Dynamics of Emergency Cardiovascular Hospital Admissions and In-Hospital Mortality During the COVID-19 Pandemic: Time Series Analysis and Impact of Socioeconomic Factors

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Aims: This study aimed to evaluate the decline in urgent cardiovascular hospital admissions and in-hospital mortality during the COVID pandemic in two successive waves, and to evaluate differences by sex, age, and deprivation index subgroups.

Methods and Results: We obtained acute cardiovascular hospital episodes during the years 2019–2020 from region-wide data on public healthcare usage for the population of Catalonia (North-East Spain). We fitted time models to estimate the incidence rate ratios (IRRs) of the acute coronary syndrome (ACS) and acute heart failure (HF) admissions during the first pandemic wave, the between-waves period, and the second wave compared with the corresponding pre-COVID-19 periods and to test for the interaction with sex, age, and area-based socioeconomic level. We evaluated the effect of COVID-19 period on in-hospital mortality. ACS (n = 8,636) and HF (n = 27,566) episodes were defined using primary diagnostic ICD-10 codes. ACS and HF admissions decreased during the first wave (IRR = 0.66, 95%CI: 0.58–0.76 and IRR = 0.61, 95% CI: 0.55–0.68, respectively) and during the second wave (IRR = 0.80, 95%CI: 0.72–0.88 and IRR = 0.76, 95%CI: 0.69–0.84, respectively); acute HF admissions also decreased in the
期间有显著下降。这些下降可能与优先分配医疗资源有关（18）。可能的原因包括急症住院的减少，解释为改变急症条件，尽管这可能意味着对老化和机构化病人的犹豫，未能治疗，诊断错误，以及与COVID-19死亡率在老年人中的风险增加（19）。分析不同趋势的急症心血管住院在连续波段中可能有助于了解机制并预测未来趋势。在两次波段之间（BWP）分析可能有帮助。

结论：在第一波COVID-19疫情期间，急症心血管住院明显减少，但期间影响有所减弱。影响相似，不同性别、年龄、和经济地位的患者。老年人ACS的影响更大。在所有亚组，没有预期的ACS和HF事件增加。在所有性别中，住院死亡率高于预期的仅在第一波。

Keywords: COVID-19, acute coronary syndrome, myocardial infarction, heart failure, time-series

INTRODUCTION

During the first pandemic wave (FW) of coronavirus disease 2019 (COVID-19) between March and April 2020, there was a marked decline in admissions for acute coronary syndrome (ACS) (1–11), heart failure (HF) (12–14), and other non-COVID health conditions (15–17).

While prioritization of healthcare services explains decreases in elective admissions, explanations for the decrease in the attention of emergent conditions remain conjectural (18). Possible reasons attributed to the steep decrease in hospital admissions for acute cardiovascular problems were patients’ hesitation to refer to the hospital, missed diagnosis, and competing risk with COVID-19 mortality in the elderly and institutionalized patients (19). The analysis of differing trends of emergent cardiovascular admissions in successive waves periods and in the between-waves periods (BWP) might be useful to unravel the underlying mechanisms and to anticipate future trends. A few reports of results during the second pandemic wave (SW, between April and September 2020) indicate a second decline of unknown magnitude (20) despite information campaigns targeted at the affected populations.

Moreover, the COVID-19 pandemic has been shown to increase geographic, gender, and socioeconomic inequalities in access to healthcare (21). Age, gender, and deprivation level might influence behaviors in such ways that would imply a greater impact on more disadvantaged groups. Gender and age differences in admissions for acute myocardial infarction (MI) have been analyzed previously with differing results (22); but to the best of our knowledge, it has not been assessed in longer series (beyond the FW) considering socioeconomic indices. The potential influence of gender, age, and socioeconomic differences on the dynamic of admissions for acute HF decompensations has not been assessed so far.

Therefore, we aimed to evaluate the variations in ACS and acute HF hospital admissions during the COVID-19 pandemic period, including the FW and the SW, in comparison with the hospital admissions of the corresponding pre-COVID-19 pandemic periods. In addition, we aimed to assess whether age, gender, and socioeconomic status might have influenced these variations. Finally, we analyzed the predictors of in-hospital death.

