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Implications of COVID-19 on Time-Sensitive STEMI Care: A Report From a North American Epicenter

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ABSTRACT

Background: Coronavirus disease 2019 (COVID-19) has forced dramatic changes to the healthcare systems throughout the world. Time-sensitive management of cardiovascular emergencies such as ST-elevation myocardial infarction (STEMI) has yet to be evaluated in the context of these new policies, particularly in so-called "hot spot" cities.

Methods: We evaluated the early impact of the pandemic on STEMI performance in the Greater Montreal Area. A total of 167 patients from 3 different study periods were included. Patients presenting in the lockdown period from mid-March to mid-May 2020 (Group C, 53 patients) were compared to those from mid-March to mid-May 2019 (Group A, 60 patients) and the 2020 pre-COVID-19 period (Group B, 54 patients).

Results: The number of STEMI admissions was unaffected during the lockdown. However, significantly longer delays between symptom onset and first medical contact (FMC) were noted (Group C 189.0 IQR [70.0, 840.0] min vs. Group A 103.0 IQR [42.5, 263.0] min vs. Group B 91.0 IQR [38.0, 235.5 min], $P = 0.007$). In contrast, additional safety protocols do not appear to have significantly affected delays between FMC and first intracoronary device activation (Group C 102 IQR [73.0, 133.0] min vs. Group A 104 IQR [87.0, 146.0] min vs. Group B 99.5 IQR [80.0, 150.0] min, $P = 0.37$). Patients that presented during the outbreak were more likely to be unstable with a higher incidence of Killip classes II-IV compared to groups A and B (28.3% vs. 18.3% vs. 5.6% respectively, $P = 0.008$). Worse in-hospital outcomes were also noted with a significantly higher rate of major adverse cardiac events (Group A 5.0% vs. Group B 11.1% vs. Group C 22.6%, $P = 0.007$).

Conclusion: During the lockdown period, many patients appear to have been reluctant to present to hospitals. This was associated with more unstable STEMI presentations and worse in-hospital course. Importantly, the health care system appears able to ensure timely acute cardiac care while ensuring that COVID-19 protocols are respected.

1. Introduction

Coronavirus disease 2019 (COVID-19), caused by severe acute respiratory syndrome coronavirus-2 (SARS-CoV-2), is the major global healthcare challenge of the 21st century and has exerted significant pressures on healthcare systems worldwide [1]. Geographic differences and temporal changes in rates and spread of infection have also been noted. In particular, there have been much-higher rates of diagnoses infection so-called "hot spot" regions, such as the Greater Montreal Area, Canada's COVID-19 epicenter. While the direct impacts of COVID-19 are increasingly understood typified by respiratory insufficiency, a pro-inflammatory and pro-thrombotic state leading to multi-organ dysfunction and an associated risk of mortality [2], data on the indirect costs of COVID-19 are still lacking.

In the context of a global lockdown, both new organizational barriers and patients' fear of acquiring COVID-19 have led to major concerns of undue delays in seeking appropriate emergent care, in particular for ST-elevation myocardial infarction (STEMI) patients. To our knowledge, no study has yet analyzed changes in the pattern of STEMI presentations or related complications in the Canadian epicenter of infection. The magnitude of the effect on STEMI system performance metrics is also not known. As such, we report herein early results demonstrating the impact of the COVID-19 outbreak on time-sensitive STEMI care delivery in the Greater Montreal Area; a hot-spot metropolitan region where the impact would be expected to be most pronounced.

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2. Methods

2.1. Study design

This is a retrospective observational study of patients presenting with a diagnosis of STEMI at either the *Centre Hospitalier de l'Université de Montréal* (CHUM) in Montreal or the *Cité-de-la-Santé* Hospital in Laval, Québec. Data were collected for the lockdown period between mid-March and mid-May 2020. Data comparison was made with (a) the same period in 2019 and (b) the pre-lockdown period from January to mid-March 2020. STEMI was defined according to the Fourth Universal Definition of Myocardial infarction [3]. The only exclusion criterion was the occurrence of in-hospital STEMI.

