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Original Article

Cardiovascular Outcomes in Nova Scotia During the Early Phase of the COVID-19 Pandemic

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ABSTRACT

Background: This study sought to determine the impact of the COVID-19 pandemic response to healthcare delivery on outcomes in patients with cardiovascular disease.

Methods: This is a population-based cohort study performed in the province of Nova Scotia, Canada (population 979,499), between the pre-COVID (March 1, 2017-March 16, 2020) and in-COVID (March 17, 2020-December 31, 2020) periods. Adult patients (age $\geq$ 18 years) with new-onset or existing cardiovascular disease were included for comparison between periods. The main outcome measures included the following: cardiovascular emergency department visits or hospitalizations, mortality, and out-of-hospital cardiac arrest.

RÉSUMÉ

Contexte : Cette étude visait à déterminer les répercussions de la réponse à la pandémie de COVID-19 sur la prestation des soins de santé et son incidence sur les résultats obtenus par les patients atteints d'une maladie cardiovasculaire.

Méthodologie : Il s'agit d'une étude de cohorte représentative de la population réalisée dans la province de la Nouvelle-Écosse, au Canada (population de 979 499 habitants), entre la période précédant le début de la pandémie de COVID-19 (du 1er mars 2017 au 16 mars 2020) et la période de pandémie (du 17 mars 2020 au 31 décembre 2020). Des patients adultes (âge $\geq$ 18 ans) atteints d'une maladie cardiovasculaire préexistante ou d'apparition récente ont été inclus pour

In March 2020, the novel coronavirus (severe acute respiratory syndrome coronavirus-2 [SARS CoV-2]) and the ensuing COVID-19 pandemic changed the delivery of healthcare services around the world. Large numbers of critically ill patients pushed multiple healthcare systems to the brink of collapse.[1] In preparation for surges of COVID-19 cases, with their attendant need for acute and critical care resources, hospitals markedly reduced the delivery of non-COVID services in anticipation of the need to liberate resources and curtail spread of disease among patients and healthcare workers.[2] A lack of accurate predictive models resulted in a cautious approach, with severe reduction in non−COVID-19 care, particularly of scheduled procedures that could result in patient admission.[1] Heart disease remains a leading cause of death globally[3] and requires time-sensitive therapy to prevent significant morbidity and mortality.[4] Due to the COVID-19 pandemic, severe restrictions on some cardiovascular procedures were implemented, limiting care.[5] In jurisdictions with high early burdens of COVID-19 in the community,

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Ethics Statement: The study was approved by the Nova Scotia Health Authority Ethics Board on May 6, 2020 (file #1025720).

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Results: In the first month of the in-COVID period, emergency department visits (n = 51,750) for cardiac symptoms decreased by 20.8% (95% confidence interval [CI] 14.0%-27.0%, $P < 0.001$). Cardiovascular hospitalizations (n = 20,609) declined by 48.1% (95% CI 40.4% to 54.9%, $P < 0.001$). The in-hospital mortality rate increased in patients with cardiovascular admissions in secondary care institutions by 55.1% (95% CI 10.1%-118%, $P = 0.013$). A decline of 20.4%-44.0% occurred in cardiovascular surgical/interventional procedures. The number of out-of-hospital cardiac arrests (n = 5528) increased from a monthly mean of 115 ± 15 to 136 ± 14, beginning in May 2020. Mortality for ambulatory patients awaiting cardiac intervention (n = 14,083) increased from 0.16% (n = 12,501) to 2.49% (n = 361) in the in-COVID period ($P < 0.0001$).

Conclusions: This study demonstrates increased cardiovascular morbidity and mortality during restrictions maintained during the COVID-19 period, in an area with a low burden of COVID-19. As the healthcare system recovers or enters subsequent waves of COVID-19, these findings should inform communication to the public regarding cardiovascular symptoms, and policy for delivery of cardiovascular care.

la comparaison entre les périodes. Les principaux paramètres d'évaluation comprenaient les visites ou hospitalisations dans un service d'urgences cardiovasculaires, la mortalité et l'arrêt cardiaque en milieu extrahospitalier.

Résultats : Au cours du premier mois de la période de pandémie, les visites aux services des urgences (n = 51 750) pour des symptômes cardiaques ont diminué de 20,8 % (intervalle de confiance [IC] à 95 % : 14,0 % − 27,0 %, $p < 0,001$). Les hospitalisations en raison d'un événement cardiovasculaire (n = 20 609) ont décliné de 48,1 % (IC à 95 % : 40,4 % − 54,9 %, $p < 0,001$). Le taux de mortalité hospitalière parmi les patients admis dans des établissements de soins secondaires a augmenté de 55,1 % (IC à 95 % : 10,1 % − 118 %, $p = 0,013$). Une baisse de 20,4 à 44,0 % du nombre d'interventions chirurgicales ou interventionnelles visant à prendre en charge un événement cardiovasculaire a également été enregistrée. Le nombre d'arrêts cardiaques survenus en milieu extrahospitalier (n = 5 528) est passé d'une moyenne mensuelle de 115 ± 15 à 136 ± 14, à compter de mai 2020. La mortalité des patients ambulatoires en attente d'une intervention cardiaque (n = 14 083) a augmenté, passant de 0,16 % (n = 12 501) à 2,49 % (n = 361) pendant la période de pandémie ($p < 0,0001$).

Conclusions : Cette étude révèle une augmentation de la morbidité et de la mortalité cardiovasculaires durant le maintien des restrictions liées à la COVID-19 dans une région où le fardeau associé à cette maladie est faible. À mesure que le système de santé se rétablit ou affronte les vagues subséquentes de COVID-19, ces résultats devraient éclairer les communications au public concernant les symptômes cardiovasculaires et orienter la politique de prestation de soins cardiovasculaires.

dramatically increased rates of out-of-hospital cardiac arrest were observed.[6,7] Whether this increase was due to unexpected deaths at home from COVID-19, or the combined effects of public avoidance of healthcare institutions and restricted access to care, is unclear.[8,9]

On March 16, 2020, a series of public health−mandated measures to reduce the spread of COVID-19 were implemented in the province of Nova Scotia, Canada. This implementation resulted in restricted access to ambulatory, elective, and nonurgent medical and surgical procedures, including valvular and revascularization procedures.[10] Restrictions included no inpatient transfers for cardiac catheterization for patients that were not emergent, and no elective ambulatory procedures, including catheter ablation, device implantation, cardiac catheterization, and cardiovascular surgery. These measures remained in effect for the first month of the "in-COVID" period, and they were gradually loosened based on COVID-19 infection rates in the province. We performed this study to determine the effect of healthcare restrictions and the public response on outcomes in cardiovascular disease.

Methods

Study design

A quasi-experimental design using an interrupted time series was used, comparing outcomes in patients with existing or new-onset cardiovascular disease in the pre-COVID (March 1, 2017—March 16, 2020) vs the in-COVID (March 17, 2020 to December 31, 2020) time periods. March 17, 2020 was the day emergency measures were enacted in the province of Nova Scotia in response to the pandemic.

