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The association of mode of location activity and mobility with acute coronary syndrome: a nationwide ecological study

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Abstract. Mohammad MA, Koul S, Gale CP, Alfredsson J, James S, Fröbert O, Omerovic E, Erlinge D (Skåne University Hospital, Lund, Sweden; University of Leeds, Leeds, UK; Linköping University, Linköping; Uppsala University, Uppsala; Örebro University, Örebro; and Sahlgrenska Academy at University of Gothenburg, Gothenburg, Sweden). The association of mode of location activity and mobility with acute coronary syndrome: a nationwide ecological study. *J Intern Med* 2021; **289**: 247–254.

Background. We aimed to study the effect of social containment mandates on ACS presentation during COVID-19 pandemic using location activity and mobility data from mobile phone map services.

Methods. We conducted a cross-sectional study using data from the Swedish Coronary Angiography and Angioplasty Registry (SCAAR) including all ACS presentations during the pandemic until 7 May 2020. Using a count regression model, we adjusted for day of the week, daily weather and incidence of COVID-19.

Results. A 10% increase in activity around areas of residence was associated with 38% lower rates of ACS hospitalizations, whereas increased activity relating to retail and recreation, grocery stores and pharmacies, workplaces and mode of mobility was associated with 10-20% higher rates of ACS hospitalizations.

Conclusion. Government policy regarding social containment mandates has important public health implications for medical emergencies such as ACS and may explain the decline in ACS presentations observed during COVID-19 pandemic.

Keywords: acute coronary syndromes, location activity, mobility.

Introduction

The social containment mandates for coronavirus disease 2019 (COVID-19), ranging from social distancing to so-called 'lockdowns', have been differentially implemented between countries. To assist governments and public health agencies, Google and Apple have released aggregated mobility data from their map services to facilitate monitoring social distancing and interventions intended to minimize disease transmission [1,2]. In addition to the direct effects of COVID-19, the indirect effects of the pandemic, including declining rates of hospital admissions for a range of medical emergencies such as acute coronary syndrome (ACS), are being reported throughout the world [3–5]. Given the presentation and treatment of ACS are emergent, it could be considered a 'litmus test' for the study of the potential impact of COVID-19 on public health. We hypothesized that mode of location activity and mobility activity during COVID-19 may be associated with ACS hospitalizations. We used aggregated location activity data to determine whether day-to-day location activity relating to retail and recreation, grocery stores and pharmacies, transit stations, parks, workplaces and residential areas was associated with the incidence of admission with ACS. By combining clinical data from the nationwide Swedish Coronary Angiography and Angioplasty

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Registry (SCAAR) with mobility data available from Google, we were able to estimate the associations of movement trends and location activity with incident ACS hospitalization in Sweden. The results were subsequently validated using activity data categorized into driving, transits and walking, available from Apple.

Methods

Data sources and cohort study

All coronary angiographies with subsequent interventions in the 29 catheterization laboratories in Sweden are recorded in the SCAAR database providing complete, real-time coverage of angiographies and percutaneous coronary interventions in the country. Using SCAAR, we included all patients with ACS referred for coronary angiography. Mode of location data was obtained for 15 February–7 May 2020 made available by Google (https://www.google.com/covid19/mobility) and mode of mobility data for 14 January–7 May 2020 made available by Apple (https://www.apple.com/covid19/mobility). Location activity and mobility data show daily movement trends across several categories of locations and mobility forms compared with reference periods. Location activity data from Google report data in relation to the median value during the period from 3 January to 6 February 2020, whereas mobility data from Apple report data using 13 January 2020 as reference. Mode of location activity data from Google is categorized as retail and recreation, grocery and pharmacy, parks, transit stations, workplaces and residential areas, and mode of mobility data from Apple is categorized as driving, transit and walking. No personally identifiable information such as a specific individual's location or movement is reported by either data distributor.

