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Effect of Austrian COVID-19 lockdowns on acute myocardial infarction frequency and long-term mortality: a multicentre observational study

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ABSTRACT

Objectives The aim of this study was to find out if the decrease in acute myocardial infarction (AMI) admissions during the first COVID-19 lockdowns (LD), which was described by previous studies, occurred equally in all LD periods (LD1, LD2, LD2021), which had identical restrictions. Further, we wanted to analyse if the decrease of AMI admission had any association with the 1-year mortality rate.

Design and setting This study is a prospective observational study of two centres that are participating in the Vienna ST-elevation myocardial infarction network.

Participants A total of 1732 patients who presented with AMI according to the 4th universal definition of myocardial infarction in 2019, 2020 and the LD period of 2021 were included in our study. Patients with myocardial infarction with non-obstructive coronary arteries were excluded from our study.

Main outcome measures The primary outcome of this study was the frequency of AMI during the LD periods and the all-cause and cardiac-cause 1-year mortality rate of 2019 (pre-COVID-19) and 2020.

Results Out of 1732 patients, 70% (n=1205) were male and median age was 64 years. There was a decrease in AMI admissions of 55% in LD1, 28% in LD2 and 17% in LD2021 compared with 2019.

There were no differences in all-cause 1-year mortality between the year 2019 (11%; n=110) and 2020 (11%; n=79; p=0.92) or death by cardiac causes [10% (n=97) 2019 vs 10% (n=71) 2020; p=0.983].

Conclusion All LDs showed a decrease in AMI admissions, though not to the same extent, even though the regulatory measures were equal. Admission in an LD period was not associated with cardiac or all-cause 1-year mortality rate in AMI patients in our study.

STRENGTHS AND LIMITATIONS OF THIS STUDY

⇒ Prospective, multicentre study with large sample size.
⇒ First study to analyse the effect of the COVID-19 lockdowns on the long-term outcome of patients with acute myocardial infarction in a western population.
⇒ Contains data of only two major ST-elevation myocardial infarction network centres in Vienna.
⇒ Observational study cannot be used to demonstrate causality.

INTRODUCTION

Since the worldwide outbreak of SARS-CoV-2 coronavirus disease-2019 (COVID-19) and the following strict government restrictions (so-called lockdowns (LD)), many studies worldwide have reported a decrease in acute myocardial infarction (AMI) hospital admissions.[1–8] Some studies described a decrease in the admission rate of ST-elevation myocardial infarction (STEMI),[9–13] while others reported a decrease in non-STEMI (NSTEMI) admissions[14] and some observed a decrease in both STEMI and NSTEMI admissions.[1 3 5–7]

Literature on whether this decrease in AMI hospital admissions has any effect on the in-hospital outcome and mortality is still scarce and shows conflicting results. While some studies described an increase in in-hospital mortality in STEMI[3 11] or NSTEMI patients[15] others did not find any changes of the in-hospital mortality in AMI patients during the COVID-19 pandemic.[7 10]

In Austria, three nationwide LD with identical restrictions (closed schools, restaurants, hotels, non-essential businesses, shops and facilities) were implemented. The first LD started on 16 March 2020 and lasted until the 1 May 2020. The second LD was from 17 November to 6 December 2020. In 2021, an additional 3-week nationwide strict LD was announced from 22 November 2021 to 11 December 2021.

The aim of this study was to determine whether the widely described decrease in

AMI during the COVID-19 LDs only occurred in the first or also in the second and third LDs, which had identical contact restrictions as the initial one.

Further, we wanted to evaluate if there was an impact on long-term mortality in AMI patients.

METHODS

Study design

In this prospective multicentre study, data of all patients with AMI who had been admitted through the emergency departments in two major STEMI network centres were collected prospectively from 2019 to 2020 and the LD period of 2021. All patients were treated in the cardiac catheterisation laboratory where the diagnosis acute coronary syndrome was confirmed. We did not include patients that were not admitted to the catheterisation lab. Diagnostic criteria of type 1 myocardial infarction according to the fourth universal definition of myocardial infarction[16] were applied. Patients with types 2–5 myocardial infarction and myocardial infarction with non-obstructive coronary arteries were excluded from our study.