Setting

Healthcare in the province of Nova Scotia, Canada (population of 979,449)[11] is delivered via a single emergency/ambulance system, and a single-payer system across a network of 36 hospitals in a regionalized system of secondary care and a single tertiary/quaternary referral centre. The province has 4 health authority zones, based on region—Western, Eastern, Northern, and Central. The Central zone encompasses the capital city of Halifax, Halifax County, and West Hants. The Queen Elizabeth II Health Sciences Centre (QEII HSC) in Halifax, Nova Scotia, is the only institution in the province that provides tertiary and quaternary cardiovascular care and serves the network of 36 peripheral hospitals. The healthcare system is public and universal, with no parallel private system, which makes complete data capture possible.

During the time period of this study, early aggressive public health measures resulted in minimal community spread of COVID-19 and no major surge in hospitalizations for COVID-19. The COVID-19 hospitalization rate in the province ranged from 0 to 8 patients per day during the study period.[12]

Table 1. Cardiovascular (CV) diagnosis, procedural outcomes, and data source

Diagnosis	Data source	Description/ICD-10 codes
Out-of-hospital cardiac arrest	Emergency health services	Provides first response and ambulance services to the province of Nova Scotia
CV-related ED visits (acute coronary syndrome, chest pain not yet diagnosed, atrial fibrillation, heart failure, syncope/presyncope)	NACRS (via ED information system)	All patients admitted to the ED in the Central zone of Nova Scotia with a CV-related diagnosis
CV hospitalizations	Cardiovascular Health Nova Scotia HDNS Data[25]	Provincially mandated data capture of all patients admitted in Nova Scotia with a diagnosis of heart failure (ICD-10 codes: I42, I43, I50), unstable angina (I20, I25), NSTEMI or STEMI (I21,I22,I23,I24) Arrhythmia-related: ICD-10 codes: I46, I47, I48, I49 Conductive heart disease: ICD-10 codes: I44, I45 Valvular-related: ICD-10 codes: I34, I35, I37, I39
STEMI presenting for primary PCI	STEMI database	Clinical database including all patients presenting for primary or rescue PCI
Procedural outcomes	**Data source**	
PCI and cardiac catheterization	APPROACH, January 1, 2017—Mar 16, 2020[26] Pathway Healthcare Scheduling (Mar 17, 2020—December 31, 2020) Electronic medical record	Hospital administrative data systems
TAVI	TAVI database Electronic medical record for follow-up	Clinical database for all patients assessed or waitlisted for TAVI
Catheter ablation	Electrophysiology lab database (January 1, 2017—March 16, 2020) Pathway Healthcare Scheduling (March 17,2020—December 31, 2020) Electronic medical records	Clinical database for all electrophysiological procedures at the Queen Elizabeth II Health Sciences Centre
Prophylactic implantable cardioverter defibrillator	Pathway Healthcare Scheduling Electronic medical records	Hospital administrative data systems
CABG and/or surgical mitral or aortic valve replacement or repair)	Retrospective chart review	Manual data collection
Mortality	HDNS data	Vital statistics

APPROACH, Alberta Provincial Project for Coronary Heart Disease Database; CABG, coronary artery bypass grafting; ED, emergency department; HDNS, Health Data Nova Scotia; ICD-10, International Classification of Diseases, 10th edition; NACRS, National Ambulatory Care Reporting System; NSTEMI, non-STEMI; PCI, percutaneous coronary intervention; STEMI, ST-elevation myocardial infarction; TAVI, transcatheter aortic valve intervention.

Participants

Adult patients (age $\geq$18 years) with a cardiovascular diagnosis as listed in Table 1were included in the study.

Data sources

The data sources for each of the cardiovascular diagnoses are listed in Table 1. Comprehensive emergency department (ED) visit data were available within the Central zone of the province, which utilizes a shared electronic medical record and provides data directly to the National Ambulatory Care Reporting System (NACRS). Hospitalized patients who were not transferred for acute cardiovascular care (ie, were admitted to secondary care institutions) were identified and analyzed separately. Demographic data on ambulatory patients awaiting cardiac interventional procedures were collected through the electronic medical record, all of which is created at the tertiary care centre, resulting in complete data capture for the province. These data were collected by trained research personnel and were held in a Redcap database, for procedural outcomes, and in an Excel spreadsheet, for surgical outcomes.

Outcomes

The outcomes included rates of ED visits and hospitalization for acute cardiovascular disease, rates of out-of-hospital cardiac arrest (OHCA), rates of ST-elevation myocardial infarction (STEMI), in-hospital and 30-day mortality, and mortality while awaiting a procedure. For patients admitted to the ED, the Canadian Triage Acuity Score was assessed.[13] For patients with STEMI, other outcomes measured included time to balloon procedure, ejection fraction, and end-diastolic pressure at the time of cardiac catheterization.

Statistical methods

Baseline characteristics were summarized as means (standard deviation) or counts (frequency percentages), as appropriate. Means for the pre-COVID vs the in-COVID groups were compared using the independent-samples *t*-test for continuous variables; proportions were compared using the χ^2 or Fisher's exact test (when expected cell counts were < 5) for categorical variables.

Interrupted time series analysis using segmented Poisson regression models was performed to compare trends in

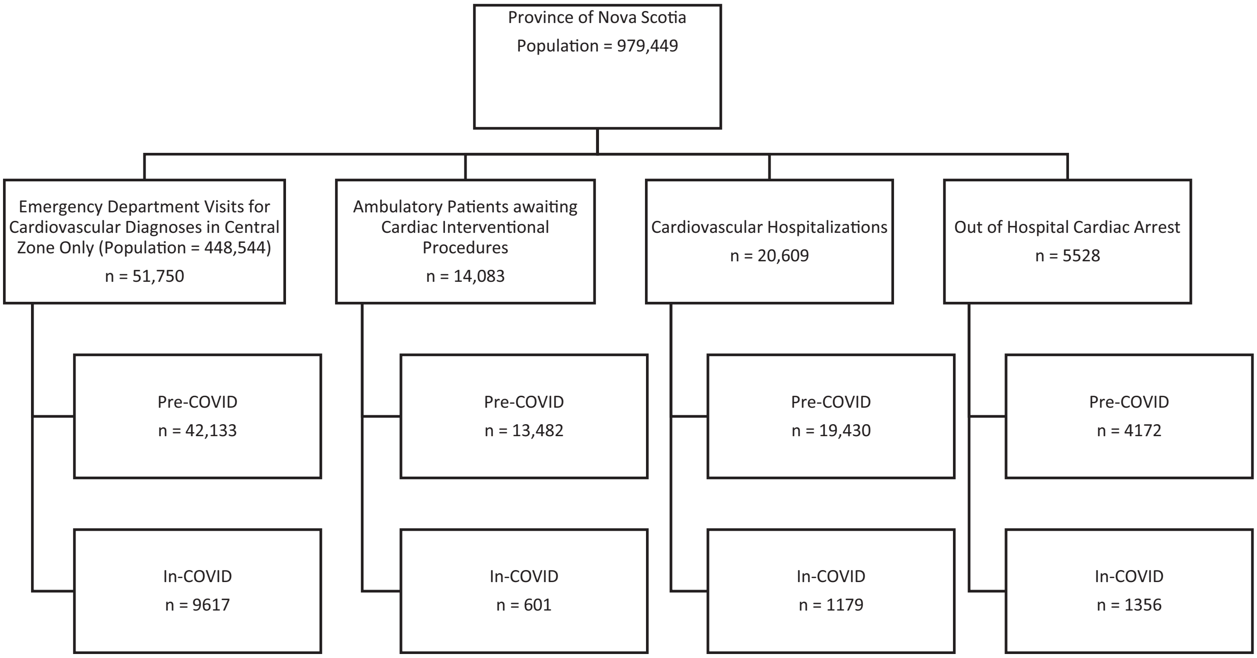

Figure 1. Patient population.

