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Research paper

The impact of a national COVID-19 lockdown on acute coronary syndrome hospitalisations in New Zealand (ANZACS-QI 55)

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ABSTRACT

Background: Countries with a high incidence of coronavirus 2019 (COVID-19) reported reduced hospitalisations for acute coronary syndromes (ACS) during the pandemic. This study describes the impact of a nationwide lockdown on ACS hospitalisations in New Zealand (NZ), a country with a low incidence of COVID-19.

Methods: All patients admitted to a NZ Hospital with ACS who underwent coronary angiography in the All NZ ACS Quality Improvement registry during the lockdown (23 March – 26 April 2020) were compared with equivalent weeks in 2015–2019. Ambulance attendances and regional community troponin-I testing were compared for lockdown and non-lockdown (1 July 2019 to 16 February 2020) periods.

Findings: Hospitalisation for ACS was lower during the 5-week lockdown (105 vs. 146 per-week, rate ratio 0.72 [95% CI 0.61–0.83], $p = 0.003$). This was explained by fewer admissions for non-ST-segment elevation ACS (NSTEMI-ACS; $p = 0.002$) but not ST-segment elevation myocardial infarction (STEMI; $p = 0.31$). Patient characteristics and in-hospital mortality were similar. For STEMI, door-to-balloon times were similar (70 vs. 72 min, $p = 0.52$). For NSTEMI-ACS, there was an increase in percutaneous revascularisation (59% vs. 49%, $p < 0.001$) and reduction in surgical revascularisation (9% vs. 15%, $p = 0.005$). There were fewer ambulance attendances for cardiac arrests (98 vs. 110 per-week, $p = 0.04$) but no difference for suspected ACS (408 vs. 420 per-week, $p = 0.44$). Community troponin testing was lower throughout the lockdown (182 vs. 394 per-week, $p < 0.001$).

Interpretation: Despite the low incidence of COVID-19, there was a nationwide decrease in ACS hospitalisations during the lockdown. These findings have important implications for future pandemic planning.

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Research in context

Evidence before this study

A significant reduction in hospitalisations for acute coronary syndromes (ACS) during the COVID-19 pandemic have been reported in several countries. It has not been possible to identify potential contributing factors for the observed reductions in ACS presentations on the basis of limited patient demographic, clinical characteristic, management and outcome data reported to date. Current reports have come from countries with a relatively high incidence of COVID-19 cases (e.g. Italy, Spain, England, USA) and it is not known whether similar findings have occurred in countries with a low incidence of COVID-19.

Added value of this study

Our study reports nationwide data during the COVID-19 lockdown in New Zealand, from established registries of inpatients with confirmed ACS, and patients with suspected ACS in out-of-hospital settings. There was a 28% reduction in ACS hospitalisations observed, with a 34% reduction in hospitalisations for non-ST-segment elevation ACS (NSTEMI-ACS) and no significant change in hospitalisations for ST-segment elevation myocardial infarction (STEMI). There were no observed differences in clinical characteristics of patients hospitalised, in particular there was no suggestion that they were presenting later with more severe disease as evidenced by similar GRACE scores and in-hospital mortality. Door-to-balloon times were similar, and length of hospital stays were shorter, suggesting that the ability to care for patients with ACS in-hospital was preserved. There was no reduction in ambulance attendances for suspected ACS suggesting that failure to seek medical attention was not the only contributing factor to the reduction in ACS hospitalisations. An 11% reduction in ambulance attendances for out-of-hospital cardiac arrests supports a possible true decline in the incidence of ACS during the lockdown. A 54% decrease in community troponin testing suggests changes in the delivery of primary healthcare during lockdown, which may have led to less referrals for hospitalisation.

Implications of all available evidence

Reductions in ACS presentations to hospital have been observed in countries with both a high and low incidence of COVID-19 related pathology. The reasons for these findings are likely multifactorial and cannot be solely explained by patient failure to seek medical attention, or healthcare systems inability to provide routine care for ACS patients due to prioritisation of services towards COVID-19 pathology. These findings are important for healthcare delivery planning and public health policy in any future pandemic.

1. Introduction

Lockdowns, a form of enforced social distancing, have been successfully implemented to limit the transmission of severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) in several countries [1,2] and have led to the elimination of community transmission in New Zealand (NZ) [3]. During the NZ nationwide lockdown, implemented on the 23 March 2020, individuals were instructed to stay at home other than for essential personal movement, and all non-essential businesses and facilities were closed for 5 weeks. By the end of the lockdown on the 27 April 2020, there had been 1122 confirmed coronavirus disease 2019 (COVID-19) cases (233 per million population) and 19 deaths (3.9 deaths per million population). In comparison, on the same date, there were 166 and 354 deaths

per million population in the United States and United Kingdom respectively [4]. Hospital occupancy with COVID-19 cases in NZ was extremely low, with no more than 20 patients in hospital or 5 in an intensive care unit at any time throughout the country (Supplementary Material, Figure S1). The NZ national lockdown was successful in eliminating COVID-19 from NZ for ~120 days, when there was further limited community spread after COVID-19 was reintroduced following international travellers.

While lockdowns slow the progression of a pandemic, they can have undesired effects. A significant decrease in hospitalisations for acute coronary syndrome (ACS) was observed in many regions around the world during the COVID-19 pandemic [5-12]. The inability of overwhelmed healthcare systems to deliver routine care to patients with ACS may partially explain this reduction [13]. In addition, individual behaviour may change during a lockdown, in particular, a reluctance to seek medical attention for non-COVID-19 conditions due to a fear of contracting COVID-19 at healthcare facilities. The relative contributions of the pandemic itself and the lockdowns to the decline in ACS hospitalisation are unknown.