MATERIALS AND METHODS

Population and Data Sources

We used region-wide data on public healthcare usage for the population of Catalonia, a North-East region in Spain with universal public healthcare coverage, with a reference population of more than 7 M and a hospital network of 11 reference tertiary hospitals performing percutaneous coronary intervention (PCI).

Data were accessed through the Public Data Analysis for Health Research and Innovation Program (PADRIS). PADRIS allows access to information from different sources linked at the patient level with warranted accomplishment of ethical principles and the Spanish Law of data protection 3/2018.

Acute coronary syndrome and HF episodes from 31 December 2018 to 27 December 2020 were extracted from the Minimum Basic Data Set (MBD). Index admissions were identified with the International Classification of Diseases (ICD)-10 as the primary diagnostic (see diagnostic codes in Supplementary Table 1). We selected only emergency admissions.

Weekly COVID-19 cases were obtained from the Open Access Data Portal of the Catalan Government. Confirmed cases were defined as having a positive RT-PCR test or rapid antigen test for SARS-CoV-2.

For each episode, we extracted sex, age in 5 years’ intervals, all diagnostic and procedure ICD-10 codes, region of residence, primary care service areas (PCSA), comorbidity status (AMG), and PCSA-based socioeconomic status (PCSA index). Despite information campaigns targeted at the affected populations.

Primary Care Service Areas Index

To strengthen territorial equity in the allocation of primary care resources, in 2015, the Catalan Health Department developed a socioeconomic deprivation indicator representative of the PCSA linked to adverse health outcomes. The indicator score ranges from 0 (less deprived) to 100 (more deprived) (23).

Comorbidity

The comorbidity index [Adjusted Morbidity Groups (AMGs)] score is a morbidity measure that enables assigning a weight based on the preexisting comorbidities (24). AMG explanatory value has been checked by comparing it with morbidity
measures such as the Charlson Index or the number of chronic
diseases (24).

Statistical Analysis
Based on the visual representation of the weekly number of
COVID-19 diagnostics, we defined the following periods of
analysis: pre-COVID (from 31 December 2018 to 23 February
2020), FW (from 24 February 2020 to 27 April 2020), BWP
(from 28 April 2020 to 20 September 2020), and SW (from
21 September 2020 to 27 December 2020). We considered the
beginning of the FW as the date when the first case in the
region was reported in the press (24 February 2020), although the
COVID registry started later.

Patients' characteristics were compared between each COVID
period and the corresponding pre-COVID period (same calendar
period in 2019). Continuous variables were reported as mean
(SD) or median (P25 to P75) and compared using Student's
\( t \)-tests or Kruskal-Wallis tests. Categorical variables were reported as \( n \)
(percentage) and compared using \( \chi^2 \) tests.

Weekly admissions for ACS and HF were depicted from
31 December 2018 to 27 December 2020. Negative binomial
regression was used to estimate the incidence rate ratios
(IRRs) and their 95% confidence intervals for ACS and acute
HF hospital admissions during the COVID-19 FW, during the
BWP, and during the SW compared with the expected admissions,
based on the pre-COVID-19 period. Using this approach, each IRR represents the ratio between the weekly number
of admissions in each period and the weekly number of admissions in the reference period. First, we modeled the
pre-COVID-19 time series to estimate the expected number of admissions in the COVID-19 periods by fitting sinusoidal
functions to control seasonality and autocorrelation. Best-fitted models were selected on the basis of minimizing deviance of the model and then fitted to the whole series including
COVID waves as indicators to calculate IRR. To show graphically the variations in ACS and HF hospital admissions attributable to the pandemic phases, we depicted the observed
vs. the expected admissions estimated from the pre-COVID-
19 model.

Finally, we fitted an additional set of models using fractional
polynomial coefficients to parameterize in a flexible way the
different descending and ascending slopes observed during the
pandemic period. We used the parameters of the fitted models to estimate the instantaneous rate of change in the different periods and the absolute decrease in each wave.

Different effects of COVID periods [FW, BWP, and SW
among sex, age (\(<80/\geq80\)), and PCSA index quartiles (first
quartile/fourth quartile)] were estimated by including two-way
interaction terms in regression models.