pre-COVID vs in-COVID cardiovascular event rates, including hospitalizations, for all cardiovascular diagnoses, and in-hospital and 30-day mortality. Segmented Poisson models were used to assess the immediate (defined as first month of the in-COVID period, level change) and over-time (trend change) effect of the reductions and restrictions implemented on March 17, 2020. Models were assessed for overdispersion using a regression-based test for overdispersion and seasonality using plots of residuals, autocorrelation functions, and partial autocorrelation functions. They were adjusted using a quasi-Poisson model and Fourier terms, respectively, as needed. Results from the interrupted time series analysis are presented in the form of level and trend differences.[14] Change point analysis was performed for primary percutaneous coronary intervention (PPCI) and cardiac arrest admissions using 4 approaches—Bayesian,[15] the segmented method (changes in regression),[16] regression tree,[17] and the segmented method of trend partition in data. The impact of in-COVID on PPCI and cardiac arrest admissions could take several forms. One possibility is an abrupt drop in the number of PPCI procedures and the number of cardiac arrest admissions that remains at the lower level over a time interval. Another possible form of change is a linear trend over time, which would indicate a structural change in the trend—that is, the parameter coefficient that determines the trend changes during the in-COVID period. Another possibility is that the outcomes series have a broken line pattern over time—that is, during the in-COVID period, the trend might change direction from positive to negative. Various statistical procedures were performed to determine whether, during the in-COVID period, an impact of PPCI and cardiac arrest admissions occurred; these procedures were Bayesian, the segmented method (changes in regression), regression tree, and the segmented method of trend partition of the series.

A 2-sided P value of < 0.05 was used as the threshold for statistical significance. Statistical analysis was carried out using SAS version 9.4 (SAS Institute, Cary, NC).

Research ethics

The study was approved by the Nova Scotia Health Authority Ethics Board on May 6, 2020 (file #1025720).

Results

The numbers of patients included in the study are outlined in Figure 1, with a total of 91,970 patients with cardiovascular disease represented in the study. During the study period, 51,750 visits to the ED occurred for acute cardiac symptoms, with 14,083 patients awaiting ambulatory cardiac interventional procedures. A total of 20,609 cardiovascular hospitalizations occurred, with 5528 OHCAs from March 1, 2017, to December 31, 2020. Baseline demographic data for the study population are presented in Table 2.

ED visits

In March 2020, the number of ED visits for cardiac diagnoses declined by 20.8% (95% confidence interval [CI] 14.0%-27.0%, $P < 0.001$) in the immediate COVID period. Thereafter, ED visits increased by 2.6% every month, returning to pre-pandemic levels 8 months after the onset of restrictions. No difference in either rate of admission to the hospital or mortality rate in the ED was found between the 2 periods. Changes in number of ED visits for specific diagnoses are shown in Table 3 and Figure 2. The Canadian Triage

Table 2. Baseline demographics

Population	Pre-COVID	In-COVID
ED visits for CV diagnoses	n = 42,133	n = 9617
Age, y	58.0 ± 19	58.1 ± 19
Women	50.8	48.9
CTAS*		
1	2.7	3.0
2	56.2	50.4
3	38.0	43.8
4−5	3.0	2.8
Acute coronary syndrome	6.7	6.1
Atrial fibrillation	7.3	7.5
Syncope/presyncope	12.6	13.7
HF	13.3	14.5
Chest pain NYD	53.3	52.3
Admitted	12.9	12.9
Died in ED	0.1	0.1
Ambulatory patients awaiting cardiac interventional procedures	n = 13,482	n = 601
Cardiac catheterization PCI	n = 11,863	n = 266
Age, y	66.9 ± 11	65.5 ± 14
Women	32.9	34.9
ICD implantation	n = 48	n = 21
Age, y	64.0 ± 10	44.9 ± 44
Women	20.8	14.3
CV surgery	n = 1051	n = 234
Age, y	67.5 ± 9	67.3 ± 9
Women	25.2	25.9
TAVI	n = 180	n = 37
Age, y	80.8 ± 9	82.2 ± 6
Women	39.7	37.8
Catheter ablation for atrial fibrillation	n = 409	n = 87
Age, y	62.2 ± 11	61.3 ± 11
Women	29.3	32.2
CV hospitalizations	n = 19,430	n = 1179
STEMI	995 (7.8)	67 (8.8)
NSTEMI	3147 (24.5)	191 (25.0)
HF	9209 (71.8)	551 (72.0)
Out-of-hospital cardiac arrest	n = 4172	n = 1356
Age, y	68.6 ± 15.2	69.6 ± 15.1
Women	34.9	34.3

Values are %; n (%); or mean ± standard deviation, unless otherwise indicated.

CTAS, Canadian Triage Acuity Score; CV, cardiovascular; ED, emergency department; HF, heart failure; ICD, implantable cardioverter defibrillator; NSTEMI, non-STEMI; NYD, not yet diagnosed; PCI, percutaneous coronary intervention; STEMI, ST-elevation myocardial infarction; TAVI, transcatheter aortic valve implantation.

* Score of 1 = resuscitation (conditions that affect life or limb); 2 = emergent (conditions that are a potential threat to life, limb, or function); 3 = urgent (serious conditions that require emergency intervention); 4 = less urgent (conditions that relate to patient distress or potential complications that would benefit from intervention); 5 = non-urgent.

Acuity Score demonstrated no change between the pre-COVID and in-COVID periods.

OHCA data

No change in number of OHCAs was observed immediately in the in-COVID period; however, OHCAs (n = 5528) increased from a mean of 116 ± 14 to 136 ± 14 beginning in May 2020 (Fig. 3). The monthly number of OHCAs displayed seasonal variation from 2017 to 2019, falling from a mean of 126.9 arrests during winter months to 106.8 arrests during summer months. In 2020, the number of OHCAs did not diminish during summer months, but rather increased, with a mean of 137.7 events from June to August. Using the regression tree method for identification of a change point, May 2020 was identified as a point at which the number of OHCAs increased, above the 95% CI. Other change points that were identified were in keeping with the seasonal variation described above—that is, a decrease each summer and an increase in the winter. In May 2020, the number of OHCAs increased, unlike the preceding pattern. (Fig. 3). The proportional increase in OHCAs did not differ between men and women.