New Zealand, an island nation of 5 million people, is in a unique position to study the impact of lockdown measures on patients presenting with ACS, largely without the confounding effects of COVID-19 pathology. We evaluated the impact of the national lockdown on the presentation and management of patients with ACS from national and regional registries of hospitalisations for ACS, ambulance attendances for suspected ACS and cardiac arrests, and from community troponin testing, a surrogate measure of primary health care assessment of chest pain.

2. Methods

In this study, patient contacts with healthcare systems were investigated during the 5-week national lockdown between 23 March and 26 April 2020.

2.1. Hospitalisations with confirmed ACS and coronary angiography

Hospitalisations with ACS were identified from the All New Zealand Acute Coronary Syndrome Quality Improvement (ANZACS-QI) registry. This nationwide web-based electronic database records a mandatory dataset entered by clinicians for all patients hospitalised with ACS and referred for coronary angiography. Data was collected prospectively from all NZ public hospitals and patients are included regardless of whether they are managed in a coronary care unit or ward-based setting. Further details regarding data collection were previously reported [14]. The completeness of patient capture and accuracy of ACS diagnosis was previously validated against national administrative datasets [15]. In this study, patients admitted during the 5-week lockdown were compared with those admitted during a non-lockdown period comprising the same dates in the preceding 5 years (23 March to 26 April 2015-2019). All patients hospitalised for a confirmed ACS that underwent coronary angiography during the study period were included. Analyses were performed on a per-hospitalisation basis, rather than per-person. Registry entries with incomplete data were excluded from analysis - 10 hospitalisations (1.9%) during the lockdown and 11 hospitalisations (0.3%) during the non-lockdown period.

Data variables recorded in the ANZACS-QI registry included patient demographics, the Global Registry of ACS (GRACE) admission to six-month score [16], left ventricular ejection fraction (LVEF), coronary angiography findings, revascularisation details and in-hospital outcomes. Significant coronary artery disease was defined as $\geq 50\%$ stenosis in any major native epicardial vessel or coronary bypass graft. Time from symptom onset to hospital presentation was recorded for those with ST-segment elevation myocardial

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infarction (STEMI). Door-to-balloon time was recorded for those treated with primary percutaneous coronary intervention (PCI).

2.2. Ambulance attendances

Ambulance attendances were captured from the Out-of-Hospital Heart Attack and Out-of-Hospital Cardiac Arrest registries. These two nationwide registries capture all ambulance attendances by the St John Ambulance Service and Wellington Free Ambulance. Data was collected from: computer-aided dispatch data and supporting systems; and on-scene data that was entered into electronic patient report forms by the ambulance personnel in attendance. Ambulance attendances during the 5-week lockdown were compared with those during a 33-week baseline period between 1 July 2019 and 16 February 2020. Data from the first six months of 2019 was not available due to industrial action during that time. Ambulance attendances for any reason, and specifically for suspected ACS and out-of-hospital cardiac arrests (OHCA) were investigated. Attendances for suspected ACS events were defined as pre-hospital clinician coding of either cardiac chest pain, myocardial ischemia or STEMI. All ambulance attendances for OHCA were included, regardless of suspected aetiology of arrest or if resuscitation was attempted.

The data variables recorded in this registry included patient demographics, location of ambulance attendance, final clinical status (1-immediate threat to life, 2-potential threat to life, 3-unlikely threat to life, 4-no threat to life, 0-dead) and patient disposition. Rural and urban localities were derived from meshblock census area units according to Statistics NZ.

In the absence of meshblock data, attendances by the Wellington Free Ambulance were designated as urban.

2.3. Community laboratory testing

Anonymised community laboratory testing data was obtained from Labtests NZ. Labtests NZ provides funded community laboratory testing for the wider Auckland Region. It serves a population of approximately 1.7 million and has testing volumes that represent about 40% of all those performed nationally. The laboratory does not process specimens collected from emergency departments or inpatient services, which are analysed in regional hospital laboratories. As part of pandemic preparations, a number of laboratory testing depots were reduced temporarily by arrangement with the funder, however ample patient access was provided and all biochemistry tests remained available, including urgent requests. For example, troponin requests are automatically processed urgently, and this turnaround did not change during lockdown (average 3 h and 45 min, including transport time).

The number of high-sensitivity Troponin I (Siemens TNIH) assays performed each week, and the proportion of results above the upper limit of normal (non-gender specific 99th population percentile 47 ng/L) were assessed during the 5-week lockdown and compared with a 33-week baseline period between 1 July 2019 and 16 February 2020. The performance of other common laboratory tests, including full blood counts, serum creatinine and liver function tests, were also measured. These other tests were performed using Siemens Advia and Sysmex automated laboratory platforms. Labtests is accredited under International Accreditation New Zealand (IANZ), according to the international ISO15189 standard.

2.4. Ethics

The ANZACS-QI registry is part of the Vascular Informatics using Epidemiology and Web (VIEW) programme at the University

of Auckland. The VIEW programme was approved by the Northern Region Ethics Committee Y in 2003 (AKY/03/12/314) and National Multi-Region Ethics Committee since 2007 (MEC07/19/EXP). The ambulance Out-of-Hospital Heart Attack Registry and the Out-of-Hospital Cardiac Arrest Registry studies are approved by New Zealand Health and Disabilities Ethics Committee 19/NTB/186 and 19/NTB/187 respectively. Individual patient consent was not required.

2.5. Statistics

Descriptive statistics for categorical variables were reported by frequency and percentage, and Pearson's chi-square was used. Continuous variables were presented as mean \pm standard deviations or median with interquartile range. Comparison of continuous data between groups were tested using Student's *t*-test or Mann-Whitney *U* test where appropriate.