Study design

We assessed the incidence rates of hospital presentations due to ACS for the period in which location activity and mobility data were available. Because location activity trends around workplaces, shopping centres, or residential areas and mobility such as driving and walking typically vary according to the day of the week and weather, factors known to be associated with the incidence of ACS/MI, these factors were adjusted for [6,7]. Meteorological data were obtained from the Swedish Meteorological and Hydrological Institute. Finally, we adjusted for daily incidence of COVID-19 (defined as laboratory-confirmed COVID-19 infections and obtained from the Swedish Public Health Agency website www.folkhalsomyndigheten.se) in order to exclude potential confounding related to the indirect effects of the pandemic. The study adhered to the STROBE guidelines for observational studies, and the Regional Ethical Review Board in Lund approved the study.

Outcomes

We assessed the incidence of admissions with ACS as the primary outcome, with separate admissions relating to unstable angina (UA), non-ST-elevation myocardial infarction (NSTEMI) and ST-elevation myocardial infarction (STEMI) as secondary measures.

Statistical analysis

A Poisson regression model was fitted to assess the incidence rate ratio (IRR) for movement variables. Zero inflation was assessed visually based on histograms and did not restrain the models. All models were tested for goodness of fit using deviance goodness of fit and Pearson's goodness of fit. When overdispersion was present, a negative binomial regression model was used. Incidence rates are reported as daily incidence of ACS (absolute numbers) and incidence rate per 100 000 population per year. The primary statistical model was a multivariable analysis adjusted for day of the week as a categorical variable, weather parameters (aggregated mean air temperature, precipitation, sunshine duration and wind velocity) and daily incidence of COVID-19 in Sweden. The results of regression analyses are reported as unadjusted and adjusted IRR with 95% confidence intervals (CI) and interpreted as change in the incidence of ACS for each 10% increase in a category of activity. False discovery rate adjustment with the Benjamini–Yekutieli method was used to control for multiple testing in regression analyses. All analyses were conducted on complete case data due to low proportions of missing values. All statistical analyses were performed using R v.3.2.2 (The R Foundation for Statistical Computing, Vienna) and Stata version 16 for Macintosh (StataCorp, College Station, TX, USA). A two-sided P-value < 0.05 was considered significant.

Subgroup analysis

The incidence of ACS was investigated in prespecified subgroups. Subgroups were based on sex, age

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and the presence of the risk factors such as diabetes, hypertension, hyperlipidaemia, history of MI and smoking status (current smoker vs. past smoker/nonsmoker).

Results

Patient characteristics and location activity data

During the study period for which Google location activity data were available (15 February–7 May 2020), there were 4388 admissions with ACS referred for coronary angiography and 6363 patients during the period for which Apple mode of mobility data was available (14 January–7 May 2020). A total of 25.4% were admitted due to UA, and 47.9% and 26.7% due to NSTEMI and STEMI, respectively. Baseline characteristics are presented in Table S1. All modes of location activity data categories except for mobility around parks and residential areas declined significantly during the study period (Fig. 1). The most pronounced decline was observed for the categories retail and recreation and transit-related activity, which saw a 40–60% decline during the study period.

Mode of location activity and incidence of acute coronary syndrome

Presentation with ACS and its subtypes decreased during the COVID-19 pandemic (Figure S1). After adjusting for day of the week, weather and COVID-19 daily incidence rate, strong associations with ACS were observed for all mobility categories except for activity around parks. A 10% increase in activity relating to retail and recreation was associated with a 15% increase in ACS incidence (IRR = 1.15, 95% CI, 1.11 to 1.20; $P < 0.001$), a 22% increase in UA alone and a 13% increase in overall MI (Fig. 2 and Fig. 3). The smoothed conditional mean plots showed a twofold incidence of ACS, increasing from approximately 170 to 340 per 100 000 years when retail and recreation activity increased from the lowest levels observed during the study period to the reference levels (Fig. 2). Similar results showing ACS-positive association with mobility around grocery stores and pharmacies were observed. Each 10% increase in this category was associated with a 14% increase in ACS incidence (adjusted IRR = 1.14, 95% CI, 1.07 to 1.22; $P < 0.001$) (Fig. 2). An increase in activity around transit stations was associated with 17% increase in ACS (adjusted IRR = 1.17, 95% CI, 1.13 to 1.22; $P < 0.001$) (Fig. 2). A 10% increase in activity around workplaces was associated with 12% increase in ACS incidence (adjusted IRR = 1.12, 95% CI, 1.08 to 1.15; $P < 0.001$), and a 10% increase in activity around homes was associated with 38% decline in ACS incidence (adjusted IRR = 0.62, 95% CI, 0.56 to 0.70; $P < 0.001$) (Fig. 2).