Reduction in services

A total of 20,609 cardiovascular hospitalizations occurred during the study period. In the first month of the in-COVID period, the number of acute cardiovascular hospitalizations decreased by 48.1% (95% CI 40.4%-54.9%, $P < 0.001$). The weekly mortality rate for those that were admitted increased by 55.1% (95% CI 10.1%-118%, $P = 0.013$) in the in-COVID group, with a reduction in mortality by 6.1% per week (95% CI 1.3%-10.6%, $P = 0.012$) thereafter. The rate returned to pre-COVID levels within 9 weeks. Admissions for most cardiovascular reasons declined significantly, except for STEMI (Fig. 4). In-hospital mortality rates were associated with an increase for patients presenting with non-STEMI (10.6% per week (95% CI 0.9%-19.3%, $P = 0.03$), and heart failure (HF; 7.5% per week (95% CI 2.2%-12.4%, $P = 0.006$; Fig. 5).

Transfers from secondary to tertiary care for acute cardiovascular care

A total of 13,603 patients were transferred from the regional care centres to the tertiary/quaternary care institution. Reductions in patient transfer, as dictated by COVID-19 restrictions, to the tertiary care centre occurred in the

Table 3. Emergency department (ED) visits, hospitalization rates, and in-hospital mortality by diagnosis, in the immediate in-COVID period, controlling for trends pre-COVID and trend change during in-COVID

Diagnosis	Change in ED visits	Daily change in hospitalization	In-hospital mortality change
STEMI	−30.8 (−44.5, −13.6)*	−29.1 (−49.9,0.005)	−47.0% (−83.6,70.9)
NSTEMI	—	−45.3 (−30.3, −57.1)	84 (−5.7,259)
Unstable angina	—	−63.2 (−35.4, −79.1)	0
Heart failure	−14.2 (−26.8, 0.06)	−47.0 (−35.7, −56.3)	84 (27.2, 166)
Arrhythmia†	−54.8‡ (−64.0, −43.2)	−18.9 (−6.7, −29.5)	19.3 (6.8, 52.7)§
Chest pain	−16.5 (−25.2, −6.7)	—	—
Valvular	—	−18.7 (−36.3, 3.7)	2.0 (−0.06, 1.8)§

Values are % (95% confidence interval).

NSTEMI, non-STEMI; STEMI, ST-elevation myocardial infarction.

* Includes STEMI, NSTEMI, unstable angina.

† Arrhythmia includes supraventricular tachycardia, ventricular tachycardia, cardiac arrest, atrial fibrillation.

‡ Atrial fibrillation only.

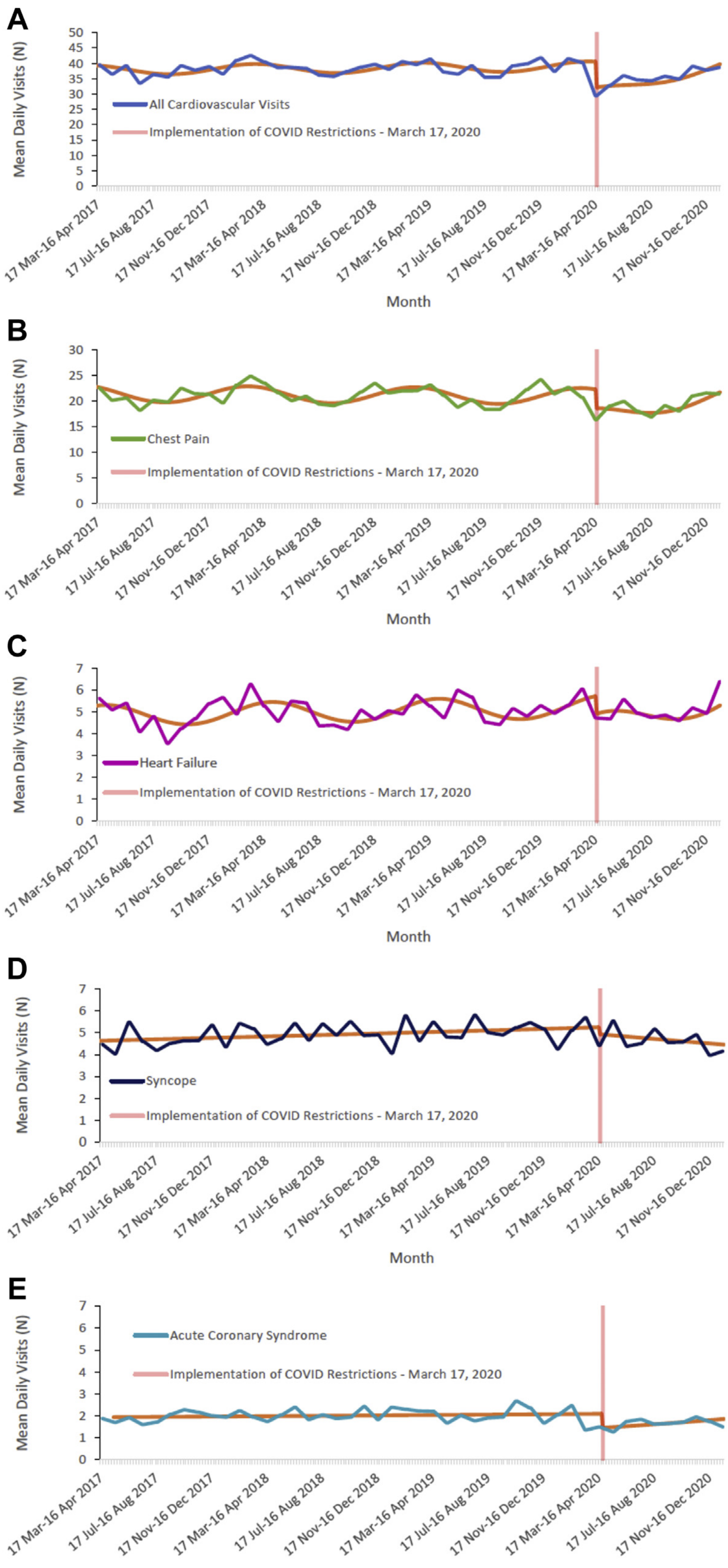

Figure 2. Monthly emergency department visits for cardiovascular causes. The **orange line** represents the fitted regression lines for the interrupted time series. A decline of 20.8% (95% confidence interval 14.0% to 27.0%, $P < 0.001$) was seen immediately after the onset of COVID-19. A gradual increase was seen of 2.6% per month, returning to pre-COVID levels at 8 months. (**A**) All cardiovascular emergency department visits; (**B-E**) mean daily visits by diagnosis. Apr, April; Aug, August; Dec, December; Jul, July; Mar, March; Nov, November.