Mean event rates per week (ACS hospitalisations, ambulance attendances and laboratory testing) were calculated by dividing the number of events by the number of weeks for each time period and were compared with the Mann-Whitney *U* test. Mean rate ratios were calculated by dividing the mean event rate during the lockdown period by the mean event rate during non-lockdown periods and confidence intervals were calculated by Fieller's method. The analysis did not adjust for potential confounding variables as there were no significant differences in baseline characteristics of patients hospitalised for ACS between time periods, and equivalent weeks in prior years were used as the control period to reduce effects of seasonal variation. All *P*-values were two tailed and a *P*-value of <0.05 was considered significant. Data was analysed using SAS statistical package, version 9.4 (SAS Institute, Cary, NC)

2.6. Role of the funding source

No funders had any role in study design, data collection, data analysis, interpretation and writing of the report. The corresponding author had full access to all the data in the study.

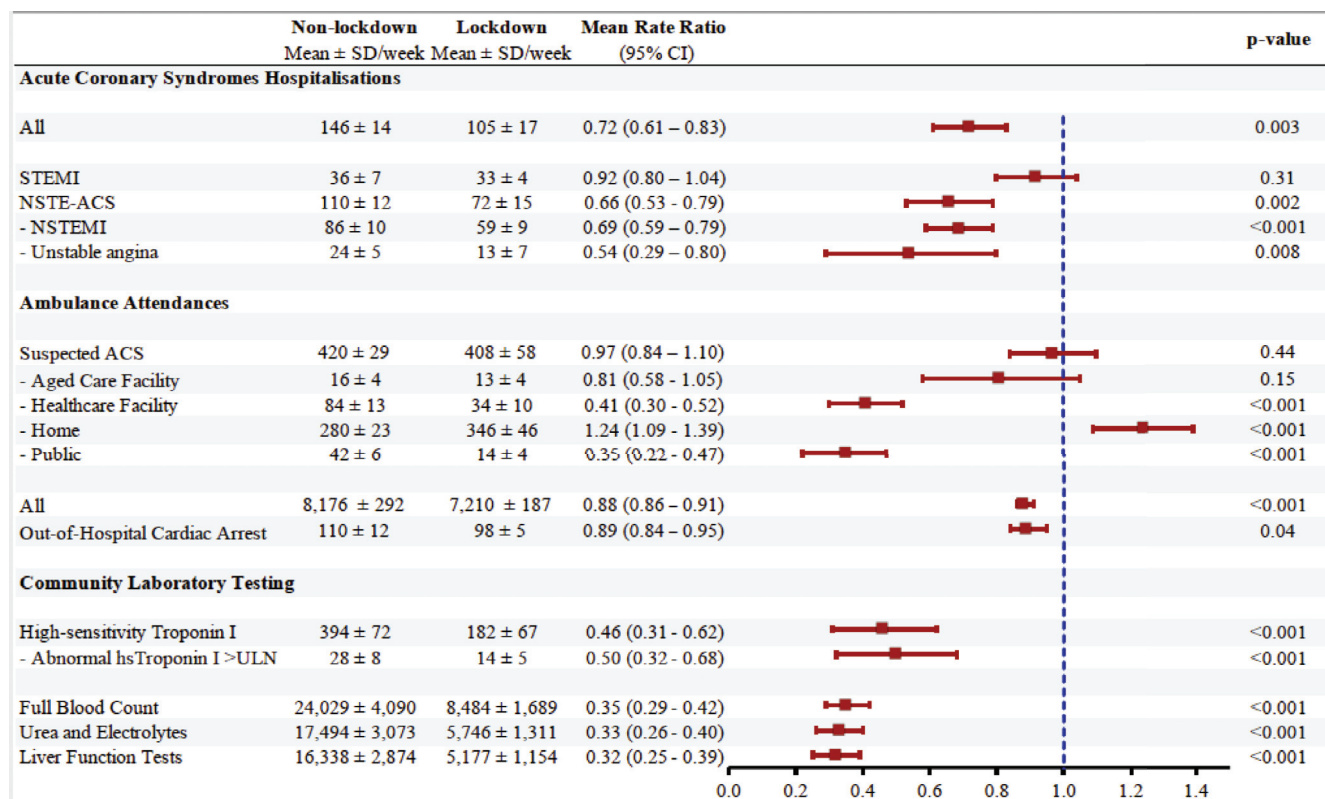
3. Results

3.1. Acute coronary syndrome hospital admissions

There was a mean of 105 ± 17 hospitalisations with confirmed ACS per-week during the 5-week lockdown compared to a mean 146 ± 14 hospitalisations per-week in the same time period in 2015–2019 (mean rate ratio 0.72, 95% CI 0.61 – 0.83, $p = 0.003$). This decrease was largely explained by a reduction in non-ST-segment elevation myocardial infarction (NSTEMI) (59 ± 9 vs. 86 ± 10 per-week, mean rate ratio 0.69, 95% CI 0.59 – 0.79, $p < 0.001$). Unstable angina presentations also reduced (13 ± 7 vs. 24 ± 5 per-week, mean rate ratio 0.54, 95% CI 0.29 – 0.80, $p = 0.008$). However, there was no change in frequency of STEMI presentations during the lockdown period (33 ± 4 vs. 36 ± 7 per-week, $p = 0.31$) (Fig. 1-2).

There were no differences in patient demographics or characteristics observed during the lockdown compared to the non-lockdown period (Table 1). Median age was 66 years, 70% were male, there was no difference in ethnicity and the mean GRACE score for mortality at 6 months was 3.4% in both periods. Coronary angiography and echocardiography findings were also similar. Length of hospital stay was one day shorter during lockdown for both patients with non-ST-segment elevation acute coronary syndromes (NSTE-ACS) and STEMI ($p < 0.001$).