2.2. Data collection and endpoints

Pre-hospital data was collected using the emergency medical service records (when applicable) and in-hospital records. Time from symptom onset and FMC to first device activation were gathered for all patients. The Killip classification was used to quantify severity of associate heart failure for all patients, and left ventricular ejection fraction (LVEF) was available for most patients using a transthoracic ultrasound. Major adverse cardiac events (MACE) were defined as a composite of cardiac death, reinfarction, cardiogenic shock, target-vessel urgent revascularization, stroke, stent thrombosis, the occurrence of malignant arrhythmia, or mechanical complications of infarction (ventricular septal defect, papillary muscle rupture, or free wall rupture and pseudoaneurysm). Patients were followed for the duration of the index hospitalization.

2.3. Statistical analysis

Statistical analyses were performed using the Statistical Package for Social Sciences (SPSS, IBM, Version 25). Continuous variables were all tested for normality using the Shapiro-Wilk test. Data are presented as either means ± standard deviation (SD) or medians and interquartile ranges, when appropriate. Categorical data are presented as counts and percentages of the total, and were analyzed using a $\chi 2$ test across groups. Comparisons of continuous and normally-distributed variables were accomplished by a one-way ANOVA test. A Kruskal-Wallis test was used for non-normal continuous data. A two-tailed alpha of 0.05 was used for all analyses.

3. Results

3.1. Baseline patient characteristics

A total of 167 patients with STEMI were included in our analysis (72 from the *Cité-de-la-Santé* Hospital and 95 from CHUM). Patients were separated in 3 groups based on the reference period of the index event. Group A (first reference group) included 60 patients with a STEMI presentation between mid-March and mid-May 2019. Group B (second reference group) included 54 patients with an index event recorded in the pre COVID-19 period, between January and Mid-March 2020. Group C (53 patients) represents the COVID-19 lockdown from mid-March to mid-May 2020. Baseline clinical characteristics are presented in Table 1. The average age was 64.2 IQR [57.2, 72.7] and 76.6% of patients were males. Of note, patients in Group A were older than the 2 other groups (median age 69.5 years IQR [59.8, 78.7] vs. 61.1 IQR [55.7, 69.9] and. 60.6 IQR [56.8, 66.1], $P = 0.006$). Overall prevalence

Table 1
Baseline patient characteristics in total population and subgroup of patients in 3 different timeline periods.

	Mid-March to mid-May 2019 (Group A) (60 patients)	January to mid-March 2020 (Group B) (54 patients)	Lockdown period from mid-March to mid-May 2020 (Group C) (53 patients)	P-value
Demographic variables				
Age, median [IQR]	69.5 [59.8, 78.7]	61.1 [55.7, 69.9]	60.6 [56.8, 66.1]	0.006
Males, % (n)	70.0 (42)	77.8 (42)	83.0 (44)	0.23
Clinical variables				
HTN, % (n)	50.0 (30)	50.0 (27)	41.5 (22)	0.59
Dyslipidemia, % (n)	46.7 (28)	46.3 (25)	37.7 (20)	0.57
Diabetes, % (n)	21.7 (13)	18.5 (10)	11.3 (6)	0.34
Current smoking, %(n)	41.7 (25)	40.7 (22)	35.8 (19)	0.96
Known CAD, % (n)	26.7 (16)	13.0 (7)	13.2 (7)	0.09
Previous PCI, % (n)	18.3 (11)	11.1 (6)	5.7 (3)	0.11
Previous CABG, % (n)	1.7 (1)	0.0 (0)	1.9 (1)	0.61
CKD, % (n)	15.0 (9)	5.6 (3)	5.7 (3)	0.13
COPD, % (n)	10.0 (6)	7.4 (4)	5.7 (3)	0.69
Stroke, % (n)	10.0 (6)	3.7 (2)	3.8 (2)	0.26
Killip class >1 at presentation, % (n)	18.3 (11)	5.6 (3)	28.3 (15)	0.008
LVEF at presentation, median [IQR]	50.5 [40.8, 60.0]	53.0 [45.0, 60.0]	45.0 [40.0, 55.0]	0.09

Values are given as % (n), mean ± standard deviation or median [IQR] when appropriate.
CABG, coronary artery bypass surgery; CAD, coronary artery disease; CKD, chronic kidney disease; COPD, chronic obstructive pulmonary disease; HTN, hypertension; LVEF, left ventricular ejection fraction; PCI, percutaneous coronary intervention.

of hypertension, dyslipidemia and diabetes in the study population were 47.3%, 43.7% and 17.4% respectively. Nearly 39.5% of patients were current smokers.