Results were consistent across subgroups with respect to sex and age, as well as the presence of diabetes, hypertension, hyperlipidaemia, history of MI and smoking (Table S2). The effect estimates were higher for UA than MI for all modes of location activity categories (Fig. 3). No association of increased or decreased activity in any category with the incidence of STEMI was observed. Comparable results were obtained using the mobility data from Apple Inc. For each 10% increase in transit-related activity, there was an associated 10% increase in ACS admissions (adjusted IRR = 1.10, 95% CI, 1.07 to 1.12], $P < 0.001$) with similar results obtained for walking and driving (Fig. 2 and Fig. 3).

Discussion

This nationwide ecological study identified the types of public location activities associated with the incidence of hospitalized ACS – a common medical emergency. We found that during the COVID-19 pandemic, increased activity around homes and areas of residence was associated with a lower rates of ACS hospitalizations, whereas increased activity relating to retail and recreation, grocery stores and pharmacies, workplaces and mode of mobility (driving, walking and transit) was associated with higher rates of ACS hospitalizations.

Aggregated mobility data have been used to understand the spread of epidemics and are currently being employed to limit the spread of COVID-19 [8–11]. To the best of our knowledge, this is the first time this type of data has been used to elucidate the incidence of ACS. The onset of social containment – a state of lockdown – has been implemented in many but not all countries in an attempt to reduce the spread of COVID-19. Sweden has remained a more open society during the COVID-19 pandemic but still with strong restrictions. Yet, analysis of location activity data reveals significant alterations during this period. Activity related to all measured categories declined except for activity around parks and residential areas, which increased during the pandemic (Fig. 1), correlating with the warnings issued by the Swedish Public

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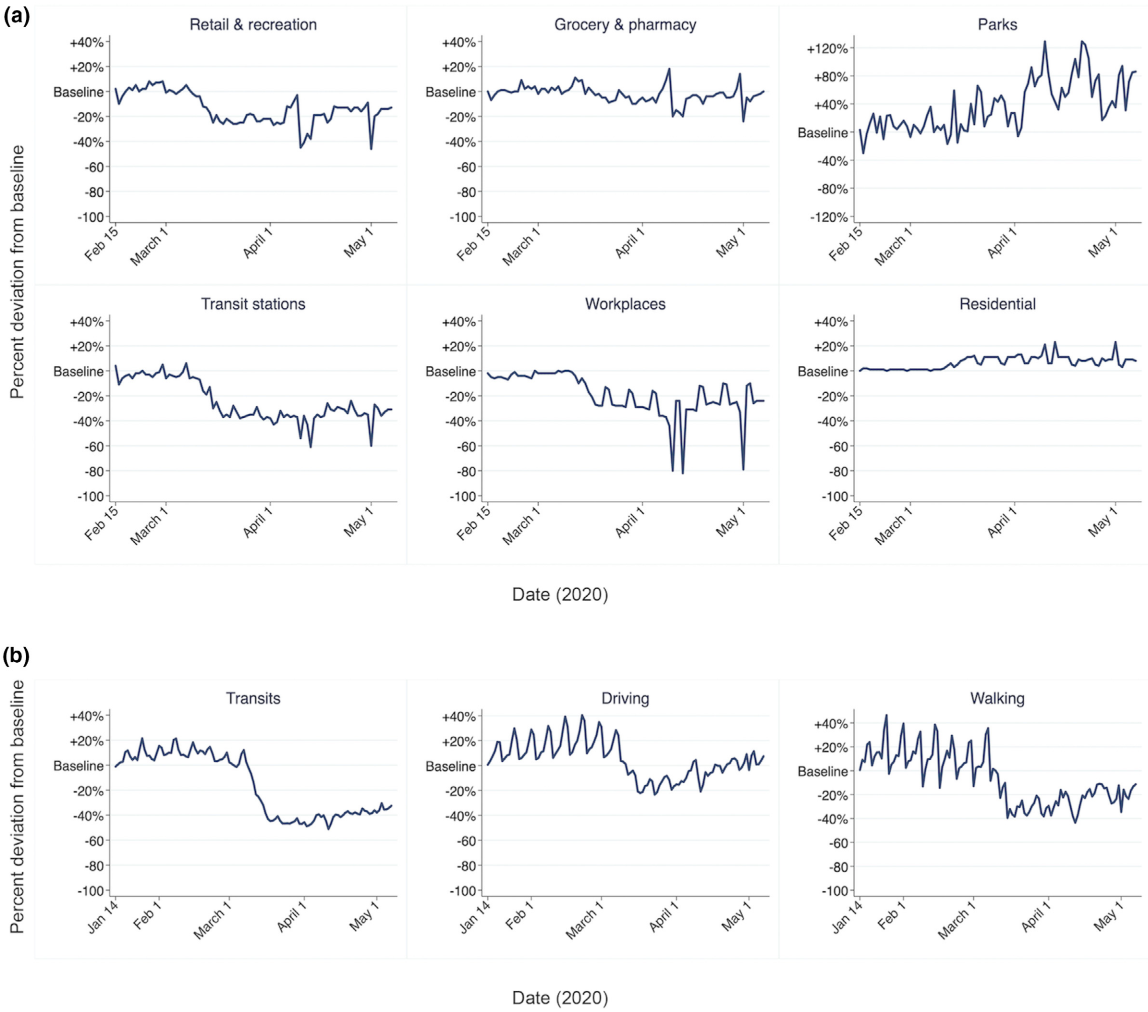