Of those presenting with STEMI, rates of reperfusion therapy were similar between time periods (79% vs. 78%, $p = 0.89$). A similar proportion of patients received reperfusion with fibrinolytic



ACS = acute coronary syndrome; CI = confidence interval; hsTroponin = high-sensitivity Troponin; NSTEMI-ACS = non-ST-segment elevation acute coronary syndrome; NSTEMI = non-ST-segment elevation myocardial infarction; STEMI = ST-segment elevation myocardial infarction; SD = standard deviation; ULN = upper limit of normal p-value calculated using Mann-Whitney U test

Fig. 1. Changes in event rates during the lockdown compared to non-lockdown period

ACS = acute coronary syndrome; CI = confidence interval; hsTroponin = high-sensitivity Troponin; NSTEMI-ACS = non-ST-segment elevation acute coronary syndrome; NSTEMI = non-ST-segment elevation myocardial infarction; STEMI = ST-segment elevation myocardial infarction; SD = standard deviation; ULN = upper limit of normal p-value calculated using Mann-Whitney U test.

therapy during lockdown (20% vs. 25%, $p = 0.20$). Door-to-balloon time was similar for those treated with primary PCI (69.5 [45 to 97.5] vs. 72 [46 to 103] minutes, $p = 0.52$). No increased delays to symptom onset to hospital presentation was observed during lockdown (124 [76 to 208] vs. 112 [67 to 194] minutes, $p = 0.20$).

Of those presenting with NSTEMI-ACS, time from hospital admission to coronary angiography was shorter during lockdown (2.2 ± 2.6 vs. 2.9 ± 2.6 days, $p < 0.001$). The proportion of patients who were revascularised remained similar although there was an increase in percutaneous coronary intervention (59% vs. 49%, $p < 0.001$) and a corresponding reduction in coronary artery bypass grafting (9% vs 15%, $p = 0.005$).

3.2. Ambulance attendances

Ambulance attendances for suspected ACS were similar during the lockdown compared to the non-lockdown period (408 ± 58 vs. 420 ± 29 per-week, $p = 0.44$). Total weekly ambulance attendances during the lockdown were reduced by compared to the non-lockdown period (7210 ± 187 vs. 8176 ± 191 per-week, mean rate ratio 0.88, 95% CI 0.86 – 0.91, $p < 0.001$). A reduction in ambulance attendances for OHCA was also observed (98 ± 5 vs. 110 ± 12 per-week, mean rate ratio 0.89, 95% CI 0.84 – 0.95, $p < 0.001$) (Fig. 1, 3 and Supplementary Material, Figure S2–3).

Amongst ambulance attendances for suspected ACS, age (median 69 vs. 68 years), male sex (55% vs. 54%) and ethnicity were similar between the lockdown and non-lockdown periods. There was a 24% increase in attendances at individuals' homes (346 vs. 280 per week), a 59% reduction in attendances to healthcare fa-

cilities (34 vs. 8 per week) and a 65% reduction in attendances to individuals in public places (14 per vs. 42 per week). There were slightly fewer attendances for status 1 and 2 presentations representing immediate or potential threat to life (37% vs. 40%) and a small increase in individuals not transferred to hospital for further management (4% vs. 2%) (Table 2). Similar findings were observed for all ambulance attendances and ambulance attendances for OHCA (Supplementary Material, Table S6–7).

3.3. Community laboratory testing

There was a decrease in community high-sensitivity troponin I testing performed during the lockdown compared to the non-lockdown period (182 ± 67 vs. 394 ± 72 per-week, mean rate ratio 0.46, 95% CI 0.31 – 0.62, $p < 0.001$) (Fig. 1 and 3). The total number of troponin I tests per-week that were above the upper limit of normal were reduced during lockdown, although the proportion of above the upper limit of normal was similar for the two periods (7.7% vs. 7.1%, $p = 0.80$). Community testing for other common laboratory tests were also reduced during the lockdown (Supplementary Material, Figure S4).

4. Discussion

This is the first nationwide description of ACS hospitalisations in the context of a strict nationwide COVID-19 lockdown, but in the absence of widespread community transmission and low hospital occupancy with COVID-19 cases. During the 5-week nationwide COVID-19 lockdown period in NZ, there was a decrease in