3.2. Pre-hospital evaluation and initial presentation

The overall study population showed a median time from symptom onset to first medical contact of 126.0 min IQR [50.0, 358.0]. However, STEMI patients during the COVID-19 lockdown period showed significantly longer durations before FMC (189.0 IQR [70.0, 840.0] min) compared to Group A (103.0 IQR [42.5, 263.0] min) and Group B (91.0 IQR [38.0, 235.5 min]), $P = 0.007$. See Table 2 and Fig. 1.1. In contrast, durations between FMC to first device activation and arrival to hospital to first device activation were each comparable among the groups. See Supplemental Tables S1 and S2.

Killip class at time of hospital presentation was more advanced for patients with a STEMI during the lockdown period compared to the pre-COVID era, with significantly more cases categorized as a Killip class >1 (Group A 18.3% vs. Group B 5.6% vs. Group C 28.3%, $P = 0.008$).

3.3. In-hospital evolution

The rate of anterior STEMI was 46.7% from mid-March to mid-May 2019 and 50.9% during the same period in 2020 ($P = 0.71$). No differences were recorded between groups regarding the number of diseased vessels, TIMI score post revascularization and the number of devices used during the index procedure. The LVEF of the overall population was 50.0% IQR [43.0, 60.0]. Patients with a STEMI presentation during the COVID-19 lockdown period showed a trend towards a lower LVEF (45.0% IQR [40.0, 55.0]) as compared to patients in groups A (50.5% IQR [40.8, 60.0]) and B (53.0% IQR [45.0, 60.0]). However, the difference across groups was not statistically significant ($P = 0.09$).

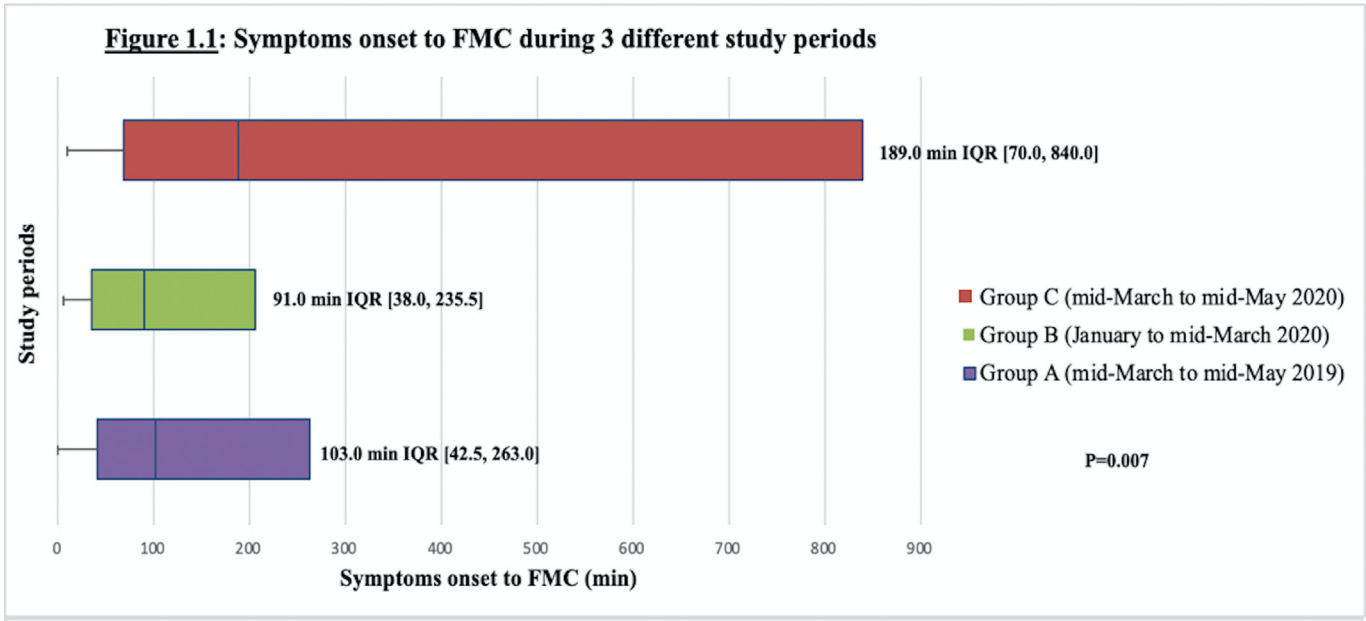
MACE rates after the index procedure for patients admitted during the lockdown period were significantly higher than those observed in 2019 during the same period or the one recorded between January and mid-March 2020 (22.6% vs. 5.0% vs. 11.1%, respectively, $P = 0.007$). In a post-hoc analysis, a composite endpoint of mechanical complications, shock, or death was significantly higher during the COVID-19 lockdown period (Group A 1.7% vs. Group B 3.7% vs. Group C 13.2%, $P = 0.03$).