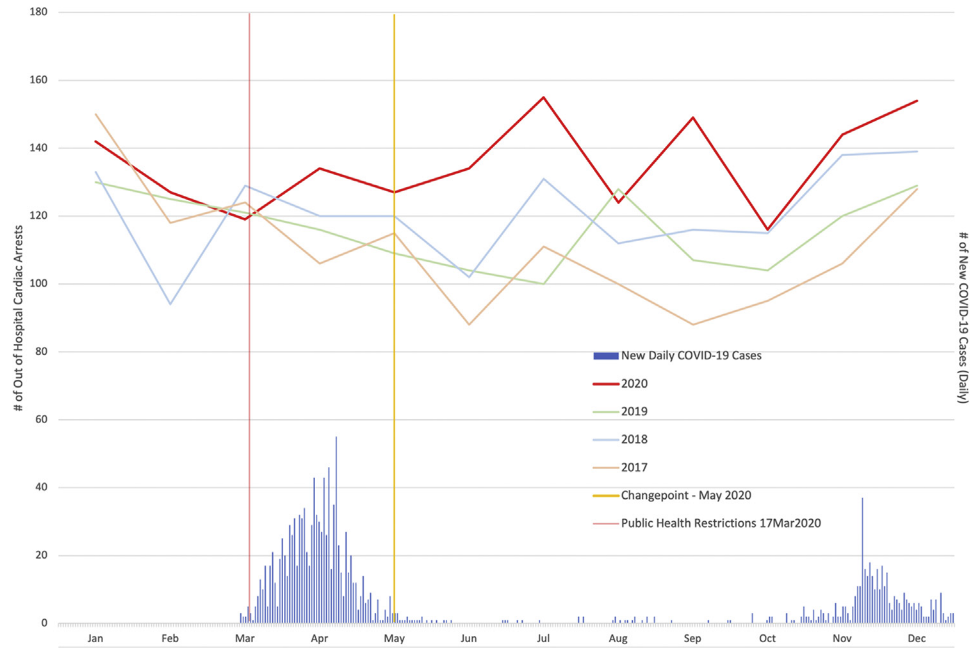

Figure 3. Out-of-hospital cardiac arrests (OHCAs) by year. The number of daily COVID-19 cases is shown in **blue** as a bar graph. The **vertical red line** represents the time that public health restrictions came into effect, and the **vertical yellow line** indicates the significant change point in May 2020, at which a significant rise in the number of cardiac arrests is observed, rather than a decrease as in prior years at this same time. Apr, April; Aug, August; Dec, December; Feb, February; Jan, January; Jul, July; Jun, June; Mar, March; Nov, November; Oct, October; Sep, September.

immediate in-COVID period. A trend toward an increase in in-hospital mortality occurred, by 38.6% (95% CI 5%-102%, $P = 0.090$), in the secondary care hospitals in the month following onset of the in-COVID period. Patients admitted to a secondary care hospital with HF had a 74.3% (95% CI 17.0%-160%, $P = 0.006$) increase in weekly in-hospital mortality rate in the first month. For patients admitted with STEMI and non-STEMI, no significant change in the weekly in-hospital mortality rate occurred (Fig. 6).

Cardiovascular procedures and surgeries

A 44% reduction in cardiac catheterization was observed in the in-COVID period (Fig. 7). The mortality rate for ambulatory cardiac catheterization and percutaneous coronary intervention procedures increased from 0.15% in pre-COVID patients to 2.63% in patients from the in-COVID period ($P < 0.0001$). No statistically significant increase occurred in waitlist mortality among patients undergoing other procedures in the in-COVID period. Patients awaiting transcatheter aortic valve replacement exhibited a trend toward increasing mortality—from no deaths to 9.52% of patients on the waitlist ($P = 0.1524$). The percentage of ambulatory patients undergoing cardiac surgical procedures decreased by 20.3% in the first month of the in-COVID period. In patients scheduled for coronary artery bypass grafting, this rate exhibited a trend toward increased mortality—from 0.38% in the pre-COVID group to 0.94% in the in-COVID group ($P = 0.4272$). For other cardiac surgical procedures, no difference occurred in mortality for ambulatory patients (Fig. 8).

The number of STEMI presentations increased from 59 $\pm$ 8 per month to 65 $\pm$ 10 per month in the in-COVID period ($P = 0.08$). The trend partition-segmented methodrevealed 6 splits, one of which was in May 2020. This time period was the only identified time after the onset of the pandemic during which an increasing number of patients presented for primary or rescue percutaneous coronary intervention for STEMI (Fig. 9). In the years prior, the change points occurred in September 2017, January 2018, August 2018, April 2019, and September 2019. Time from symptom onset to balloon procedure increased from 5.1 $\pm$ 6.0 hours to 7.4 $\pm$ 17.9 hours in the in-COVID period, with a significant change point noted in July 2020 (Fig. 10). Higher end-diastolic pressures were observed, by 4.8 $\pm$ 2.2 mm Hg in the first month of the in-COVID time period ($P = 0.03$). This level gradually decreased to the pre-COVID level, by 0.93 mm Hg per month ($P = 0.01$). Ejection fraction at discharge was unchanged, as was in-hospital mortality and 30-day mortality.

Discussion

This study quantifies the impact that reductions in healthcare delivery due to the first wave of COVID-19 had on outcomes in patients with new-onset or existing cardiovascular disease in an area with a low burden of COVID-19 disease. A reduction in cardiac service delivery and reductions in cardiovascular ED visits were followed by increased mortality rates for patients awaiting intervention for coronary disease. Although fewer hospitalizations occurred, in-hospital mortality rates increased, particularly in patients with HF. An increased rate of OHCA and STEMI was observed in the months following the onset of these restrictions.

Multiple factors may have led to these observed changes. First, during the course of this study, the burden of COVID-19 in Nova Scotia was low,[12] meaning the observed changes