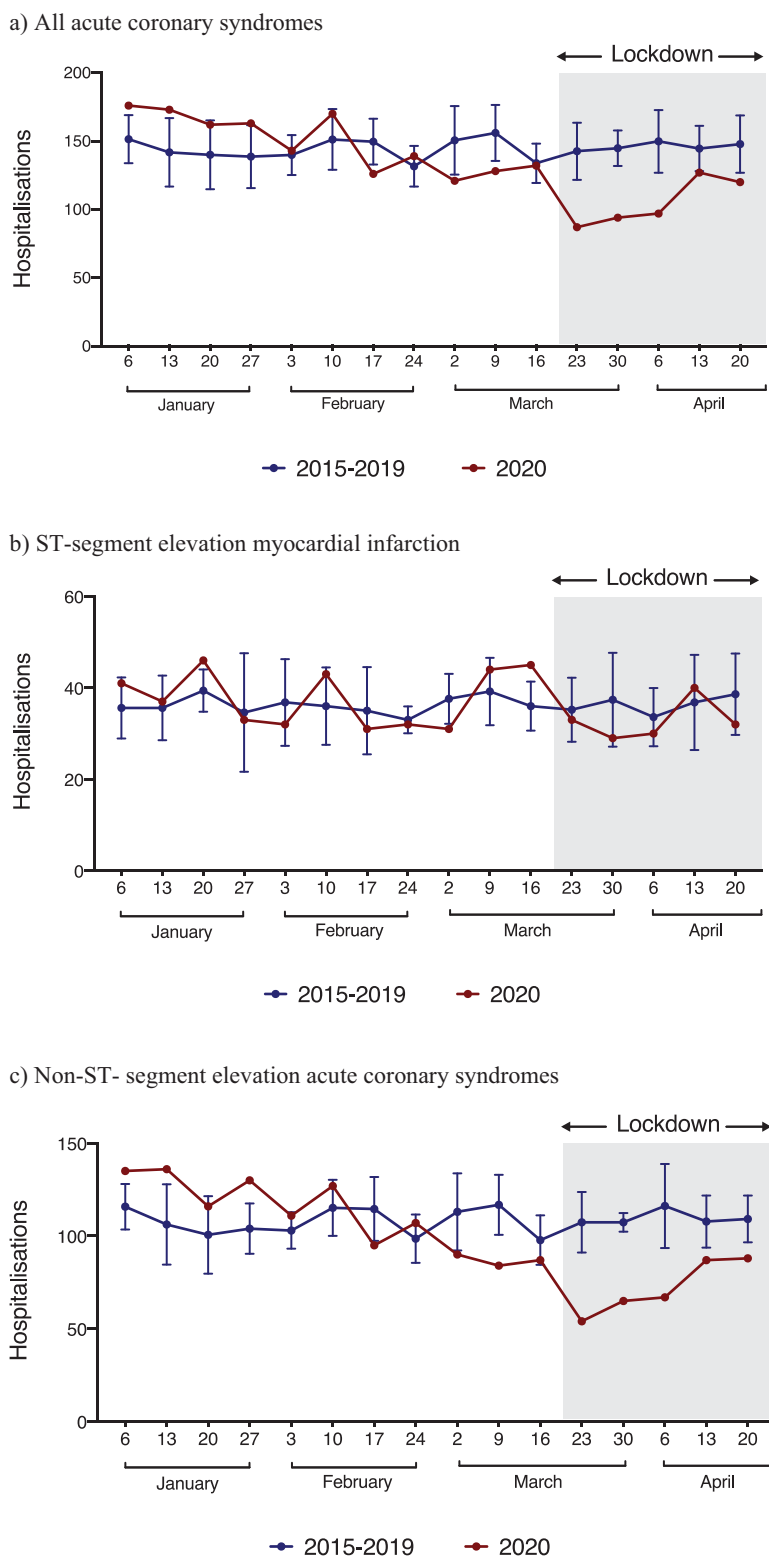


Fig. 2. Hospitalisations for acute coronary syndrome by week.
 a) All acute coronary syndromes.
 b) ST-segment elevation myocardial infarction.
 c) Non-ST-segment elevation acute coronary syndromes.

Table 1

Demographics, clinical characteristics and outcomes for patients with acute coronary syndrome hospitalisations during the lockdown compared to non-lockdown period.

	STEMI Non-lockdown n = 908	Lockdown n = 164	p-value	NSTE-ACS Non-lockdown n = 2740	Lockdown n = 361	p-value
Mean admissions per week ± SD	36 ± 7	33 ± 4	0.31	110 ± 12	72 ± 15	0.002
Demographics						
Age (years), median (IQR)	65 (55 to 74)	65 (57 to 72)	0.67	67 (58 to 75)	66 (59 to 74)	0.69
Male gender	648 (71%)	125 (76%)	0.20	1869 (68%)	243 (67%)	0.73
Ethnicity			0.91			0.07
- NZ Maori	89 (10%)	14 (9%)		286 (10%)	35 (10%)	
- Pacific	45 (5%)	9 (5%)		144 (5%)	22 (6%)	
- Indian	51 (6%)	12 (7%)		123 (4%)	27 (7%)	
- Other Asian	39 (4%)	7 (4%)		103 (4%)	8 (2%)	
- European/Other	684 (75%)	122 (74%)		2084 (76%)	269 (75%)	
Comorbidities						
Prior MI	151 (17%)	23 (14%)	0.41	787 (29%)	112 (31%)	0.36
Current smoker	264 (29%)	44 (27%)	0.56	538 (20%)	60 (17%)	0.17
Diabetes	179 (20%)	25 (15%)	0.18	719 (26%)	91 (25%)	0.67
Clinical presentation						
Cardiac arrest prior to hospitalisation	89 (10%)	17 (10%)	0.83	45 (2%)	3 (1%)	0.24
GRACE score*, mean ± SD	6.1 ± 9.2	6.1 ± 8.3	0.91	2.5 ± 4.3	2.2 ± 3.8	0.07
LV ejection fraction <40%	201 (22%)	38 (23%)	0.77	244 (9%)	36 (10%)	0.51
Coronary anatomy			0.57			0.20
- No significant CAD	46 (5%)	11 (7%)		441 (16%)	50 (14%)	
- 1–2 vessel disease	646 (71%)	111 (68%)		1428 (52%)	206 (57%)	
- 3 vessel disease/left main stem	216 (24%)	42 (26%)		871 (32%)	105 (29%)	
Symptom onset to hospital (minutes), median (IQR)	112 (67 to 194)	124 (76 to 208)	0.20	..	..	..
Management						
Door-to-balloon time (minutes) median (IQR)	72 (46 to 103)	69.5 (45 to 97.5)	0.52	..	..	..
Reperfusion therapy			0.38			..
- Primary PCI	485 (53%)	96 (59%)		..	..
- Fibrinolysis	225 (25%)	33 (20%)		..	..
- No reperfusion	198 (22%)	35 (21%)		..	..
Time from admission to angiogram (days), mean ± SD	..	..	..	2.9 ± 2.6	2.2 ± 1.8	<0.001
Revascularisation						
- PCI	714 (79%)	132 (80%)	0.59	1342 (49%)	213 (59%)	<0.001
- CABG	72 (8%)	8 (5%)	0.17	410 (15%)	34 (9%)	0.005
- No revascularisation	122 (13%)	24 (15%)	0.68	988 (36%)	114 (32%)	0.09
Length of hospital stay (days), mean ± SD	5.1 ± 5.2	4.0 ± 4.3	<0.001	6.0 ± 5.6	4.5 ± 4.5	<0.001
In-hospital mortality	45 (5%)	7 (4%)	0.71	18 (1%)	4 (1%)	0.34