Rates of other cardiovascular events were also significantly higher from mid-March to mid-May 2020 compared to those observed in 2019 during the same period or those recorded in early 2020: mechanical complications (9.4% vs. 0.0% vs. 1.9%, respectively, $P = 0.02$), malignant arrhythmias (11.3% vs. 0.0% vs. 5.6%, respectively, $P = 0.03$), target-vessel urgent revascularization (11.3% vs. 1.7% vs. 1.9%, respectively, P = 0.03) and death (9.4% vs. 1.7% vs. 0.0%, respectively, P = 0.02). See Table 2 and Fig. 1.2.

Table 2
Clinical presentation, pre-hospital and in-hospital variables in total population and subgroup of patients in 3 different timeline periods.

	Mid-March to mid-May 2019 (Group A) (60 patients)	January to mid-March 2020 (Group B) (54 patients)	Lockdown period from mid-March to mid-May 2020 (Group C) (53 patients)	P-value
Angiographic variables				
Anterior STEMI, %(n)	46.7 (28)	31.5 (17)	50.9 (27)	0.10
2 or 3 vessels disease, %(n)	55.0 (33)	50.0 (27)	39.6 (21)	0.27
Final TIMI 3	93.3 (56)	96.3 (52)	86.8 (46)	0.17
Number of stents used >1	46.7 (28)	47.8 (22)	39.6 (21)	0.71
Reperfusion treatment time delays				
Beginning of symptoms to FMC, median [IQR] min	103.0 [42.5, 263.0]	91.0 [38.0, 235.5]	189.0 [70.0, 840.0]	0.007
FMC to first device activation, median [IQR] min	104 [87.0, 146.0]	99.5 [80.0, 150.0]	102 [73.0, 133.0]	0.37
Arrival to hospital to first device activation, median [IQR] min	71.0 [42.5, 108.5]	59 [40.0, 101.0]	63 [35.0, 104.0]	0.66
Clinical endpoints				
MACE, % (n)	5.0 (3)	11.1 (6)	22.6 (12)	0.02
Mechanical complications, death and shock, % (n)	1.7 (7)	3.7 (2)	13.2 (1)	0.03
Mechanical complications, % (n)	0.0 0	1.9 1	9.4 5	0.02
Death, % (n)	1.7 (1)	0.0 (0)	9.4 (5)	0.02
Stent thrombosis, % (n)	0.0 (0)	1.9 (1)	0.0 (0)	0.35
Reinfarction, %(n)	0.0 (0)	0.0 (0)	0.0 (0)	–
Malignant arrhythmia, % (n)	0.0 (0)	5.6 (3)	11.3 (6)	0.03
Cardiogenic shock, % (n)	3.3 (2)	0.0 (0)	3.8 (2)	0.37
Target-vessel urgent revascularization, % (n)	1.7 (1)	1.9 (1)	11.3 (6)	0.03
Stroke, % (n)	0.0 (0)	0.0 (0)	0.0 (0)	–

Values are given as % (n), mean ± standard deviation or median [IQR] when appropriate.
FMC, first medical contact; MACE, major adverse cardiac events; STEMI, ST-elevation myocardial infarction.