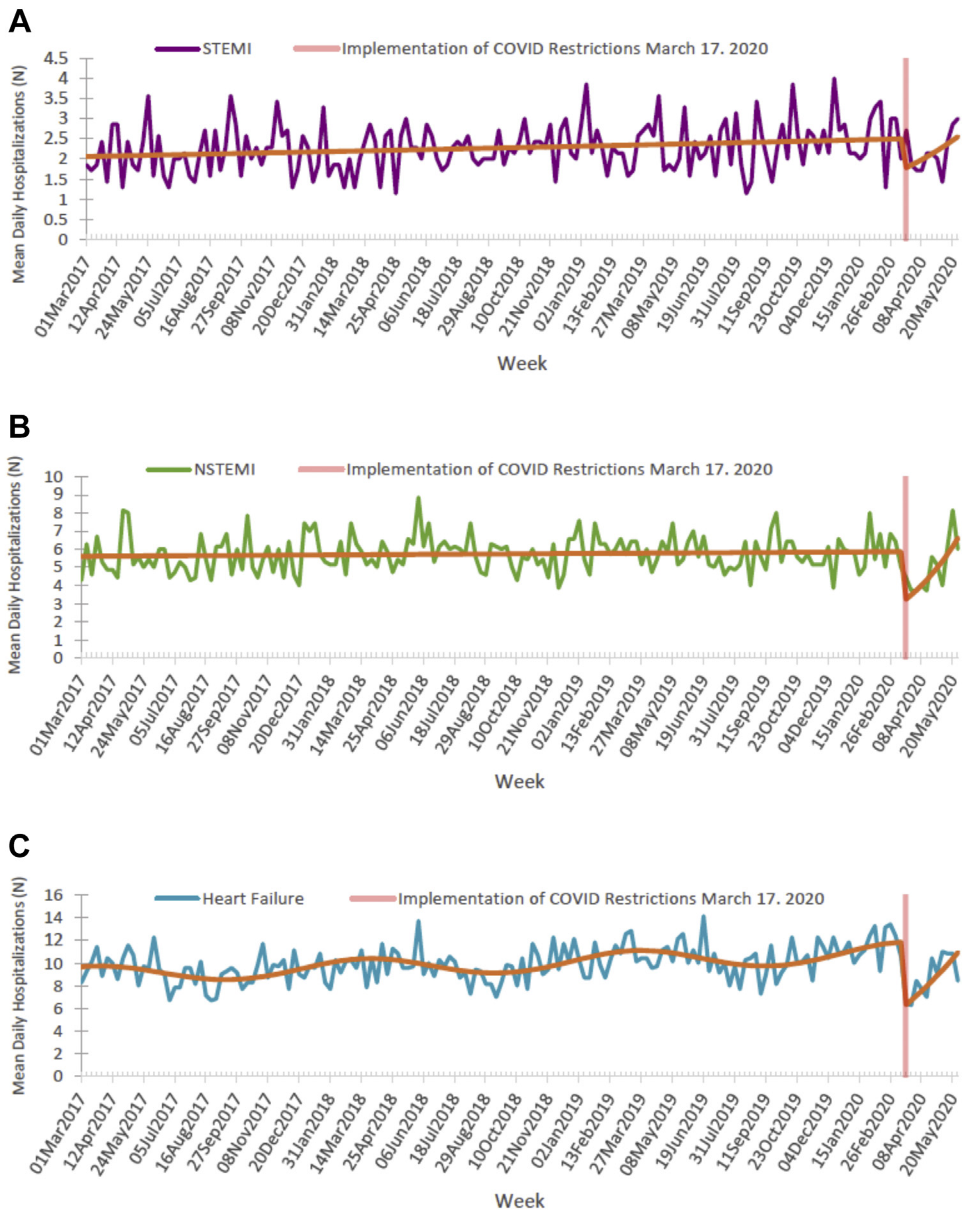

Figure 4. Weekly hospitalizations for patients with diagnosis of (**A**) ST elevation myocardial infarction (STEMI), (**B**) non-STEMI, and (**C**) heart failure. The **orange lines** represent the fitted regression lines for the interrupted time series (ITS) analysis. **Vertical red lines** represent March 17, 2020, which was the date of implementation of healthcare restrictions due to COVID-19. Apr, April; Aug, August; Dec, December; Feb, February; Jan, January; Jul, July; Jun, June; Mar, March; Nov, November; Oct, October; Sep, September.

were more likely due to the effects of public avoidance of hospital care and of restricted healthcare delivery, rather than the impact of COVID-19 disease itself. ED visits for cardiovascular reasons rapidly declined in the initial COVID period, as public health measures promoted “stay-at-home” orders with the goal of “flattening the curve.” We observed a slow return of the number of visits for cardiovascular causes to pre-pandemic levels, due to ongoing concern, despite there being few cases of COVID-19 (n = 106 of 100,000) in the province. These measures may have resulted in patients who normally would have sought medical attention instead choosing to remain at home due to fear of presenting to the hospital with the possibility of contracting a Covid-19 infection.[8,9] Such action could have led to missed opportunities for effective intervention earlier in the course of a cardiac or neurovascular event, and to higher OHCA rates. Lack of access to primary care physicians may have led to patients having more advanced symptoms. The increased mortality rate in patients admitted with HF in the in-COVID period may reflect a higher acuity among patients admitted to the hospital, although lack of access to heart function clinics and primary care, and lack of transfer for advanced therapies to the tertiary care centre cannot be excluded as contributors.

Prior studies have found similar trends in HF, acute coronary syndromes, and OHCAs.[6,18-20] One of the differences in our study, compared with these studies, was a delayed

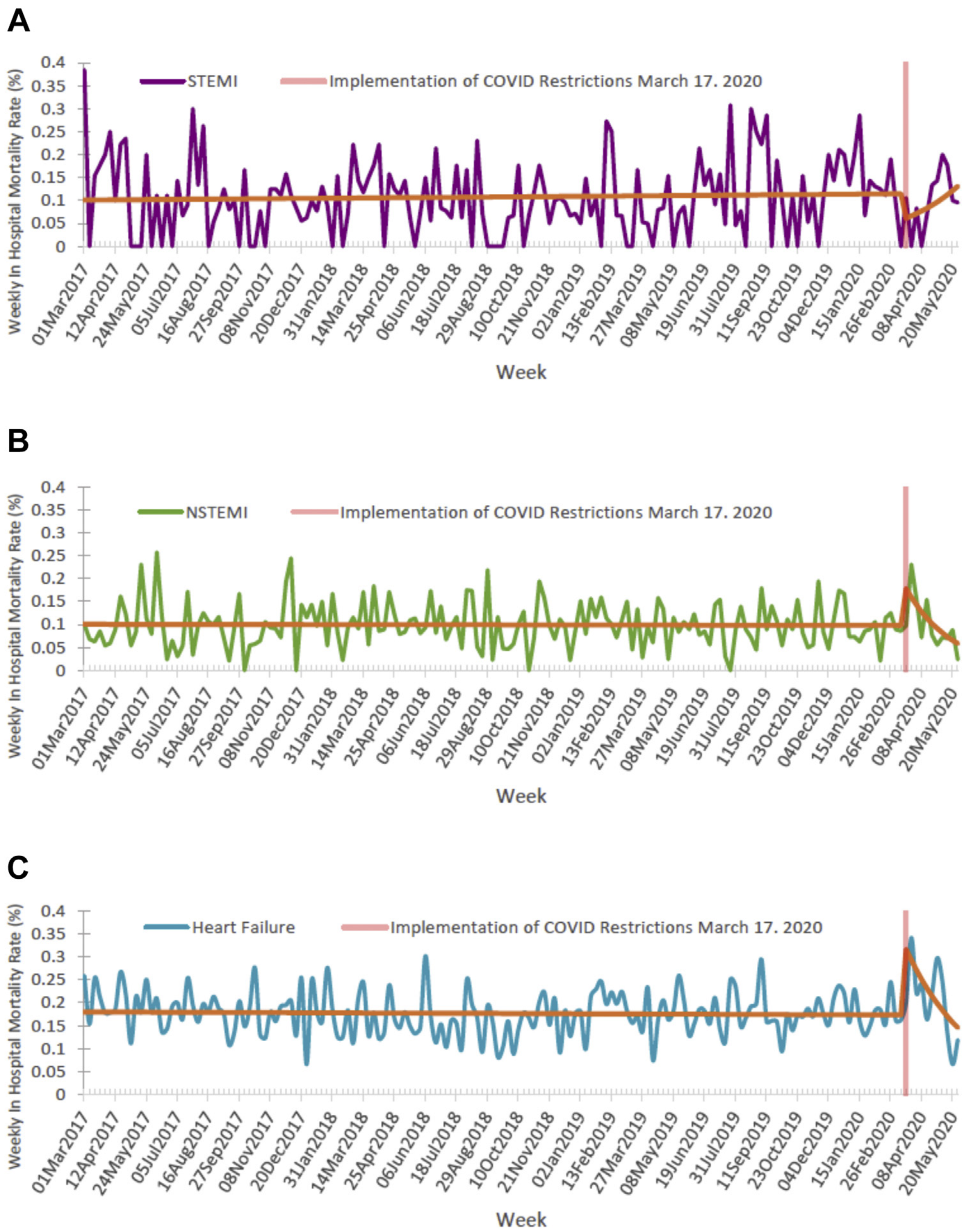

Figure 5. Weekly in-hospital mortality for cardiovascular admissions in Nova Scotia for patients admitted with (**A**) ST-elevation myocardial infarction (STEMI), (**B**) non–STEMI (NSTEMI), and (**C**) heart failure. **Orange lines** represent the fitted regression lines for the interrupted time series (ITS) analysis. **Vertical red lines** represent March 17, 2020, which was the date of implementation of healthcare restrictions due to COVID-19. Apr, April; Aug, August; Dec, December; Feb, February; Jan, January; Jul, July; Jun, June; Mar, March; Nov, November; Oct, October; Sep, September.

increase in OHCA and STEMI. One possibility is that the increase in OHCA and STEMI in these other studies was due directly to COVID-19.[21-23] Our observations may provide some insight into the effects of significant lack of access to cardiovascular care that other regions may face once the pandemic subsides globally, with the caveat that the uncertainty of the pandemic and public fears may be significantly reduced.