Fig. 1 *Movement trends revealed by (a) mode of location activity and (b) mode of mobility.*

Health Agency on 16 March, recommending that individuals aged seventy years and older remain at home. Epidemics of respiratory tract infections and flu are usually associated with higher incidence of ACS [12]. The current epidemic on the contrary has been associated with lower rates of ACS hospitalizations [3–5]. Avoidance of health care, hospital bed scarcity and overburdened healthcare systems has been suggested as explanations for the decline. However, no hospital bed scarcity, higher mortality or change in quality-of-care indicators have been observed with respect to coronary care in Sweden during this time period [13].

Self-isolation, working from home and less rigorous recreational activities may therefore have decreased stress- and exertion-induced ACS in individuals at risk and can possibly explain the decline in incidence of MI as the association between psychological stress and physical exertion, and incidence of MI/ACS is well-established [14,15]. As a result of social spacing and improved hand hygiene, the transmission of other viruses known to cause respiratory tract infections and act as triggers of underlying coronary artery disease has decreased, possibly contributing to this decline [16,17]. We obtained similar results in the mobility validation data, further strengthen our observations. We find the results intriguing as they provide insight into how big data can be used to study trends in disease incidence and predict hospitalizations. Several disease entities are known to

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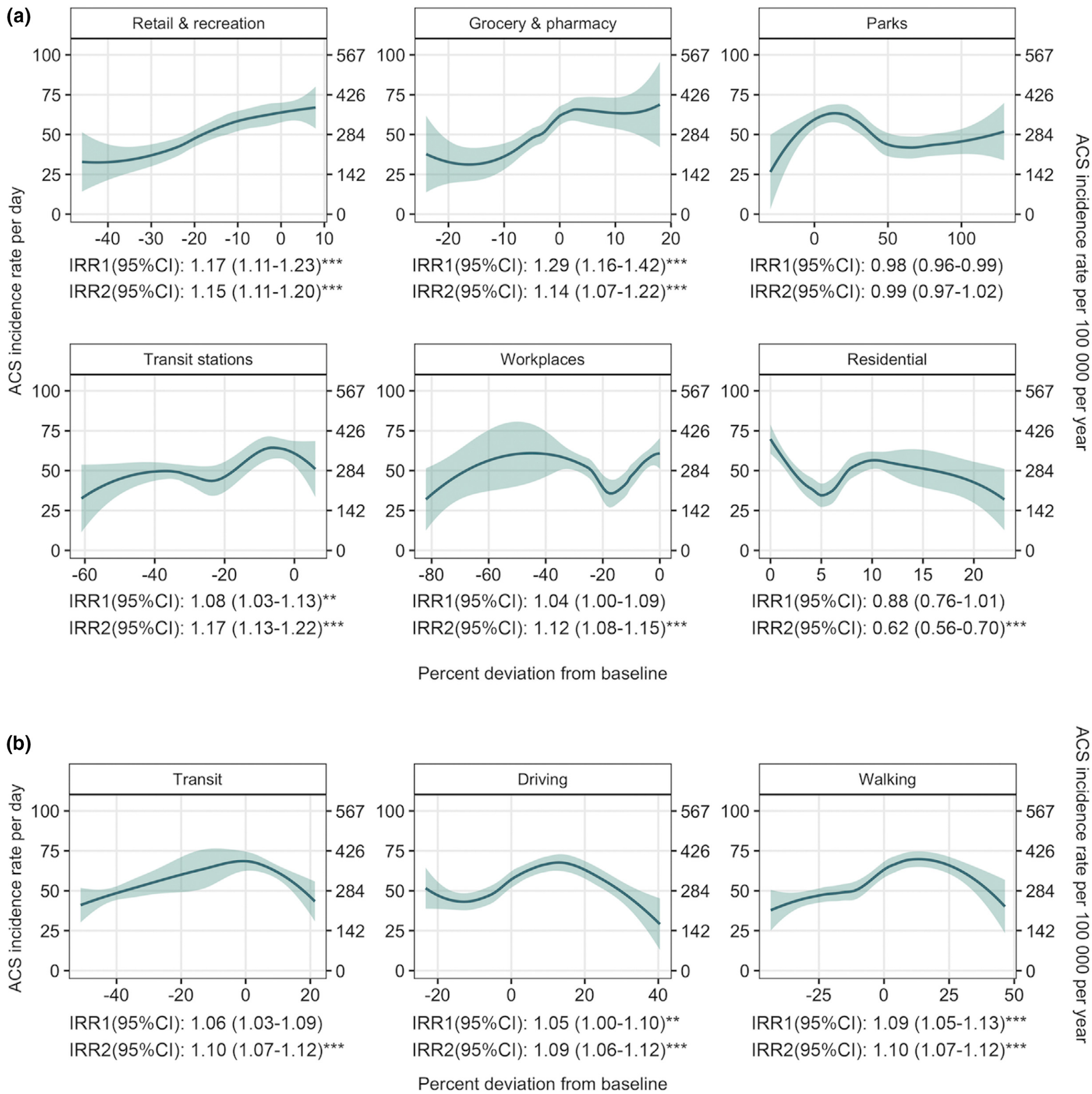

Fig. 2 *Incidence rate of acute coronary syndrome relative to mode of location activity and mobility data. Smoothed conditional mean plots illustrate the variation of incidence rates of acute coronary syndrome with 95% CI relative to mobility category. Results from the regression analyses are interpreted as ACS change per 10% increase in activity. Panel (a) illustrates mode of location activity data and (b) mode of mobility activity data. IRR1 = univariable model. IRR2 = multivariable model.* *$P < 0.05$; **$P < 0.01$; ***$P < 0.001$.

exhibit the same type of external trigger variation. For instance, stroke has been observed to have external triggers similar to those for MI, and as in MI, there have been observations of declining incidence of stroke during the COVID-19 pandemic [18].

This investigation comprised all patients with ACS referred for coronary angiography in Sweden and given that we only studied people who sought help at hospitals and referred for coronary angiography – an unknown proportion of patients may have had ACS and died at home or were treated