NB: All values are frequency (%) unless otherwise specified. p-values were calculated using Pearson's chi-square for categorical data; and Student's *t*-test or Mann-Whitney U test for continuous data where appropriate.

ACS = acute coronary syndrome; CABG = coronary artery bypass grafting; CAD = coronary artery disease; IQR = interquartile range; LV = left ventricular; MI = myocardial infarction; NSTE-ACS; non-ST-segment elevation acute coronary syndrome; PCI = percutaneous coronary intervention; SD = standard deviation; STEMI = ST-segment elevation myocardial infarction.

* For 6-month mortality.

the number of hospital admissions with confirmed ACS, due to a reduction in hospitalisations for NSTEMI and unstable angina, respectively. There was no difference in hospitalisations for STEMI. There were no observed differences in demographics or comorbidities of patients hospitalised for ACS, and no indication that pa-

tients were presenting later or with more severe disease during lockdown, with similar door-to-device times, GRACE scores, LVEF, and in-hospital mortality observed. A reduction in total ambulance attendances, ambulance attendances for OHCA and community troponin testing were also observed. This study provides a unique in-

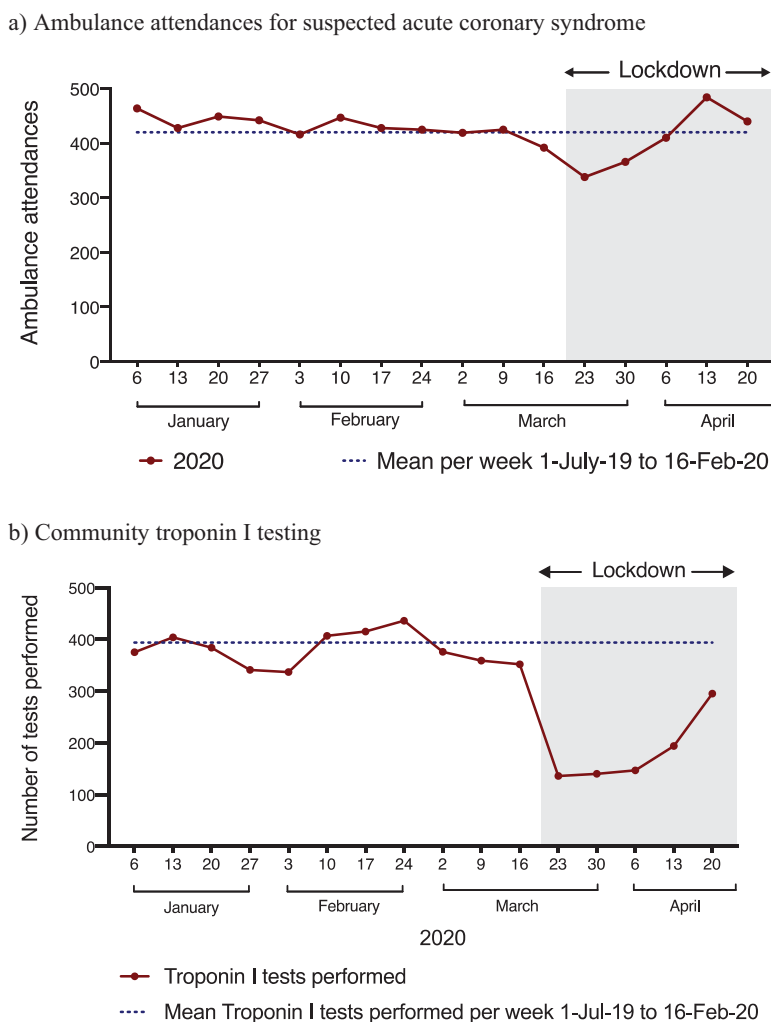


Fig. 3. Out-of-hospital healthcare encounters for suspected acute coronary syndromes by week.
 a) Ambulance attendances for suspected acute coronary syndrome.
 b) Community troponin I testing.

sight into the impact of the lockdown and other measures taken to mitigate a major pandemic on nationwide ACS hospitalisations.

An increase in ACS presentations was expected during the COVID-19 pandemic, as seen with seasonal influenza epidemics [17,18], significant public events [19] and natural disasters [20]. However the opposite was observed with reductions in ACS presentations by 25–48% reported from the United States [5, 6], Italy [7, 8], Spain [9], Austria [10], England [11] and Germany [12]. The findings of these studies were limited to specific regions or survey responses. On the basis of limited patient demographic, clinical characteristic, management and outcome data reported to date, it is not possible to establish contributing factors for observed reductions in ACS presentations. The aforementioned studies were undertaken in countries with a high burden of COVID-19 cases in comparison to NZ. As a result, the factors underlying the observed reduction in ACS hospitalisations may be different.