The collected data included baseline characteristics such as age, sex, cardiovascular risk factors and comorbidities, blood parameters, duration of preclinical-symptomatic phase (onset of chest pain to hospital admission) and outcome parameters. Cardiogenic shock, cardiopulmonary resuscitation (CPR) and in-hospital death were defined as short-term outcome parameters.

To evaluate the long-term outcome 1-year mortality, data were provided by 'Statistik Austria', an independent non-profit-making federal institution that supports scientific services.

Patient and public involvement

Patients or the public were not involved in the design, or conduct, or reporting, or dissemination plans of our research.

Statistical analysis

Patients were split into three LD groups (LD 1, LD 2, LD 2021) according to their admission date. Data of all patients with AMI from 2019 were used as reference for the pre-COVID-19 period.

Continuous variables were expressed either as a median and interquartile range (IQR) or as a mean and standard deviation (±SD) based on their distribution. For further comparison, the Student's t-test or univariate analysis of variance was performed. Categorical variables were expressed as absolute numbers and percentage and compared with a χ^2 test. Differences in baseline characteristics, cardiovascular risk factors, blood parameters and short-term outcome of each LD group were compared with the reference group of 2019.

To analyse the frequency of AMI, STEMI and NSTEMI hospital admissions during the LD periods the numbers of patients (p) were divided by the number of weeks (w) of each LD resulting in patients per week (p/w) and subsequently compared with the weekly average of admissions of 2019. Changes of the weekly hospital admission rates between 2019 and the LD periods were expressed in percentages. Additionally, data of all unplanned hospital admissions of 2019, LD 1, LD 2 and LD 2021 were collected and the ratios of AMI admissions to all unplanned hospital admissions were calculated.

Further, in order to take possible seasonal changes into account, the absolute numbers of admissions (patients) of each LD were compared with the equivalent time period of 2019.

The 1-year mortality of 2019 and 2020 was calculated with the Kaplan-Meier estimate and compared using the log-rank test. Further, the 1-year mortality of AMI patients admitted during the LD periods was compared with the 1-year mortality of all AMI patients of 2019 as well as to AMI patients of the equivalent time period of 2019. To evaluate factors predictive for the patients 1-year mortality an univariate regression model was performed. Variables that were significant in univariate analysis were included in a multiple regression model to search for independent predictors. To visualise the distribution of AMI admissions in 2020 compared with the incidence of the COVID-19 infections over time, we created a figure using the open data 'COVID-19: Timeline of data on COVID-19 cases per province' from the BMSGPK, 'Österreichisches COVID-19 Open Data Informationsportal' (https://www.data.gv.at/COVID-19) showing the 7-day incidence of COVID-19 and the AMI admissions in patients per month over the year 2020.

A (two-sided) p-value <0.05 was defined to be statistically significant. Data were managed using MS Excel 2016 (Microsoft, Redmond, California, USA). All statistical analyses were performed using SPSS statistics V.27 (IBM Corporation, Somers, NY).

RESULTS

In total 1732 patients with AMI were included in our study of whom 60% (n=1032) had an STEMI and 40% (n=700) an NSTEMI.

Baseline characteristics

All baseline characteristics are shown in table 1.

The median age was 64±13 years and 70% (n=1205) of all patients were male, 54% (n=934) had hypertension, 35% (n=608) hyperlipidaemia, 24% (n=409) were diabetics, 42% (n=735) smokers and 9% (n=149) had a positive family history for cardiovascular disease.