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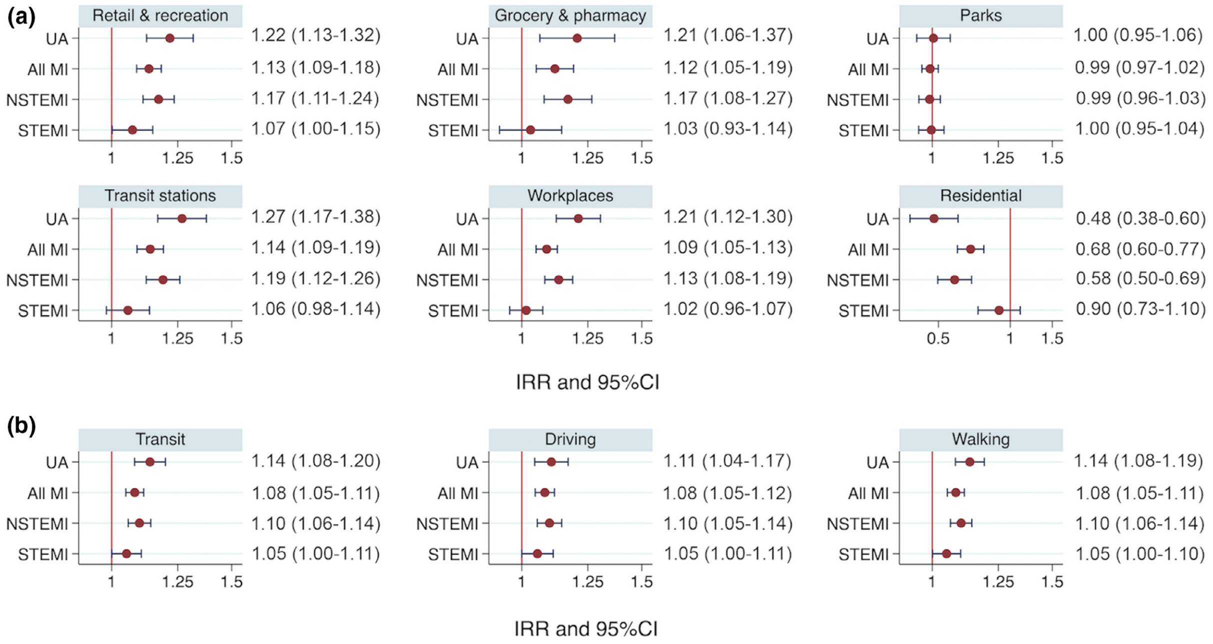

Fig. 3 *Incidence rate of subtypes of acute coronary syndromes relative to mode of location activity and mobility data. Forest plots visualizing incidence rate ratio with 95% confidence interval for subtypes of ACS by (a) mode of location activity and (b) mode of mobility activity. CI: confidence interval; IRR: incidence rate ratio; UA: unstable angina pectoris; MI: myocardial infarction; NSTEMI: non-ST-elevation myocardial infarction; STEMI: ST-elevation myocardial infarction.*

conservatively. There has been a significant decline in air pollutants secondary to travel bans and lockdowns since the outbreak of COVID-19 [19], and the association between air pollution and MI is well-established [20]. We were unable to adjust for air pollution as these data are not yet publicly available in Sweden, possibly confounding our results. Finally, because of the study's observational nature, causality cannot be established and confounding related to ecological fallacy cannot be ruled out as older patients with the highest risk of ACS may be the least active individuals.

Conclusions

Government policy regarding social containment mandates has important public health implications such as the presentation of medical emergencies such as ACS and may explain the decline in ACS presentations observed during COVID-19 pandemic. The impact of such policies may be monitored using aggregated mode of location activity and mobility data.

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Author contributions

MAM, DE and SK were involved in the study design, data analysis and drafting of the original version of the manuscript. All authors read, revised and approved the final manuscript. D. Erlinge and MA Mohammad are the guarantors. The corresponding author attests that all listed authors meet authorship criteria and that no others meeting the criteria have been omitted.

Conflicts of interest

All authors have completed the ICMJE uniform disclosure form at www.icmje.org/coi_disclosure.pdf and declare no support from any organization for the submitted work; no financial relationships

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with any organizations that might have an interest in the submitted work in the previous three years; and no other relationships or activities that could appear to have influenced the submitted work.

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Transparency statement

MA Mohammad had full access to all the data in the study and together with D Erlinge affirm that this manuscript is an honest, accurate and transparent account of the study being reported; that no important aspects of the study have been omitted; and that any discrepancies from the study as planned (and, if relevant, registered) have been explained.

Data availability statement

Data can be made available upon reasonable request.

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Supporting Information

Additional Supporting Information may be found in the online version of this article:

Figure S1. Relative difference in incidence of hospitalized ACS and it subtypes during COVID-19 pandemic compared to the same dates 2015-2019.

Table S1. Baseline characteristics.

Table S2. Subgroup analyses.

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