Limitations

Some limitations should be considered when interpreting the findings of our study. Due to low levels of the COVID-19 virus, our findings likely underestimate the morbidity/mortality from cardiovascular disease that result directly from COVID-19 infections; however, the low burden of COVID-19 disease allows us to infer that our observations are more likely to be due to the effects of healthcare restrictions and public behaviour in response to the pandemic. The policies enacted in our province may differ from those in other jurisdictions and may not be generalizable. Interruption of services may have varied across the country, particularly early in the pandemic. The Canadian Cardiovascular Society COVID-19 Rapid Response Team attempted to provide guidance on how cardiac procedures should be limited in

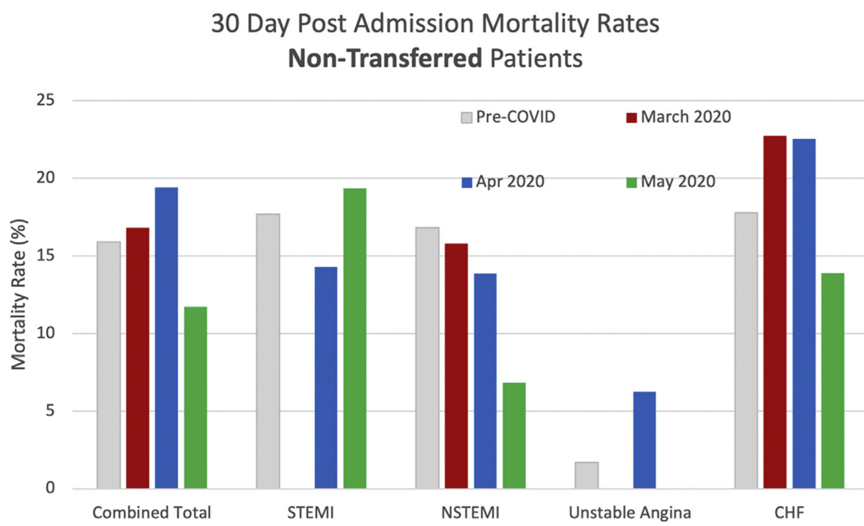

Figure 6. All-cause mortality rate post-discharge from non−tertiary care institutions for cardiovascular cause at 30 days. Mortality rate is shown by all admissions, and then by diagnosis. A nonsignificant trend toward increased mortality is present for all hospitalizations, with a significant increase in 30-day mortality for patients with a diagnosis of heart failure (HF; $P = 0.006$). NSTEMI, non-ST elevation myocardial infarction; STEMI, ST elevation myocardial infarction.

relation to the threat of the pandemic, to provide some homogeneity across the country, but this document was not released until December 1, 2020.[24]

This study used a quasi-experimental design, with possible bias due to the differing time points used in the comparison cohorts; the analysis does not prove causation. Both change point analysis and interrupted time series analysis are sensitive to changes that occur over short periods of time, and identify changes that would be detected due to seasonal variation. The trends we observed were important due to differences during the in-COVID period, compared with prior observations regarding seasonal variation for the years 2017-2019, providing support for the possibility that the observations are due to changes enacted during the in-COVID period. Nevertheless, these observations are exploratory and are subject to interpretation bias. The use of administrative data precluded obtaining patient-level characteristics in order to compare pre- and post-COVID periods in the entire cohort. The follow-up duration in our study is limited; hence, further studies investigating longer-term outcomes are required.

Conclusion

This study demonstrates increased cardiovascular morbidity and mortality as a result of indirect effects of COVID-19−related healthcare measures in a population with a low burden of COVID-19 disease. As the healthcare system recovers or enters subsequent waves of COVID-19, these findings should inform policy surrounding healthcare delivery and public health communications regarding the importance of "red-flag" symptoms in cardiovascular disease. Models promoting increased efficiency in cardiovascular care may be critical during the recovery from the pandemic, to account for the higher burden of cardiovascular disease that is likely to surface.

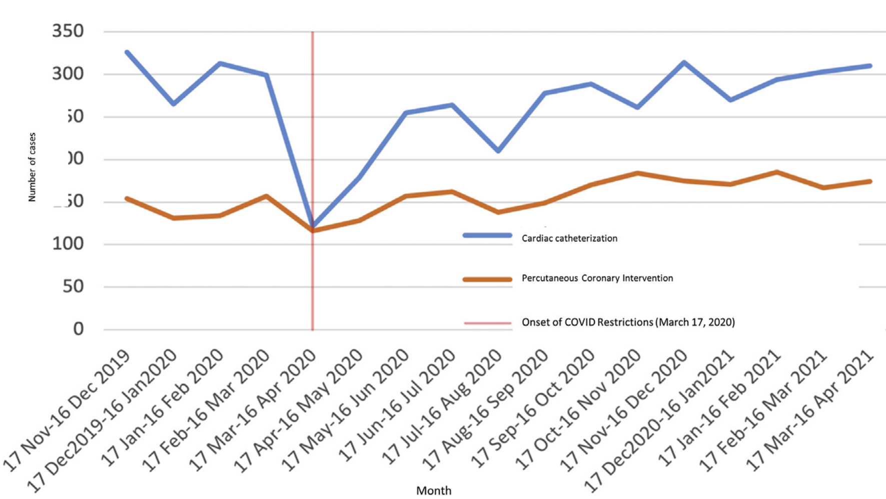

Figure 7. Cardiac catheterizations and percutaneous coronary interventions in Nova Scotia. **Vertical red line** represents March 17, 2020—the date of implementation of healthcare restrictions due to COVID-19. Apr, April; Aug, August; Dec, December; Feb, February; Jan, January; Jul, July; Jun, June; Mar, March; Nov, November; Oct, October; Sep, September.