The mean delay of onset of symptoms to admission to the emergency department was 145 (IQR: 75–420) minutes for STEMIs and 445 (IQR: 146–1513) minutes for NSTEMIs. Median troponin T values at admission were 104 ng/L (IQR: 32–556) and median N-terminal prohormone of brain natriuretic peptide (NT-proBNP) levels were 470 pg/mL (IQR: 138–1900) and there were

Table 1 Baseline characteristics

	All (n=1732)	2019 (n=962)	LD 1 (n=59)	LD 2 (n=40)	LD 2021 (n=46)
Age (years)	64±13	64±13	62±12	61±11	67±11
Male	1205 (70%)	692 (72%)	43 (73%)	29 (73%)	28 (61%)
BMI	27±5	28±5	28±3	28±6	27±5
Hypertension	934 (54%)	519 (54%)	33 (56%)	21 (53%)	30 (65%)
Hyperlipidaemia	608 (35%)	313 (33%)	27 (46%)	17 (43%)	24 (52%)
Family history	149 (9%)	84 (9%)	10 (17%)	8 (20%)	2 (4%)
Diabetes mellitus type II	409 (24%)	214 (22%)	15 (25%)	9 (23%)	11 (24%)
Smoking	735 (42%)	382 (40%)	29 (49%)	20 (50%)	17 (37%)
Atrial fibrillation	106 (6%)	58 (6%)	3 (5%)	0 (0%)	1 (2%)
Prior MI	350 (20%)	172 (18%)	18 (31%)	7 (18%)	13 (28%)
Systolic BP	139±29	139±30	136±28	140±30	135±31
Diastolic BP	81±31	81±27	79±16	83±22	77±21
HR (bpm)	84±34	83±19	85±18	85±14	81±17
Creatine Kinase (U/l)	179 (98–439)	185 (98–475)	167 (78–435)	152 (104–268)	183 (105–762)
Troponin T (ng/L)	104 (32–556)	116 (34–567)	65 (26–497)	63 (32–423)	196 (35–879)
NT-proBNP (pg/mL)	470 (138–1900)	425 (137–1896)	386 (108–1021)	623 (105–2645)	552 (147–1331)
Creatinine (mg/dL)	0.99 (0.82–1.19)	0.99 (0.82–1.19)	1.0 (0.8–1.18)	1.1 (0.9–1.3)	1.0 (0.8–1.2)
Delay symptoms—ED					
STEMI (minutes)	145 (75–420)	130 (70–450)	108 (64–283)	122 (78–331)	213 (133–767)
NSTEMI (minutes)	445 (146–1513)	460 (146–1406)	320 (92–2561)	1198 (625–2348)	411(243–726)

BMI, body mass index; BP, blood pressure; bpm, beats per minute; ED, emergency department; HR, heart rate; LD, lockdown; MI, myocardial infarction; NSTEMI, non-ST-elevation myocardial infarction; NT-proBNP, N-terminal prohormone of brain natriuretic peptide; STEMI, ST-elevation myocardial infarction.

no statistically significant differences between any of the collected laboratory parameters between the LD groups.

Frequency of hospital admissions during the LD periods

The frequency of overall AMI (with subgroups of STEMI and NSTEMI) admissions during the LD periods and the average of 2019 are shown in figure 1.

The frequency of AMI admissions decreased from a weekly average of 18.5 p/w in 2019 to 8.4 p/w in the first LD (−55%). In the second LD the admission rate of all AMI was 13.3 p/w (−28% from 2019 average). Further, an increase of AMI admissions was observed in the no LD periods after LD 1 (12.2 p/w) and LD 2 (16.3 p/w) as shown in online supplemental figure 1).

In the LD 2021, the AMI admission frequency decreased to 15.3 p/w (−17% from 2019 average).

The frequency of STEMI patients decreased by 51% from 10.7 p/w in 2019 to 5.3 p/w in the first LD. This decline in STEMI admissions was smaller in the second LD with 9.7 p/w which is a decrease of 9% as compared with the average of 2019. During the LD 2021, the STEMI admission frequency was 8.7 p/w (19% lower than 2019 average).

Moreover, NSTEMI admissions decreased substantially from 7.8 p/w in 2019 to 3.1 p/w in the first LD (60% decrease). The frequency of NSTEMI in the second LD was 3.7 p/w (53% lower than the 2019 average). In the LD 2021, the NSTEMI admissions decreased to 6.7 p/w (−14% compared with 2019 average).

Comparing each LD period to the same time period in 2019 the AMI admissions during the first LD dropped with 54% (127 patients 2019 vs 59 patients 2020), the STEMI admissions decreased by 46% (69 patients 2019 vs 37 patients 2020) and NSTEMI admissions by 62% (58 patients 2019 vs 22 patients 2020).