To assess whether changes in hospital mortality during the
COVID-19 period were due to the distortion in healthcare
during the pandemic or to changes in the risk profile of
patients, we performed logistic mixed-effects regression with in-
hospital mortality as the response variable and the pandemic
periods together as a covariable. We adjusted the model by
patients' characteristics [e.g., sex, age, comorbidity weight, type
of ACS (in ACS model), PCSA index quartiles]. We used
random slope models and non-structured covariance matrix for
random effects to account for repeated episodes of individual
patients and for the clustered structure of patients living in
different PCSA (371 PCSA). All analyses were performed with
R version 4.1.0.

RESULTS
After excluding elective admissions and patients younger
than 20 years old, we analyzed a series of 36,202 episodes
(corresponding to 34,575 patients) admitted for ACS (\( n = 8,424 \))
or HF (26,151) between 31 December 2018 and 27 December
2020 (Figure 1).

Tables 1, 2 show the characteristics of patients attended
for ACS and HF during each predefined COVID-19 period as
compared with each corresponding pre-COVID-19 period: FW,
BWP, and SW. The decline in admissions for every subgroup is
presented as a% change. The description of the complete cohort
is shown in Supplementary Table 2.

In general, patients admitted during the pandemic period had
less comorbidities, as reflected by a consistently lower AMG
score compared with the pre-COVID periods. In addition, in
both conditions, the total hospital length of stay was significantly
lower. Regarding ACS admissions (Table 1), the decline was
significantly higher for patients aged 80 years or older admitted
during the SW. Diagnostic episodes labeled as other AMI or other
ACS increased in the whole COVID-19 period. As compared
with the pre-COVID-19 period, the number of PCI remained
virtually the same during the FW but decreased slightly during
the BWP (−23%; \( p = 0.001 \)) and during the SW (−32%;
\( p = 0.01 \)). In-hospital mortality increased during the FW [8.86%
vs. 5.51% in the pre-COVID-19 period (\( p = 0.018 \)), and there
were no statistically significant differences neither during the
SW nor in the BWP.

Regarding acute HF admissions (Table 2), the proportion
of older people admitted during the BWP was significantly lower,
and in-hospital mortality was higher during the FW (7.41 vs.
9.26%; \( p = 0.022 \)) but lower during the BWP (7.46 vs. 6.38%;
\( p = 0.039 \)) and during the SW (7.63% vs. 5.94%; \( p = 0.007 \)).

Figure 2 shows the time series of ACS (Figure 2A) and HF
(Figure 2B) weekly urgent hospital admissions and the distortion
observed after the arrival of the pandemic wave. Both ACS and
HF admissions series showed a significant seasonality, with lower
admissions in summer weeks. After adjusting for seasonality and
autocorrelation, there was a marked decrease in ACS episodes
(Supplementary Figure 1A), reaching a maximum of 69.46%
cases below the expected [IRR 0.43 (0.37–0.50), \( p < 0.001 \)
coinciding with the highest peak of the FW. Then, after a recovery
in the BWP, the number of admissions decreased again in a
smoother way. Admissions for HF (Supplementary Figure 1B)
also decreased steeply to a 72.83% less than expected [IRR 0.21
(0.17–0.26), \( p < 0.001 \)] coinciding with the peak of the FW and
then returned to normal levels to immediately decrease again to
a sustained level about 30% below the expected.

The model parameters used to estimate IRRs and changes in
the weekly number of admissions are shown in Supplementary
Tables 3–6. The IRRs of ACS admissions for the FW, the BWP, and the SW were 0.66 (0.58–0.76), 0.92 (0.84–1.00), and 0.80 (0.72–0.88), respectively. The IRRs of HF admissions for the FW, the BWP, and the SW were 0.61 (0.55–0.68), 0.81 (0.74–0.89), and 0.76 (0.69–0.84), respectively. Supplementary Figures 2, 3 show the results of the models with fractional polynomic coefficients for ACS and HF.

Supplementary Figures 4–15 show the separate time series according to gender, age, and area-level deprivation index. For the IRRs of ACS admissions, there was a significant interaction with age in the BWP and in the SW (Figure 3), when the relative reduction in the weekly number of admissions was higher for older people. Despite an apparent recovery in the admissions for ACS in the BWP [IRR 0.92 (0.84–1.00)], ACS admissions remained lower than expected among women, older, and in most deprived areas. Regarding HF, there was a significant decline of a similar magnitude in all subgroups (Figure 4), and HF admissions remained significantly lower than expected during the whole pandemic period.