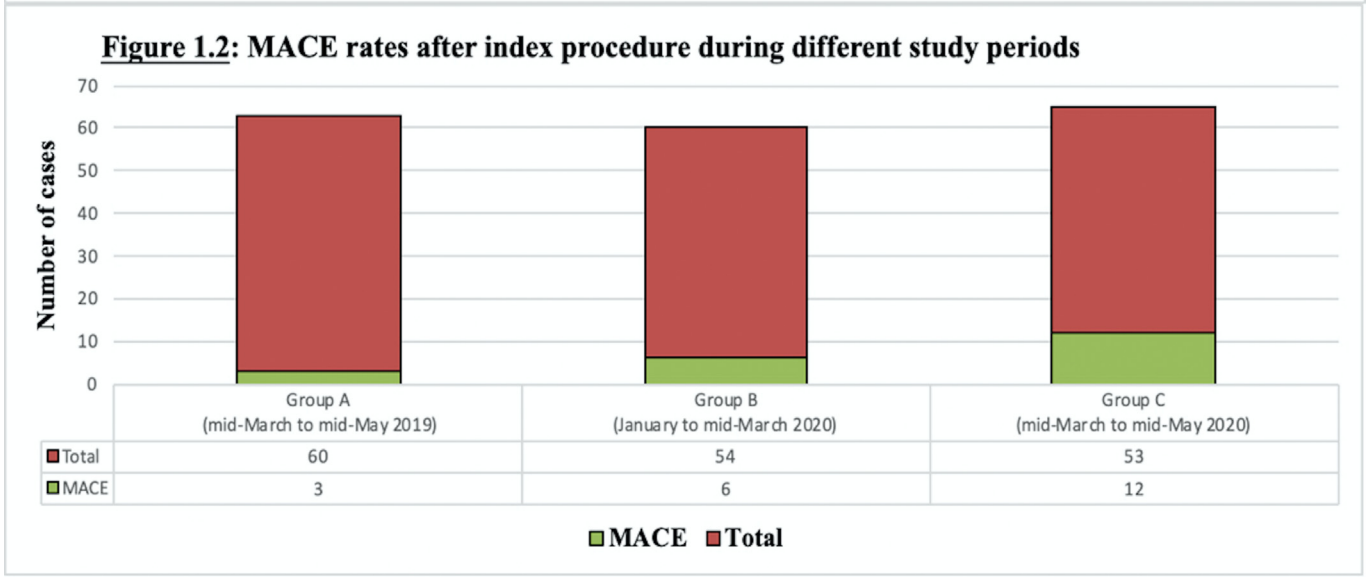


Fig. 1. Time delays before FMC and MACE rates after index procedure based on different study periods. FMC, First medical contact; MACE, Major adverse cardiac events. In panel 1.1, maximum whiskers were intentionally omitted to allow for better visualization of the boxes.

4. Discussion

Both systemic barriers to accessing emergent healthcare resources and likely also patients' perception of the risk of contracting COVD-19 in the healthcare system have changed in recent months due to the global pandemic. Our data show for the first time that, in a metropolitan area with a significant burden of COVID-19 cases, there was no decrease in the number of ST-elevation myocardial infarctions, but the pandemic is associated with a significant increase in the delay prior seeking medical attention with serious negative consequences for patients. System performance after first medical contact, on the other hand, appears to have been unhampered by addition safety protocols related COVID-19. There were no known instances of patients contracting COVID-19 during acute STEMI care and the public should be made aware that emergency health services for serious conditions should not be avoided.