In the second LD, the AMI admissions were 17% reduced (48 patients 2019 vs 40 patients 2020). There was no decrease in STEMI admissions (29 patients in 2019 and 2020), but the NSTEMI admissions in the second LD were 42% lower than in the equivalent time period of 2019 (19 patients 2019 vs 11 patients 2020).

Looking at the last LD 2021 overall 12% fewer patients with AMI were admitted than in 2019 (52 patients 2019 vs 46 patients 2021). While there was a 24% decrease in STEMI admissions (34 patients 2019

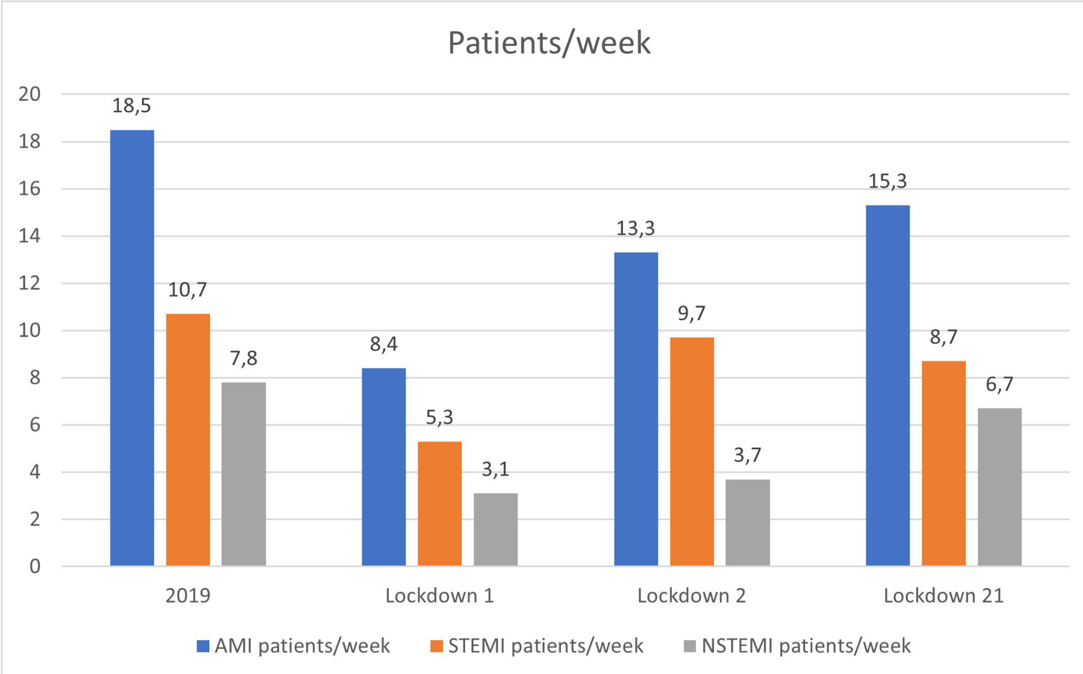

Figure 1 Admissions of acute myocardial infarctions (AMI), ST-elevation myocardial infarction (STEMI) and non-ST-elevation myocardial infarction (NSTEMI) in 2019 and during the lockdown periods (patients/week).

vs 26 patients 2021), NSTEMI admissions increased by 11% (18 patients 2019 vs 20 patients 2021).

The visualisation of the distribution of AMI frequency (patients/month) in 2020 and the 7-day COVID-19 incidence rate showed that during the decrease of AMI admissions in spring 2020 (LD 1) the COVID-19 incidence was quite low. Interestingly, during the fall of 2020 (LD 2), the decrease of AMI admission was not as pronounced as in LD 1, but the COVID-19 incidence rate was clearly higher than in the first LD (figure 2). The ratios of AMI admissions to all unplanned hospital