Patient factors including failure to seek medical attention are likely to contribute to the decrease in ACS hospitalisations during lockdown. In this nationwide study, there were no observed differences in demographics or comorbidities of patients hospitalised for ACS during the lockdown compared to previous years, suggesting factors influencing non-presentation affected all individuals equally. Strong public health messages emphasising the need for social distancing and encouraging people to stay at home dur-

ing the lockdown period may have discouraged individuals from seeking medical attention. Individuals may have avoided hospitalisation for fear of contracting COVID-19 in hospital; or separation from family due to stringent visitor restrictions during the lockdown. The reduction in hospitalisations for NSTEMI-ACS but not for STEMI, suggests that those with less severe symptoms may have avoided presenting to hospital during lockdown. A similar observation of a reduction in NSTEMI and unstable angina hospitalisations but not for STEMI was seen from a single centre study in Germany [12], where there was a higher community prevalence of COVID-19 but relatively low mortality compared to other countries. A relative increase in ACS hospitalisations, ambulance attendances for suspected ACS and community laboratory testing was observed in the second half of the 5-week lockdown. This coincided with media reports of potential harm arising from non-presentation, changes in messages from the government recommending seeking medical attention for non-COVID-19 conditions and a decline in the detection of new cases of COVID-19.

An alternate explanation is that a genuine reduction in the incidence of ACS during the lockdown resulted in fewer hospitalisations for ACS. There are several possible mechanisms for such a reduction. In Oceania, which includes Australia and New Zealand, influenza activity indicators have remained at or below inter-seasonal levels [21], possibly as a result of the various hygiene

Table 2
Description of ambulance attendances for suspected acute coronary syndrome during the lockdown compared to non-lockdown period.

	Non-lockdown ⁿ = 13,865	Lockdown ⁿ = 2038	p-value
Mean attendances per week ± SD	420 ± 29	408 ± 58	0.44
Demographics			
Age (years), median (IQR)	69 (57 to 79)	68 (56 to 79)	0.01
Male sex*	7684 (55%)	1105 (54%)	0.32
Ethnicity			0.87
- New Zealand Māori	954 (7%)	132 (6%)	
- Pacific people	527 (4%)	79 (4%)	
- Asian	729 (5%)	113 (6%)	
- European/Other	11,655 (84%)	1731 (85%)	
Clinical details			
Location			<0.001
- Aged Care Facility	513 (4%)	63 (3%)	
- Healthcare Facility	2754 (20%)	172 (8%)	
- Home	9224 (67%)	1731 (85%)	
- Public/Other	1374 (10%)	72 (4%)	
Rural location*	3184 (23%)	500 (25%)	0.21
Final clinical status ^{*,#}			0.002
- 1-2	5599 (40%)	750 (37%)	
- 3-4	8253 (60%)	1284 (63%)	
Transported to hospital*	13,527 (98%)	1953 (96%)	<0.001

NB: All values are frequency (%) unless otherwise specified. p-values were calculated using Pearson's chi-square for categorical data; and Student's *t*-test or Mann-Whitney U test for continuous data where appropriate.

IQR = interquartile range; SD = standard deviation.

* contains missing data (see Supplementary Material, Table S8).

Final clinical status: 1- immediate threat to life, 2-potential threat to life, 3-unlikely threat to life, 4-no threat to life.

and physical distancing measures implemented to reduce SARS-CoV-2 virus transmission. Numerous associations have been established between influenza and cardiovascular events [17,18,22], and a decrease in influenza may have contributed to the reduction in ACS events observed. Reduction in physical activity due to lockdown restrictions was demonstrated internationally [23] and this may have resulted in individuals experiencing less symptoms and less likelihood of physical stress leading to plaque rupture. We have no information on changes in emotional, financial or mental stresses during lockdown. Environmental factors, such as the reduction in air pollution observed in urban areas during lockdown in NZ [24] and in other countries [25], may also have influenced health outcomes.

The observed reduction in ambulance attendances for OHCA may suggest a decline in the true incidence of ACS in NZ during the lockdown, as coronary artery disease is the predominant cause of OHCA [26]. In contrast, an increase in OHCA has been observed in Italy [27], New York City [28] and France [29] where individuals with ACS may have experienced adverse outcomes due to being unable to access timely healthcare during the COVID-19 pandemic. However, the drop in ACS hospitalisations is not a unique finding during the current pandemic. Similar decreases were observed in emergency surgeries for type A aortic dissection in New York [30], coronary care unit admissions for heart failure and atrial fibrillation [8] and paediatric emergency department visits in Italy [31].

To further examine possible contributing factors for the reduction in ACS hospitalisations, we studied the ambulance attendance and community laboratory data. In contrast to the reduction in ACS hospitalisations observed, there was no change in the ambulance attendances for suspected ACS. It is difficult to identify reasons for this discrepancy with the available data and further research is required. Although there were no differences in patient demographics observed in those attended by ambulance personnel for suspected ACS, these patients during lockdown may have had less severe presentations as their clinical status codes were lower and a lower proportion were transferred to hospital. Previous research demonstrated that half of all patients transported to hos-

pital in NZ for suspected ACS did not have a final discharge diagnosis of an ACS [32]. This proportion may have increased during lockdown. Patients may have preferentially called for ambulance assistance during lockdown, rather than self-presenting to hospital or their primary care physician. Another possible reason for the discrepancy may be that less patients with ACS were investigated with coronary angiography, as these patients are not captured routinely within the ANZACS-QI registry. Guidelines for in-hospital management of ACS were published during lockdown and supported the consideration of alternative strategies for treating patients with COVID-19 [33-35]. These included the use of fibrinolytic therapy for STEMI and deferral of coronary angiography for NSTEMI-ACS without high risk features. Such a change in the investigation and management of patients with ACS is a less likely contributor to the current findings given the low incidence of COVID-19 in NZ. Furthermore, there was no change in demographics or clinical characteristics of ACS patients during lockdown, suggesting no major change in referral for angiography.

