,30]. In addition, mobility restrictions linked to the lockdown, media coverage about overloaded hospitals, congestion of calls to the emergency services and fear of unnecessarily disturbing busy health workers led the population to neglect certain symptoms, thus delaying their call or visit to their general practitioner or emergency services when experiencing MI symptoms, especially quiet or non-typical MI symptoms [7]. At the end of the first wave, public information on the importance of maintaining care despite the pandemic was disseminated to the general population' this probably contributed to the more moderate decrease in MI admissions in the second lockdown, mainly for STEMI.

During the second lockdown, the decrease in MI admissions was for NSTEMI only and, more broadly in 2020, it was observed that the decrease in admissions for NSTEMI was more persistent and more important than for STEMI. Moreover, the decrease in MI admissions was observed to be more pronounced for women and the elderly. As has already been demonstrated, women, the elderly and patients with NSTEMI may have experienced less severe or more atypical MI symptoms [31—33]. Thus, in the pandemic context, this could have contributed to disadvantage their admission for suspected MI, and these patients may have waited longer at home for the symptoms to subside on their own [34]. In the current study, the greater decrease in STEMI hospitalizations among women corroborates the findings of British and Italian studies [5,6], and highlights the need to communicate again that women can also be affected by cardiovascular diseases, and the frequency of atypical symptoms in these populations [35].

Although English and Italian studies did not find this [5,6], our data showed that the decline in MI admissions was higher among older people with NSTEMI, which is in line with the overall decline in non-COVID-19 admissions observed in the USA [36]. As age is one of the main risk factors for COVID-19

severity [37], it can be assumed that beyond the difference in clinical presentation, the fear of COVID-19 contamination was widespread among the elderly. Moreover, lockdowns increased the isolation of the elderly, who may have had greater difficulty in reporting symptoms and contacting the emergency services.

During the interim period between lockdowns, there was an increase in STEMI admissions in young men. However, these STEMIs did not become more serious in terms of cardiac complications and mortality in-hospital and at 90 days. This could be the consequence of the lower follow-up of patients as a result of postponement of cardiological follow-up consultations or lower use of care during subacute precursor cardiovascular events during the first lockdown. Another possible explanation, which would only account for a few cases, could be that a greater number of French people stayed in France during the summer compared with previous years because of the travel restrictions outside of France, and perhaps had fewer vacations and more work-related stress.

The 2020 decline in MI admissions could mean that people with MI stayed at home without seeking medical advice. Some studies suggest an increase in cardiac complications, in particular the risk of free wall rupture with STEMI, related to a delay between symptom onset and first medical contact, which could have been longer during the first lockdown [38,39]. In our study, no significant or prolonged increase in acute cardiac complications was observed for MI during 2020, except for cardiac rupture during the second lockdown. Part of the increase in cardiac rupture rate may be related to the increase in the share of STEMI among patients hospitalized for MI during the second lockdown, because STEMI is at higher risk of mechanical complications than NSTEMI [40]. In 2020, we did not observe an increase in cardiac complications or mortality in patients with STEMI. In contrast, in those with NSTEMI, we had an increase in cardiac rupture and rhythm and conduction disorders rates that could be related to increased delays in management or to selection of the most severe cases of NSTEMI, with no increase in mortality rates. French results in the first lockdown did not show an increase in the time between onset of STEMI symptoms and hospital admission [12]. In our study, we did not have information on times, but given the increase in cardiac ruptures, an increase in such delays for NSTEMI in the second lockdown cannot be ruled out. The rate of medium- and long-term complications, such as heart failure, should be monitored in the coming months.

The duration of hospitalization for MI decreased in the weeks before the first lockdown, concomitantly with the considerable increase in COVID-19 hospitalizations, and extended throughout all of 2020. This could be explained by the hospital overload from COVID-19, which created the need to quickly free up hospital beds from any cause or to change the organization of care to restructure special COVID-19 units. The rapid access to paraclinical examinations could also explain the shorter length of stay of patients with MI in 2020. Acute care did not appear to change for patients hospitalized for MI, with percutaneous coronary intervention and coronary artery bypass graft sustained at a constant rate in 2020 compared with 2017—19.

Although we did not observe an increase in the proportion of patients with MI admitted to resuscitation units, the mean age and mean SAPSII score of patients in resuscitation units were significantly lower during the first lockdown. This may reflect the selection of patients admitted to resuscitation units during the first wave of the COVID-19 pandemic, which did not persist so significantly throughout the rest of 2020.

Study strengths and limitations

Key strengths of this study include its population-based nationwide approach and the exhaustiveness of the data on MI hospitalizations in 2020. This study provides an assessment of the impact of the COVID-19 pandemic on MI hospitalizations, along with in-hospital and 90-day mortality rates over the whole year. The large size of the study population allowed us to investigate rare complications of MI with high statistical power.

However, the study has several limitations inherent to medical administrative databases. Clinical information, such as MI severity, and time delays, such as the time interval between symptom onset and first medical contact, were not available. There may have been coding errors or miscodings for associated diagnoses (confusion between complications and history) or inaccuracies in the type of MI. These errors were non-differential by year of MI, and therefore probably had minimal impact on comparisons. Data on 90-day out-of-hospital mortality rates are only available for the 76% of the French population affiliated to the general health insurance scheme. However, the affiliation rate and the characteristics of the population affiliated to this scheme do not differ for the years under investigation, thus making comparisons reliable. Finally, this analysis did not include people who died as a result of an MI without hospitalization. This study will have to be completed by an analysis of the causes of death outside hospital and an analysis of hospitalizations for MI complications, in order to evaluate the global and long-term impact of the COVID-19 pandemic on ischaemic heart disease; however, it does provide an initial assessment of the impact on hospital care in the medium term.

Conclusions

In 2020, a significant decrease in MI admissions was observed in France. The overall effect over the year on MI admissions and on acute and 3-month outcomes of patients hospitalized for MI appears limited. The MI admission decrease was most significant at the beginning of the year, during the first lockdown (up to 40%), for women, for people aged > 85 years and for NSTEMI. For the latter, the decline extended beyond the first lockdown. These decreases in MI admissions did not lead to a massive increase in in-hospital mortality, acute cardiac complications or 3-month mortality for patients hospitalized for MI. Medical follow-up and estimation of the frequency of chronic complications of MI should be carried out in the coming years in these hospitalized patients. In addition, given the drop in MI admissions at the beginning of 2020, it is essential to continue monitoring the epidemiology of chronic complications of MI at a national level, and to complete these results with an analysis of coronary mortality, to estimate the impact of the potential non-hospitalization of some patients with MI, to assess the long-term impact on MI and to draw up an overall assessment of the 2020

health crisis in France. Finally, to avoid a further decline in the use of care, the dissemination of public information on the importance of maintaining care and regular medical follow-up, despite the pandemic, as well as the promotion of awareness campaigns on atypical MI symptoms, should all be sustained.

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The other authors declare that they have no competing interest.

Appendix A. Supplementary data

Supplementary data associated with this article can be found, in the online version, at https://doi.org/10.1016/j.acvd.2021.10.008.

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