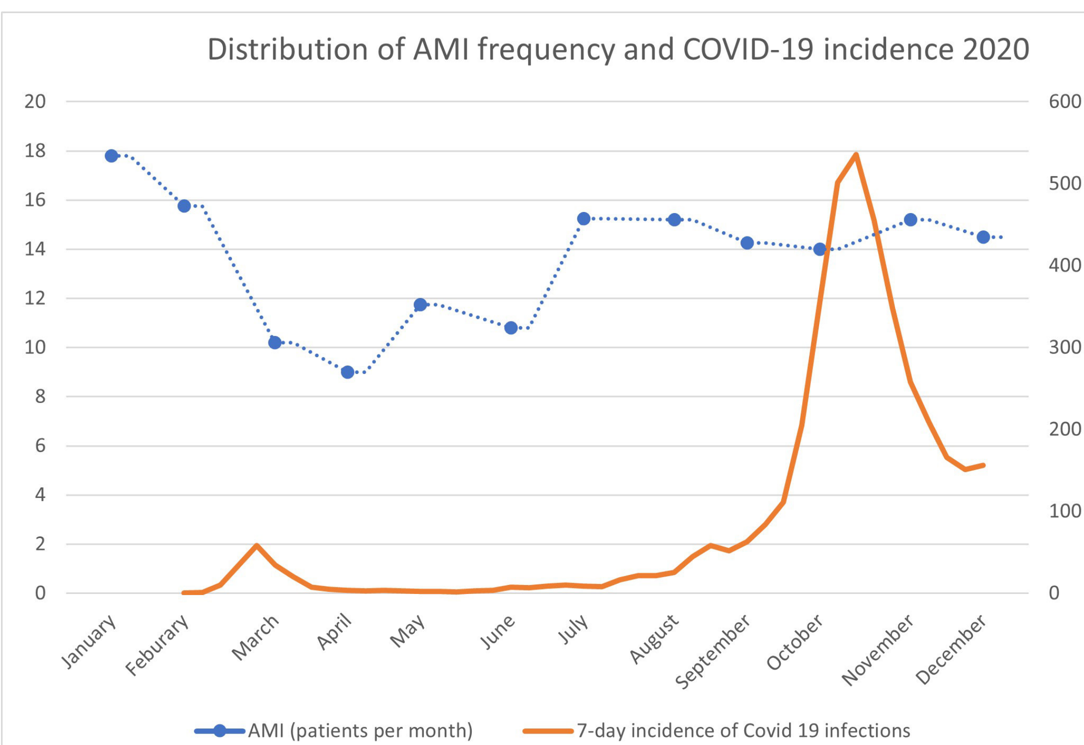

Figure 2 Distribution of acute myocardial infarction (AMI) frequency (patients/month) and COVID-19 7-day incidence rate of 2020.

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Table 2 Short-term outcome parameters and 1-year mortality

	All (n=1732)	2019 (n=962)	LD 1 (n=59)	LD 2 (n=40)	LD 2021 (n=46)	P value*	P value†	P value‡
Cardiogenic shock	94 (5%)	58 (6%)	3 (5%)	3 (8%)	2 (4%)	0.766	0.703	0.638
CPR	81 (5%)	41 (4%)	6 (10%)	3 (8%)	7 (15%)	0.036	0.327	0.001
In-hospital death	52 (3%)	29 (3%)	0 (0%)	1 (3%)	3 (7%)	0.176	0.852	0.185
One-year mortality								
All-cause mortality	189 (11%)	110 (11%)	7 (12%)	4 (10%)	–	0.920	0.780	–
Cardiac mortality	168 (10%)	97 (10%)	6 (10%)	4 (10%)	–	0.983	0.986	–

*Denotes comparison between 2019 and LD 1.
†Denotes comparison between 2019 and LD 2.
‡Denotes comparison between 2019 and LD 2021.
CPR, cardiopulmonary resuscitation; LD, lockdown.

admissions are presented in online supplemental table 1.

In-hospital outcome

Cardiogenic shock, CPR and in-hospital death were defined as short-term outcome parameters and are shown in table 2. In total 5% (n=94) of all patients had a cardiogenic shock, CPR had to be performed on 5% (n=81) of the patients and overall, 3% (n=52) died in hospital. There were significant higher numbers of CPR admissions in the first LD (p=0.036) and in the LD 2021 (p=0.001) compared with the average number of 2019, but there were no significant differences in cardiogenic shock or in-hospital death between the groups (table 2).