Table 3 shows the association between the COVID-19 epidemic periods and in-hospital mortality adjusted for patient demographics, AMG score, type of ACS, and PCSA index. Mortality risk, compared with the corresponding pre-COVID-19 periods, was higher during the FW for both ACS (OR: 2.29; 95%CI: 1.6–3.27; \( p < 0.001 \)) and HF episodes (OR: 1.33; 95% CI: 1.11–1.59; \( p = 0.002 \)). In addition, ACS episodes labeled as other MI had the highest mortality risk (8.9; 95% CI 5.44–14.58; \( p < 0.001 \)) as well as those episodes with a concomitant or recent diagnosis of coronavirus infection (OR: 4.1; 95% CI: 1.78–9.44; \( p = 0.001 \) and OR: 1.87; 95% CI: 1.22–2.86; \( p = 0.004 \) for ACS and HF, respectively).

DISCUSSION

This population-based time-trends analysis shows an important decrease in the number of emergent admissions for ACS and HF during the FW and during the SW compared with the corresponding pre-COVID-19 periods. This decrease was also present during the BWP, and it was similar among socioeconomic subgroups. However, there were less patients aged 80 years or older admitted for ACS during the BWP and the SW. Adjusted in-hospital mortality risk compared with the corresponding pre-COVID-19 periods was higher during the FW for both ACS and HF episodes despite a lower comorbidity weight and a similar rate of PCI.