The reduction in community laboratory testing is indicative of reduced referral for testing from primary care during the lockdown period. This may be due to fewer individuals seeking medical attention with their primary care physician, but there were also important changes to primary care provision during the lockdown period that may influence testing volumes. Virtual consultations were encouraged, requesting of laboratory tests that were unlikely to alter patient management were discouraged and some laboratory testing depots were closed. Access to urgent laboratory tests, including high-sensitivity troponin I, did not change and rapid turnaround times were maintained. The lower ambulance attendance rates from healthcare facilities also suggest lower rates of referral from primary care to hospital during the lockdown.

Some changes in in-hospital ACS management were observed during lockdown. The time to diagnostic coronary angiography was reduced in patients presenting with NSTEMI-ACS. This is likely due to less patients with ACS in hospital and an increase in available catheterisation laboratory capacity due to cancellation of elective coronary and structural interventional procedures. Despite re-

quiring personal protective equipment for possible COVID-19 cases, there was no increase in door-to-balloon time observed for STEMI presentations, unlike in other reports [8]. More patients received revascularisation by PCI compared to CABG during the lockdown. This may reflect a preference for multi-vessel PCI instead of surgical revascularisation to minimise intensive care unit occupancy and hospital length of stay. As a result, shorter length of hospital stay was observed. There was no effect on in-hospital mortality. The proportion of patients hospitalised with STEMI who did not receive reperfusion or revascularisation is relatively high, although consistent with previously reported national data [36]. The reasons for this are not able to be ascertained from the available ANZACS-QI registry data. Late presentation STEMI, absence of obstructive coronary disease or complex/diffuse coronary disease not amenable to revascularisation may be possible causes.

The phenomenon of reduced ACS presentations reported in this and other studies holds important lessons for the management of a “second wave” of COVID-19 or another future pandemic. While stringent pandemic management measures were effective, they are likely to have contributed to individuals refraining from accessing healthcare for non-COVID-19 conditions. In the context of ACS, such delays in presentation are associated with worse outcomes [37] including cardiac death, recurrent angina or ACS, heart failure and arrhythmias. With the easing of lockdown restrictions, healthcare systems should plan to accommodate a “catch-up” phenomenon related to these possible late presentations with ACS and their sequelae. Further research to carefully evaluate the factors contributing to delayed or non-presentation in patients with ACS are required.

4.1. Strengths and limitations

To our knowledge, this is the first study using a comprehensive and established national registry to report changes in hospitalisations for ACS during a nationwide COVID-19 lockdown. It is supported by data providing important insights into the prehospital investigation and management of patients with suspected ACS from national ambulance and regional community laboratory registries.

A limitation of this study is that it was restricted to patients admitted to hospital with ACS who underwent coronary angiography. As a result, any potential increase in the proportion of those hospitalised for ACS that were managed without an invasive strategy would not have been detected. However, this is unlikely to be a major contributor given the low number of hospital admissions for COVID-19 and current guidelines stressing the importance of maintaining standard care for patients with ACS and without concurrent COVID-19 [33–35]. This study did not capture patients with an ACS that were not hospitalised during the lockdown period and the causes for non-presentation were not identifiable. In addition, any patients that died in the community due to an ACS prior to medical contact were not recorded in the registries used in this study. The longer-term outcomes of patients with ACS admitted during the lockdown and event-rates following de-escalation of lockdown restrictions were not available for this analysis.

5. Conclusions

Despite the low incidence of COVID-19 in NZ, a decrease in ACS hospitalisations was observed during the 5-week lockdown. A number of factors are likely to have contributed to this finding. For instance, the reduction in hospitalisations for NSTEMI-ACS and not for STEMI suggests that those with less severe symptoms opted to avoid contact with hospitals. Secondly, the decrease in ambulance attendances for cardiac arrests supports a possible decline in the true incidence of ACS during lockdown. Finally, a change in the

delivery of primary healthcare, as suggested by lower community laboratory testing, may have led to less referrals for hospitalisation. This analysis suggests that the increased out-of-hospital mortality observed in regions with a high community burden of COVID-19 [27–29] may predominantly reflect the direct and indirect consequences of COVID-19, rather than the consequence of the lockdown alone. The findings of this study have important implications for healthcare delivery planning and public health policy in any future pandemic.

Author contributions

DZC, RAS, AJK, BD, CVK, TSm, AHS, VFT, MWW, JBS contributed towards the study conception and design. DZC, BD, CVK, CF, MR, ML, YBL and VFT contributed to data acquisition and analysis. RAS, AJK, PDA, GD, JE, SEJ, JME, NF, TSc, MKS, MJW, HDW contributed towards data interpretation. DZC, RAS and JBS drafted the manuscript. AJK, BD, CVK, PDA, GD, JE, SEJ, JME, NF, CF, ML, YBL, MR, TSc, TSm, MKS, VFT, MWW, MJW, HDW provided critical appraisal of the manuscript. All authors gave final approval of the version to be published and agreement to be accountable for all aspects of the work.

Data sharing statement

Deidentified participant data that underlie the results reported in this article and data dictionaries will be available beginning 3 months and ending 5 years following article publication. Data will be made available to investigators whose proposed use of the data has been approved by an independent review committee, to achieve the aims in the approved proposal. Proposals should be directed towards the corresponding author to gain data access. Data requestors will need to sign a data access agreement.

Declaration of Competing Interest

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Supplementary materials

Supplementary material associated with this article can be found, in the online version, at [doi:10.1016/j.lanwpc.2020.100056](https://doi.org/10.1016/j.lanwpc.2020.100056).

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