One-year mortality

One-year mortality data of 2019 and the LD periods of 2020 are shown in table 2.

Overall, the 1-year all-cause mortality rate for AMI patients was 11% (n=189) with no significant difference between STEMI (12%; n=117) and NSTEMI (11%; n=72) patients (p=0.506). In 2019,the all-cause 1-year mortality rate was 11% (n=110) and in 2020 11% (n=79) with no significant difference between the pre-COVID-19 year 2019 and the COVID-19 year 2020 (p=0.736). Kaplan-Meier curves demonstrated similar mortality for both years as shown in figure 3.

Further, comparing the mortality rate of cardiac related death of 2019 (10%; n=97) with 2020 (10%; n=71) no significant difference could be found (p=0.851).

The comparison of the all-cause 1-year mortality rate of LD 1 (12%; n=7) with the identical time period of 2019 (14%; n=18) also showed no significant difference (p=0.667). Looking at the second LD the mortality rate was 10% (n=4) as compared with 8% (n=4) of the identical time period of 2019 (p=0.787).

In multivariate analysis, we found a significant correlation between patients' sex, cardiac arrest before admission and cardiogenic shock on admission with all cause 1-year mortality. The admission during any of the LD periods in comparison to pre-COVID-19 era was not associated with any short-term or long-term outcome. Results of multivariate testing are displayed in table 3.

DISCUSSION

Our study confirmed the previously described trend of decreases in AMI admissions[1–8] during the first LDs at the beginning of the COVID-19 pandemic. This finding could later also be observed for both STEMI and NSTEMI in following LDs with identical restrictions as compared with the average admission frequency of 2019, although not to the same extent as in the initial LD.

Similar to findings of previous studies,[1 2] there were no differences in patient characteristics between the LD groups and the average patient population of the comparison year 2019 (table 1).

Fear of getting infected with COVID-19 in the hospital has been discussed in multiple previous studies as a possible explanation for the AMI decrease during the first LDs.[2 17 18]

In our study, the decrease in AMI admissions during the LD 2021 was the lowest of all LDs (−17% in LD 2021 vs −55% in LD 1 and −28% in LD 2 from the average of 2019). During that period, 71% of the Austrian population had already received their first COVID-19 vaccination leading to the assumption that the general fear of getting infected with COVID-19 in the hospital was lower than in the first and second LDs where no vaccinations against the virus had been available. However, our study showed a decrease in AMI admissions in all LD periods which indicates that fear of getting infected with the virus in the hospital might not be the only explanation for the drop of AMI admissions. To take possible differences in the frequency of all unplanned hospital admissions into account, we calculated ratios of AMI admissions to all unplanned hospital admissions. Interestingly, though we observed a decrease in all unplanned hospital admissions during the LD periods, a relative reduction of AMI admissions was found especially in LD 1, which strengthens our hypothesis of a true reduction of AMI admission during the LD periods.