Although the decrease in cardiovascular admissions was consistent during all the study periods, the impact of the SW
| TABLE 1 | Characteristics of patients admitted to hospital for acute coronary syndrome (ACS) in each period compared with the reference pre-COVID-19 period. |
|----------|----------------------------------------------------------------------------------------------------------------------------------|
|          | First wave period (24/02 to 27/04)                                                                                             | Between waves period (28/04 to 20/09)                                                                 | Second wave period (21/09 to 27/12)                                                                 |
|          | Pre-COVID-19 | COVID-19 | % change | P-value | Pre-COVID-19 | COVID-19 | % change | P-value | Pre-COVID-19 | COVID-19 | % change | P-value |
| N        | 817          | 519      | −36      | 0.368   | 1788         | 1308     | −12      | 0.159   | 1308         | 1001      | −23      | 0.526   |
| Women    | 250 (30.60)  | 171 (32.95) | −32      | 0.368   | 617 (34.51)  | 505 (32.21) | −18      | 0.159   | 449 (34.33)  | 331 (33.07) | −26      | 0.526   |
| Men      | 567 (69.40)  | 348 (67.05) | −39      | 0.368   | 1171 (65.49) | 1063 (67.79) | −9       | 0.159   | 859 (65.67)  | 670 (66.93) | −22      | 0.526   |
| Age      | 0.638        |          |          |         | 0.352        |          |          |         | 0.001        |          |          |         |
| < 80     | 579 (70.87)  | 374 (72.06) | −35      | 0.352   | 1288 (72.04) | 1152 (73.47) | −11      | 0.159   | 883 (67.51)  | 738 (73.73) | −16      | 0.001   |
| ≥ 80     | 238 (29.13)  | 145 (27.94) | −39      | 0.352   | 500 (27.96)  | 416 (26.53) | −17      | 0.159   | 425 (22.49)  | 263 (26.27) | −38      | 0.001   |
| Type of ACS          | < 0.001      |          |          |         | < 0.001      |          |          | < 0.001 | < 0.001      |          |          |         |
| Unstable angina    | 143 (17.50)  | 84 (16.18) | −41      | 0.054   | 272 (15.21)  | 274 (17.47) | 1        |         | 167 (12.77)  | 167 (16.68) | 0        |         |
| NSTEMI              | 560 (68.54)  | 325 (62.62) | −42      | 0.054   | 1249 (69.58) | 997 (63.58) | −20      |         | 944 (72.17)  | 671 (67.03) | 29       |         |
| STEMI               | 97 (11.87)   | 57 (10.98) | −41      | 0.054   | 228 (12.75)  | 95 (6.06)   | −58      |         | 173 (13.23)  | 63 (6.29)   | 64       |         |
| Other MI            | 8 (0.98)     | 43 (8.29)  | 438      | 0.054   | 14 (0.78)    | 161 (10.27) | 1050     |         | 10 (0.76)    | 75 (7.49)   | 650      |         |
| Other ACS           | 9 (1.10)     | 10 (1.93)  | 11       | 0.054   | 25 (1.4)     | 41 (2.61)  | 64       |         | 14 (1.07)    | 25 (2.50)   | 79       |         |
| AMG weight, mean (SD) | 32.92 (17.46) | 20.44 (16.29) | −38      | 0.054   | 31.82 (16.47) | 18.61 (14.44) | −41      | 0.054   | 31.19 (16.27) | 17.16 (13.85) | −45      | 0.054   |
| PCSA index, mean (SD) | 42.11 (15.27) | 42.68 (15.00) | 1       | 0.054   | 42.20 (14.62) | 41.24 (15.10) | −2       | 0.054   | 41.79 (14.56) | 42.05 (14.56) | 1        | 0.054   |
| Quantiles of PCSA index | 42.11 (15.27) | 42.68 (15.00) | 1       | 0.054   | 42.20 (14.62) | 41.24 (15.10) | −2       | 0.054   | 41.79 (14.56) | 42.05 (14.56) | 1        | 0.054   |
| 1st                | 202 (24.72)  | 116 (22.35) | −43      | 0.084   | 422 (23.60)  | 394 (25.13) | −7       |         | 324 (24.77)  | 221 (22.08) | −32      |         |
| 2nd                | 188 (23.01)  | 113 (21.77) | −40      | 0.084   | 428 (23.94)  | 376 (23.98) | −12      |         | 306 (23.39)  | 262 (26.17) | −14      |         |
| 3rd                | 187 (22.89)  | 139 (26.78) | −26      | 0.084   | 432 (24.16)  | 370 (23.60) | −14      |         | 305 (23.32)  | 236 (23.58) | −23      |         |
| 4th                | 215 (26.32)  | 145 (27.94) | −33      | 0.084   | 472 (26.20)  | 389 (24.80) | −18      |         | 335 (25.61)  | 249 (24.88) | −26      |         |
| PCI during hospitalization | 353 (43.21)  | 242 (46.63) | −31      | 0.084   | 826 (46.20)  | 633 (40.37) | −23      | 0.084   | 619 (47.32)  | 420 (41.96) | −32      | 0.010   |
| In—hospital mortality | 45 (5.51)   | 46 (8.86)  | 2       | 0.018   | 69 (3.86)    | 73 (4.66)   | 6        | 0.253   | 60 (4.59)    | 48 (8.80)   | 0        | 0.814   |
| Hospital length of stay (days, mean (SD); median (p25 to p75)) | 9.41 (8.03); 7 (5 to 11) | 7.11 (6.34); 5 (3 to 9) | −24      | 0.018   | 8.88 (7.71); 7 (4 to 11) | 8.29 (7.21); 6 (4 to 10) | −7      | 0.018   | 9.47 (9.63); 7 (4 to 11) | 8.03 (6.97); 6 (4 to 10) | −15      | 0.018   |

Numbers indicate n (%) except if otherwise stated.
### TABLE 2 | Characteristics of patients admitted to hospital for acute heart failure (HF) in each period compared with the reference pre-COVID-19 period.