This study represents the first Canadian report of changes in the pattern and consequences of STEMI presentation to specifically asses both ischemic time prior to and following contact with the medical system. Our first important finding is that the rate of STEMI did not decline during the pandemic. While it had been hypothesized that factors related to STEMI onset might be reduced during a lockdown, this was either simply not the case or was otherwise offset by other aggravating factors, such as increased psychological stress. It, however, cannot be excluded that there was in fact an increased number of STEMIs during the period. Although we appear to have captured all severe STEMI patients, it is possible that patients with uncomplicated STEMI may not have presented at all and therefore have yet to come to the attention of the medical system. Also, we cannot exclude coagulation abnormalities in patients with a STEMI and a concurrent COVID-19 infection, as systematic screening for COVID-19 infection was not done for all patients who presented to our hospitals. (The majority of patients were considered low risk based on absence of signs or symptoms of infection or a history of possible exposure or travel). Some recent data suggest that STEMI patients with COVID-19 may present with a higher thrombus burden [4]. Whether this contributed to either the number or clinical severity of STEMI admissions in our area remains a hypothesis in need of exploration.

Secondly, significantly longer delays between symptoms onset and FMC were recorded during the lockdown period, which is in line with recent reports from abroad [5]. Our data makes plain that public health and political leaders must actively communicate the message that patients with symptoms of a heart attack should not delay seeking medical help for fear of COVID-19. Of note, there is no evidence in our cohort of patients contracting COVID-19 by accessing emergency healthcare services.

Indeed, our study highlights that, during the lockdown period, delays in seeking care were associated with more advanced heart failure on presentation and significantly higher rates of in-hospital MACE. Moreover, the increase in MACE was primarily driven by the most serious complications, including a marked surge in mechanical complications, cardiogenic shock, and death. Nearly 1 in every 5 patients during the lockdown period had a complicated STEMI that included higher than historic rates of ventricular septal, free wall and papillary muscle rupture.

Importantly, the use of protective equipment during the pandemic and reorganization of pre-hospital and in-hospital care had no appreciable impact on FMC to device times. Therefore, maintaining a safe working environment for both essential workers and patients in the context of COVID-19 without sacrificing the expediency of quality of cardiac care is clearly feasible. This aligns with recent data from London showing that, despite the COVID-19 outbreak, primary percutaneous coronary intervention (PCI) could be delivered in a timely fashion with a short door-to-balloon time according to existing guidelines [4,6].

It is important to note that this report may not be generalizable to non-urban settings or cities with a lower burden of COVID-19. Moreover, as the organization of STEMI services may well vary from a metropolitan area to metropolitan area, caution must be exercised in interpreting the results. However, as future public health and healthcare system policy decisions will need to be tailored to each regional setting, taking into account population density, the baseline organization structure of local emergent healthcare delivery, and the local burden of COVID-19, providing granular data on a regional level of the impact of recent policy decisions on the provision and quality of care is essential. Moreover, it appears likely that the local burden of disease would be an important predictor of patients' attitudes regarding whether to delay seeking medical attention for an acute coronary syndrome.

In conclusion, the rate of STEMI in the Greater Montreal Area appears unaffected so far by the COVID-19 pandemic. However, patients have delayed, to their detriment, seeking emergent medical treatment. At the very least, clinical suspicion of STEMI should remain high even in the context of the COVID-19 pandemic or any future large-scale sanitary crisis. Public health, political, and physician leaders must conduct awareness campaigns to ensure that patients with symptoms of a heart attack do not delay seeking care. Moreover, such campaigns should stress that the system is able to provide prompt and effective care in a manner that is safe for both patients and healthcare workers. Finally, front-line healthcare workers should remain vigilant for potential mechanical complications of STEMI in patients with delayed presentation.

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CRediT authorship contribution statement

Kevin Haddad: Investigation, Formal analysis, Data curation, Writing - original draft, Writing - review & editing. **Brian J. Potter:** Formal analysis, Writing - review & editing. **Alexis Matteau:** Writing - review & editing. **François Gobeil:** Resources. **Samer Mansour:** Conceptualization, Methodology, Validation, Investigation, Resources, Data curation, Writing - review & editing, Supervision, Project administration, Funding acquisition.

Declaration of competing interest

There are no conflicts of interest to disclose.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.carrev.2020.09.024.

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