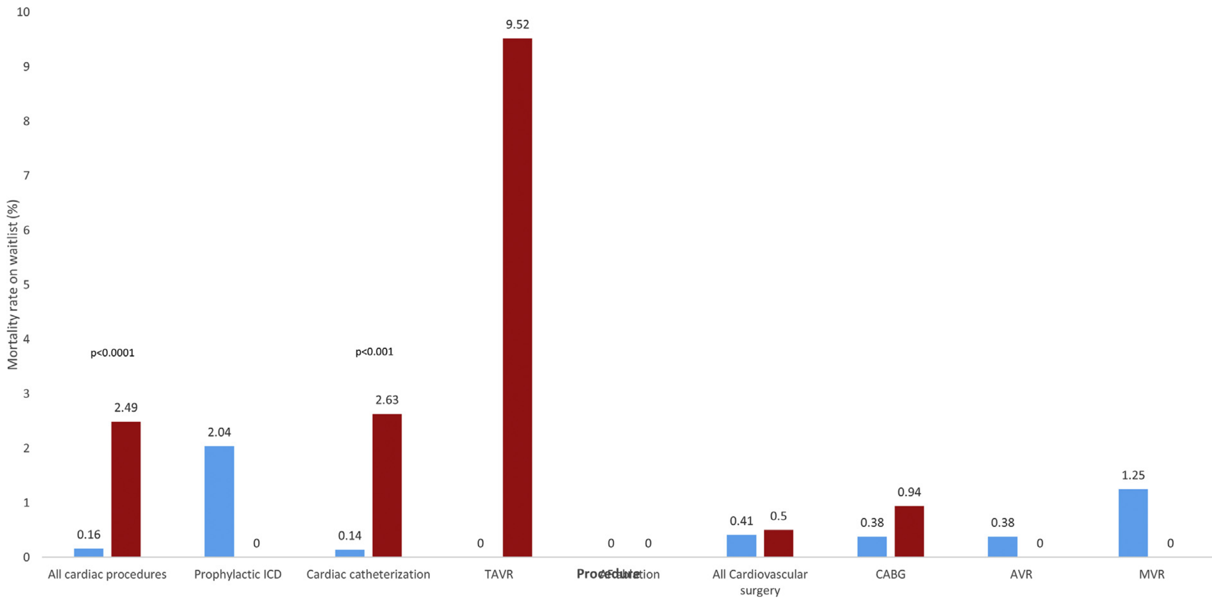

Figure 8. Mortality in ambulatory patients for cardiac interventional procedures. **Blue bars** represent the time period before the implementation of COVID-19 restrictions (pre-COVID period). **Red bars** represent the time after the implementation of COVID-19 restrictions (in-COVID period). All cardiac procedures (n = 14,083) were included: prophylactic implantable cardioverter defibrillator (ICD; n = 180); cardiac catheterization (n = 12,129); transcatheter aortic valve replacement (TAVR; n = 217); atrial fibrillation (AF) ablation (n = 496); cardiovascular surgery (n = 1285); coronary artery bypass grafting (CABG; n = 697); aortic valve replacement (AVR; n = 350); mitral valve replacement (MVR; n = 102) cases.

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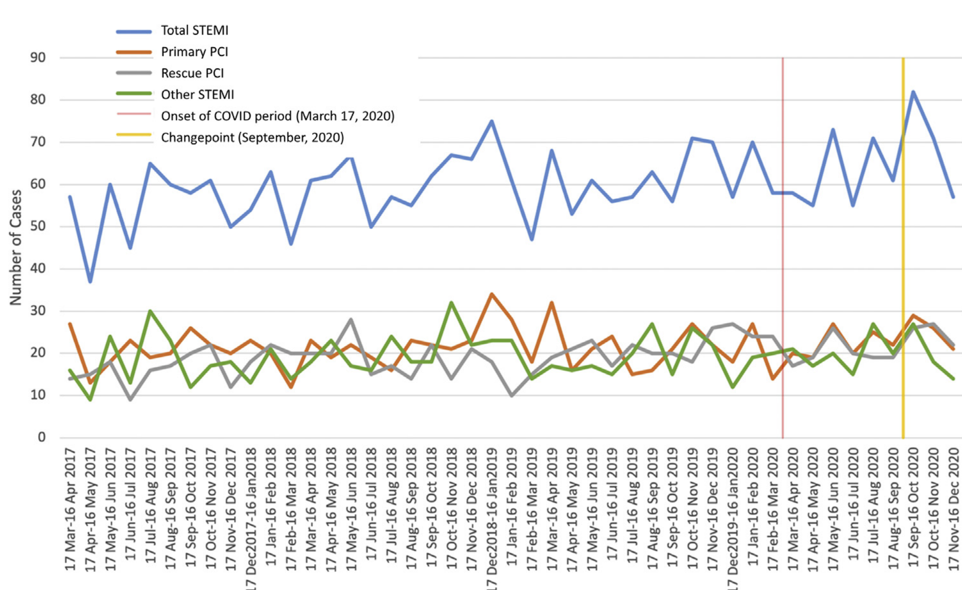

Figure 9. ST-elevation myocardial infarction (STEMI) patients transferred for cardiac catheterization. The **red vertical line** indicates the time that public health restrictions due to COVID-19 came into effect. The **vertical yellow line** indicates the change point in September 2020, at which cases of STEMI increased significantly. Apr, April; Aug, August; Dec, December; Feb, February; Jan, January; Jul, July; Jun, June; Mar, March; Nov, November; Oct, October; PCI, percutaneous coronary intervention; Sep, September.

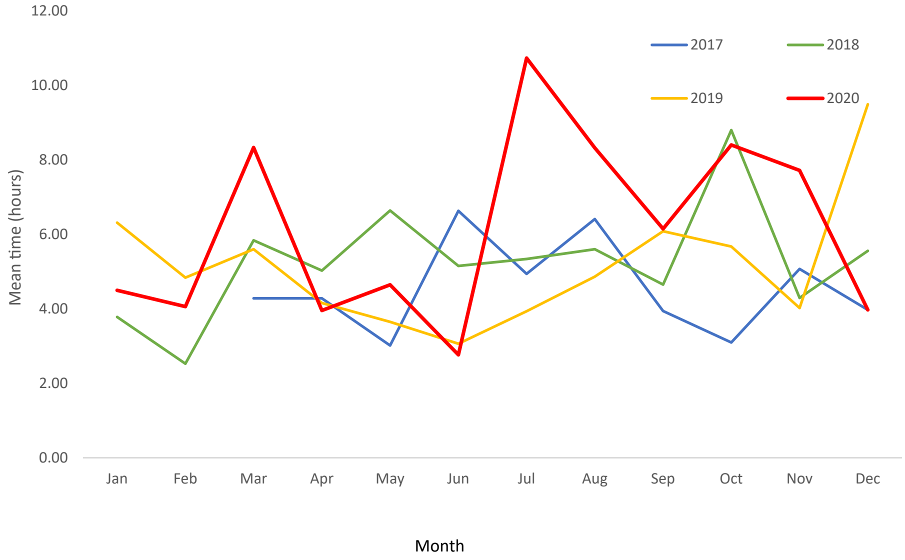

Figure 10. Annual trends in mean time from symptom onset to first balloon procedure in primary percutaneous coronary intervention. A sharp rise in mean time from symptom onset to first balloon procedure for patients who underwent primary percutaneous intervention is seen. Apr, April; Aug, August; Dec, December; Feb, February; Jan, January; Jul, July; Jun, June; Mar, March; Nov, November; Oct, October; Sep, September.

Disclosures

The authors have no conflicts of interest to disclose.

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