|                          | First wave period (24/02 to 27/04) | Between waves period (28/04 to 20/09) | Second wave period (21/09 to 27/112) |
|--------------------------|-------------------------------------|--------------------------------------|--------------------------------------|
|                          | Pre-COVID-19 | COVID-19   | % change | Pre-COVID-19 | COVID-19   | % change | Pre-COVID-19 | COVID-19   | % change | P-value |
| **N**                    | 3,200       | 1,749      | −45       | 5,641       | 4,026      | −29       | 4,090       | 2,795      | −32       |         |
| **Women**                | 1,741 (54.41) | 946 (54.09) | −46       | 3,130 (55.49) | 2,200 (54.16) | −30       | 2,315 (56.60) | 1,525 (54.56) | −34       | 0.094   |
| **Men**                  | 1,459 (45.59) | 803 (45.91) | −45       | 2,511 (44.51) | 1,862 (45.84) | −26       | 1,775 (43.40) | 1,270 (45.44) | −28       |         |
| **Age**                  | 0.107       |            |           | 0.001       |            |           | 0.061       |            |           |         |
| **< 80**                 | 1,246 (38.94) | 722 (41.28) | −42       | 2,106 (37.33) | 1,651 (40.65) | −22       | 1,517 (37.09) | 1,099 (39.32) | −28       |         |
| **≥ 80**                 | 1,954 (61.06) | 1,027 (58.72) | −47       | 3,535 (62.67) | 2,411 (59.35) | −32       | 2,573 (62.91) | 1,696 (60.68) | −34       |         |
| **AMG weight, mean (SD)** | 48.33 (15.39) | 33.86 (18.22) | −30 <0.001 | 48.74 (15.86) | 31.18 (17.69) | −36 <0.001 | 48.40 (15.73) | 28.08 (15.59) | −39 <0.001 |         |
| **PCSA index, mean (SD)** | 41.03 (15.08) | 41.76 (14.68) | 2 <0.108 | 40.76 (15.27) | 41.73 (15.15) | 2 0.002 | 40.73 (15.33) | 40.96 (14.99) | 1 0.556   | 0.751   |
| **Quantiles of PCSA index** | 0.166       |            |           | 0.110       |            |           | 0.178       |            |           |         |
| **1st**                  | 836 (26.13)  | 426 (24.36) | −49       | 1,534 (27.19) | 1,008 (24.82) | −34       | 1,137 (27.80) | 754 (26.98) | −34       |         |
| **2nd**                  | 790 (24.69)  | 408 (23.33) | −48       | 1,349 (23.91) | 989 (24.35) | −27       | 995 (24.33) | 681 (24.36) | −32       |         |
| **3rd**                  | 681 (21.28)  | 419 (23.96) | −38       | 1,220 (21.63) | 929 (22.87) | −24       | 861 (21.05) | 573 (20.50) | −33       |         |
| **4th**                  | 790 (24.69)  | 446 (25.44) | −44       | 1,370 (24.29) | 1,006 (24.77) | −27       | 986 (24.11) | 712 (25.47) | −28       |         |
| **In-hospital mortality** | 237 (7.41)   | 162 (9.26)  | −32 0.022 | 421 (7.46) | 259 (8.38) | −38 0.039 | 312 (7.63) | 168 (5.94) | −47 0.007 |         |
| **Hospital length of stay** | 10.33 (4.04) | 8.64 (3.72) | −16 <0.001 | 9.59 (8.66) | 8.98 (7.75) | −6 0.017 | 9.77 (9.34) | 8.47 (7.13) | −13 <0.001 |         |

Numbers indicate n (%) except if otherwise stated.
was clearly different from the impact of the FW. The impact of
the SW was quite attenuated, probably due to the rapid reaction
of hospitals to increase their intensive care capacity and to the
information campaigns launched to raise awareness of the need
to contact the emergency services when experiencing symptoms
compatible with MI.

There were also remarkable differences between ACS episodes
and acute HF episodes. While the number of ACS admissions
gradually returned to the expected levels in the BWP, admissions
for acute HF remained low for almost the whole observed
pandemic period studied. Whether the number of admissions
has recovered to usual values or has decreased again to similar
levels in the successive waves needs to be further addressed.

Besides patients’ hesitation to go to the hospital, this sustained
decrease might be related in part to the fact that HF symptoms
are closer to COVID-19 symptoms. Since the primary focus of
health professionals has been a rapid COVID-19 diagnosis, it
might have led to underdiagnoses of HF cases. In addition, acute
HF hospitalizations might have been lower because patients were
preferably attended to in the primary care setting or due to the
increased use of telemedicine, which is less practicable in the
setting of the acute ischemic heart disease.

It has been speculated that lifestyle changes occurring during
the lockdown periods might have influenced acute coronary
disease incidence (25). However, the observations, as in other
contexts (8), that the decline in admissions preceded the
lockdown and that the return to “normal” levels preceded the reopening suggest that environmental changes, decreased physical activity, or diminished stress are unlikely to be major contributors to these trends.