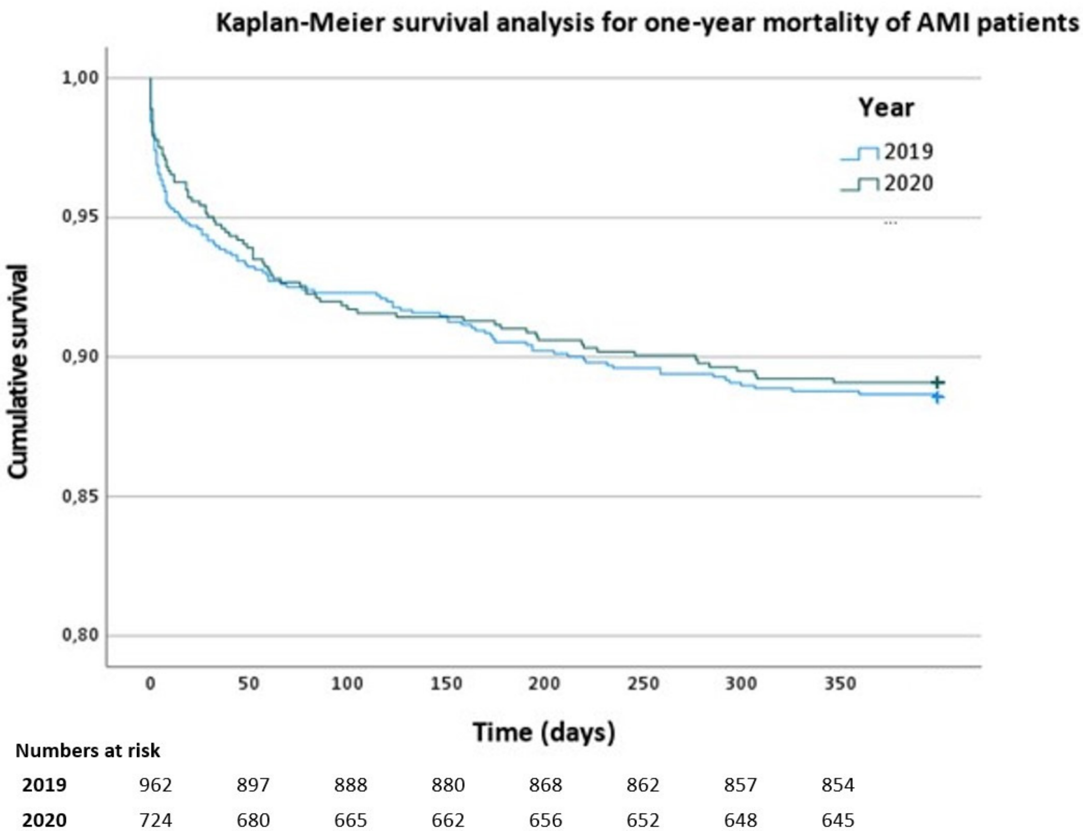

Figure 3 Kaplan-Meier analysis for all-cause 1-year mortality in acute myocardial infarction (AMI) patients 2019 vs 2020 (log rank: p=0.7).

A study from the Austrian Corona panel,[19] which questioned people about their risk assessment of COVID-19 showed that the fear of COVID-19 was similar in the first and second LD.[20]

However, the populations' compliance to follow the government restrictions decreased after the first LD. Kittel *et al* showed that in Austria ~90% of the people did not leave their home to visit friends or family members during the first LD, but this number decreased to ~41% during the second LD.[20]

In our opinion, this may well imply that the observed decrease in AMI admissions in our study was not only due to fear of getting infected with COVID-19 in the hospital, but also to a reduction in actual AMI triggers due to the LD restrictions. A relationship between AMI frequency and work-related stress has been discussed in previous studies which described an increase in AMI admissions in the working population on Monday[21 22] and an association between higher AMI risk and working overtime.[23] However, a higher risk of AMI on Mondays has also been described in elderly, retired patient populations leading to the assumption that other stress factors arising from life circumstances (eg, requirements due to family roles) have an impact on the AMI admission rate.[24] Therefore, reduction of work-related stress and social requirements due to the LDs (home-office, contact restrictions) may also have contributed to the decrease in AMI admissions during the LD periods.

Taking into consideration that the 1-year mortality of patients did not differ, regardless of admissions in COVID-19 period, in LD periods or before, we hypothesise that patients did not wait at home with ongoing AMI out of fear, but rather that the actual event rate decreased. Our data further supports this hypothesis since the intervals from pain onset to treatment did not differ.

Less exposure to external STEMI triggers such as ambient air pollution has also been discussed as a possible explanation for the decrease in AMI admission.[25] The pathophysiological pathways of acute and chronic effects of exposure to air pollution on the cardiovascular system have already been described elsewhere.[26] Many studies showed that the reduction of mobility during the COVID-19 LDs lead to a decrease of air pollution (NO_2,

Table 3 Multivariate regression analysis for all cause 1-year mortality

	Regression coefficient	OR (95% CI)	P value
Female sex	0.38	1.46 (1.03 to 2.05)	0.03
Age	0.01	1.01 (1.0 to 1.020)	0.27
Positive family history	−0.44	0.65 (0.32 to 1.31)	0.22
Cardiac arrest	1.59	4.92 (2.85 to 8.50)	<0.001
Shock	1.35	3.85 (2.32 to 6.38)	<0.001