Some changes in the characteristics of patients attended to during the successive COVID-19 periods compared with the corresponding pre-COVID-19 periods might give some hints for the interpretation of trends. Overall, patients admitted during the COVID-19 period had much lower comorbidity weight assessed by AMG score. This suggests that those patients with more comorbidities and higher risk who had a cardiovascular event did not seek care or that the healthcare system collapsed at some point and could not hospitalize these more fragile patients. Another possibility is a certain degree of competitive risk between COVID-19 disease and cardiovascular events, which could result in a lower rate of cardiovascular events in the population with a higher rate of severe COVID-19 disease, which was precisely the elderly and the more fragile population, especially during the FW.

Another indirect finding that suggests the burden of the healthcare facilities during certain periods was the hospital length of stay. It declined steadily during the epidemic waves and, to a lesser extent, during the BWP. In the future, it will become clear whether this indicates a simple trend in a complex context or a
TABLE 3 | Association of patient characteristics and COVID-19 periods with in-hospital mortality for acute coronary syndrome (ACS) and heart failure (HF).

|                      | ACS valid (n* = 8,622) |         | HF valid (n** = 27,531) |         |
|----------------------|------------------------|---------|-------------------------|---------|
|                      | OR (95% CI)            | P-value | OR (95% CI)             | P-value |
| Women                | 0.93 (0.75 to 1.15)    | 0.487   | 0.86 (0.78 to 0.95)     | 0.002   |
| Age (for 5 years)    | 1.44 (1.36 to 1.52)    | <0.001  | 1.30 (1.26 to 1.34)     | <0.001  |
| AMG weight           | 1.02 (1.01 to 1.02)    | <0.001  | 1.01 (1.00 to 1.01)     | <0.001  |
| Type of ACS          |                        |         |                         |         |
| Unstable angina (ref)| 1                      |         |                         |         |
| Other ACS            | 2.81 (1.32 to 5.99)    | 0.007   |                         |         |
| NSTEMI               | 2.22 (1.51 to 3.26)    | <0.001  |                         |         |
| STEMI                | 6.13 (4.03 to 9.35)    | <0.001  |                         |         |
| Other MI             | 8.67 (5.32 to 14.13)   | <0.001  |                         |         |
| Quartiles of PCSA    |                        |         |                         |         |
| 1st                  |                        |         |                         |         |
| 2nd                  |                        |         |                         |         |
| 3rd                  |                        |         |                         |         |
| 4th                  |                        |         |                         |         |
| COVID19 period       |                        |         |                         |         |
| 1st wave             | 2.14 (1.50 to 3.05)    | <0.001  | 1.36 (1.14 to 1.62)     | 0.001   |
| Between waves        | 1.20 (0.90 to 1.62)    | 0.217   | 0.94 (0.82 to 1.09)     | 0.432   |
| 2nd wave             | 1.37 (0.97 to 1.93)    | 0.072   | 0.86 (0.72 to 1.03)     | 0.094   |

*14 missing values for PCSA; **35 missing values for PCSA.
ACS, acute coronary syndrome; HF, heart failure; OR, odds ratio; AMG, adjusted morbidity groups; NSTEMI, non-ST elevation myocardial infarction; STEMI, ST elevation myocardial infarction; MI, myocardial infarction; PCSA, primary care service areas.

real change in the efficiency of the health system for managing these cardiovascular events. In any case, it indicates the effort of the healthcare professionals to minimize the overload of the system and the awareness of the risk of infection during admission by professionals and by the patients and their families.

The increase in the number of diagnoses labeled as other ACS or other MI, present in only few cases, might be due to codification problems during the overwhelming working conditions of the professionals responsible for codification during the pandemic peaks. This fact prevents us to draw conclusions about the differential changes by type of ACS.

The analysis of mortality determinants reveals that, unlike the results observed in other series (26), there was a significantly increased risk of in-hospital mortality after ACS and acute HF episodes in the FW but not in the SW. The increase in mortality was independent of case mix and despite a lower comorbidity weight and a similar rate of PCI compared with the pre-COVID-19 period. This probably reflects, on the one hand, the delay in patients seeking care increasing symptoms-to-balloon time (2), together with a more important healthcare overload during the FW and, on the other hand, a certain learning curve effect that benefited the second and subsequent waves.

Our results are consistent with those observed in other contexts. The study by Bodilsen et al. (16), in Denmark, highlighted HF as one of the health conditions not returning to baseline levels, together with respiratory and nervous system diseases, cancer, acute exacerbations of chronic pulmonary disease, sepsis, and pneumonia.

Although female sex and older age have been linked to increased delay before seeking healthcare (27), the COVID-19 pandemic does not seem to have affected differently the pattern of admission for ACS and HF in male and female patients (Figures 3, 4). This suggests that the potential different behavior of men and women for seeking care shown in other studies is attenuated in a context such as COVID-19 pandemic. However, we observed that the decline in hospital admissions was higher in older patients, but only after the FW. Huynh et al. (28) found a higher reduction of acute MI in women ≥70 years old during the COVID-19 pandemic in a Swedish healthcare region without lockdown.

To the best of our knowledge, this is the largest study showing the effects of the COVID-19 pandemic on acute cardiovascular disease admissions during a sufficiently large time window to include two successive waves. Previous reports have observed lower hospital admission rates for MI (5, 6, 11, 29, 30) and HF (13, 14, 31, 32) during the FW that are comparable with our study; however, reports of further declines in successive waves are scarce. In this sense, Wu et al. (20) reported a second decline of a similar magnitude (41% for HF and 34% for MI) during the SW in the United Kingdom.

Limitations

Despite the use of large region-wide administrative databases that offer clear advantages, disadvantages include the following: Lack of detail in clinical severity, comorbidities, out-of-hospital mortality and causes of mortality, lower data quality, and higher risk of misclassification. In the case of HF, it would have been informative to merge hospital admissions to primary care emergent admissions and telecare attentions. Adoption of telecare programs as a response to the pandemic might have influenced the rate of hospital admissions. Finally, we used related ICD-10 diagnostic codes to label cases with concomitant COVID-19, as we did not have access to data for laboratory-proven SARS-CoV-2 infection. However, the proportion of patients with a diagnosis of both cardiovascular disease and COVID-19 infection was low, and its impact on overall outcomes might not be very relevant. Finally, the depiction of the COVID wave does not correspond with the real cases, especially during the FW, when fewer RT-PCR tests or rapid antigen tests for SARS-CoV-2 were performed, and specific diagnostic codes for COVID-19 were not available.

CONCLUSION AND PRACTICAL IMPLICATIONS

The decline in hospital admissions for ACS and acute HF during the FW of the COVID-19 pandemic was marked and striking. We provide evidence that the decline was attenuated but still observed in the SW and that the impact has been similar in all age, sex, and socioeconomic subgroups in the
Catalan healthcare system. In addition, the adjusted in-hospital mortality risk comparing the corresponding pre-COVID-19 periods shows a clearly higher risk during the FW for both ACS and HF episodes but not during the SW, which indicates the difficulty of the healthcare system to adapt to new and stressful pandemic conditions.

The impact of COVID-19 in Spain was among the strongest reported worldwide, and its indirect impact on other non-COVID health conditions should be surveilled by health authorities. Numerous efforts have been made to forecast health resources needs for COVID-19 but not for other health problems that have been strongly impacted by the pandemic. Extending our temporal series to longer time frames, and including other contextual factors that might influence the rate of ACS or HF admissions, can serve to anticipate future distortions and prepare the health services to improve the attention of non-COVID health problems.

**DATA AVAILABILITY STATEMENT**

The data analyzed in this study is subject to the following licenses/restrictions: Restrictions apply to the availability of these data, which were used under license for this study. Data are available from the authors upon request with the permission of AQuAS. Requests to access these datasets should be directed to https://aquas.gencat.cat/ca/ambits/analitica-dades/padriss/.

**ETHICS STATEMENT**

The studies involving human participants were reviewed and approved by Clinical Research Ethics Committee Vall d’Hebron. Written informed consent for participation was not required by the Agency for Health Quality and Assessment of Catalonia (AQuAS), within the framework of the Public Data Analysis for Health Research and Innovation Program (PADRIS).

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**SUPPLEMENTARY MATERIAL**

The Supplementary Material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/fcvm.2022.827212/full#supplementary-material
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