$PM_{2.5}$).[27–29] However, a study from Mohajeri *et al* showed that the second LD in England had less mobility reduction resulting in higher NO_2 concentrations than the first LD.[30] The mobility in Austria was reduced by 72% in the first LD, however, the reduction was only 47% in the second LD and 30% in LD 2021 as compared with 2019.[31 32]

Because in our study the decrease in AMI frequency was higher in the first than in the second LD (−55% vs −28% compared with the average of 2019), we postulate that the higher mobility rate and the higher air pollution during the second LD might have had an impact on the frequency of AMI admissions. We further observed a return to higher AMI frequencies in the no LD periods after LD 1 and LD 2 (online supplemental figure 1) which further strengthens our hypothesis that the observed decrease of AMI admissions during LD periods might have been due to reduced exposure to factors triggering AMI.

Regarding in-hospital outcome our study showed no difference in in-hospital mortality during the LD periods. This is in line with findings of a meta-analysis from Rattka *et al* who showed that even though some studies reported an increase of in-hospital mortality of STEMI patients during the pandemic,[33 34] on a more global scale the in-hospital mortality of the post-COVID-19 group is not significantly higher than before the pandemic.[35]

To our knowledge, this is the first study that analysed both the frequency of AMI in different and recent LD periods as well as the long-term mortality of a large cohort AMI patients during the COVID-19 pandemic in a western population.

We did not find any statistically significant differences in 1-year mortality of AMI patients between the pre-COVID-19 year 2019 and the COVID-19 year 2020. Additionally, we analysed the 1-year mortality of LD 1 and LD 2 and compared it to the identical time period of 2019, which also showed no significant difference. Similar findings have been described by Phua *et al* in a study from Singapore.[36]

This indicates that the decrease in AMI frequency did not affect the prognosis and long-term outcome of AMI patients.

Further, this finding strengthens our assumption that the decrease in AMI admissions was not (only) caused by patients presenting late to the hospital due to fear of getting infected with COVID-19, but rather that a general decrease of absolute AMI numbers had occurred, due to multiple reasons such as a reduction of social and work-related stress and environmental factors.

Limitations

Our study has several limitations that need to be considered. First, it is an observational study and therefore cannot be used to demonstrate causality. Second, even though we described a decrease in AMI admissions to the hospital and the long-term outcome of those patients, we do not have data concerning out of hospital cardiac deaths caused by AMI not admitted to the hospitals. Third, our sample size only includes data from two major STEMI network centres and should therefore be considered as limited. Given the large overall sample size and the prospectively collected data of excellent quality we still consider our findings to add value to the discussion of the impact of COVID-19 and measures against it on patients with AMIs.

CONCLUSION

We observed a decrease in AMI admissions during all COVID-19 LD periods, though not to the same extent, even though the regulatory measures were equal. The observed decrease might have been due to multifactorial reasons and admission during LD periods was not associated with increased 1-year mortality in our study. Further studies are needed to evaluate the underlying causes for the observed decreases of AMI admissions during the COVID-19 LD periods.

Contributors RAM and AS planned the study, drafted the protocol, acquired and analysed data, drafted the manuscript; DR and WS acquired data, drafted the protocol, revised the manuscript critically for important intellectual content; CW, GP, PS and GDK made substantial contributions to conception, design, analysis and interpretation of data, revised the manuscript critically for important intellectual content, AS accepts full responsibility for the finished work and/or the conduct of the study, had access to the data, and controlled the decision to publish. All authors have given final approval of the version to be published and agree to be accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved.

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Patient and public involvement Patients and/or the public were not involved in the design, or conduct, or reporting, or dissemination plans of this research.

Patient consent for publication Not applicable.

Ethics approval The study was approved by the Ethics Committee of the City of Vienna (EK21-198-VK).

Provenance and peer review Not commissioned; externally peer reviewed.

Data availability statement Data are available on reasonable request.

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