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Risk of acute deterioration and care complexity individual factors associated with health outcomes in hospitalised patients with COVID-19.

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ORIGINAL ARTICLE

Risk of acute deterioration and care complexity individual factors associated with health outcomes in hospitalised patients with COVID-19.

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ABSTRACT

Background: Evidence about the impact of systematic nursing surveillance on acute deterioration risk along with care complexity individual factors on inpatient outcomes, is scarce. The study is aimed at determining the association between acute deterioration risk and care complexity individual factors with unfavourable outcomes in hospitalised patients with COVID-19.

Methods: A multicentre cohort study was conducted from March 1, 2020 to March 31, 2020 at seven hospitals in Catalonia, Spain. All COVID-19 adults patients admitted to hospitals and with completed minimum data set were recruited retrospectively. Patients were classified based on the presence or absence of a composite unfavourable outcome (in-hospital mortality and adverse events [AEs] during hospitalisation). The main measures included acute deterioration risk (as measured with VIDA early warning system) and 28 care complexity individual factors. All data were obtained blinded from electronic health records. Multivariate logistic analysis was performed to identify VIDA score and care complexity factors associated with unfavourable outcomes.

Results: From a total of 1,176 COVID-19 patients, 506 patients (43%) experienced an unfavourable outcome during hospitalisation. The frequency of unfavourable outcomes rose with increasing risk of acute deterioration as measured with VIDA score. Risk factors independently associated with unfavourable outcomes were chronic underlying disease (OR: 1.90, 95% CI: 1.32-2.72; $p < 0.001$), mental status impairment (OR: 2.31, 95% CI: 1.45-23.66; $p < 0.001$), length of hospital stay (OR: 1.16, 95% CI: 1.11-1.21; $p < 0.001$) and high risk of acute deterioration (OR: 4.32, 95% CI: 2.83-6.60; $p < 0.001$). High-tech hospital admission was a protective factor of unfavourable outcomes (OR: 0.57, 95% CI: 0.36-0.89; $p = 0.01$).

Conclusion: The systematic nursing surveillance of the status and evolution of COVID-19 inpatients, including the careful monitoring of acute deterioration risk and care

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3 complexity individual factors may contribute to reduce deleterious health outcomes in
4
5 COVID-19 inpatients.
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10 **STRENGTHS AND LIMITATIONS OF THIS STUDY**

- 12 • This was a multicentre cohort study with a large sample size in hospitalised
13 patients with COVID-19.
- 14
15 • It is the first research evaluating the association of the risk of acute deterioration
16 (as measured with VIDA early warning system), along with care complexity
17 individual factors, with COVID-19 patient outcomes.
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19 • We identify broader health-contributors of care complexity, including
20 psychosocial and mental-cognitive factors.
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22 • No previous studies have demonstrated the effectiveness VIDA early warning
23 system yet. Nevertheless, the results of this study had proved the significant
24 association between the unfavourable outcomes with VIDA score.
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26 • We not evaluate other clinical measures such as the age-adjusted Charlson
27 comorbidity index or patient lab values.
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INTRODUCTION

Along with climate change and financial crises, pandemics are one of the major global risks for the 21st century. A 2019 report stated that, in the last decade the World Health Organization (WHO) tracked 1,483 epidemic events, including Severe Acute Respiratory Syndrome (SARS), Middle East Respiratory Syndrome (MERS), Ebola or other epidemic-prone diseases, considered harbingers of a new era of high-impact, potentially fast-spreading outbreaks.¹

The potential thread became real last December 2019, when a severe acute respiratory infection caused by the new coronavirus SARS-CoV-2 began to spread first in Wuhan (China).^{2,3} The WHO announced the Wuhan pneumonia as an outbreak of potential danger in December 31st, as an outbreak of global concern in January 31st, and finally the coronavirus disease (COVID-19) was declared a global pandemic in February 2020.

COVID-19 patients frequently require hospital admission as they may rapidly develop severe potential life-threatening complications, such as acute respiratory distress syndrome, sepsis, major thromboembolic events or cardiac injury, requiring intensive care.³⁻⁵ Recent studies have found overall in-hospital mortality rates for COVID-19 inpatients ranging from 15 to 28%.^{3,6-8} Therefore, early recognition of patient deterioration and escalation of treatment to reduce the risk of progression to critical complications is a significant issue that may impact patient and organizational outcomes. Screening for acute deterioration implies nursing surveillance, data collection, interpretation and recognition of changes in patients' status, prioritization of patients' problems and decision making on the interventions to perform in order to curb the cascade towards adverse events (AEs) and death.⁹

According to the WHO *“patients hospitalized with COVID-19 require regular monitoring of vital signs and, where possible, utilization of early warning scores that*

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3 *facilitate early recognition and escalation of treatment of the deteriorating patient.*¹⁰
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5 Early warning systems have become an important component of managing inpatient
6 care, as well as a clinical decision-making support stratification tool to prevent poor
7 health outcomes.¹¹⁻¹³ Previous studies suggested the need for adaptation of these
8 systems to each context.¹⁴ According to these recommendations, several evidence-based
9 algorithms were developed and used to early identify and act upon initial or impending
10 acute deterioration among hospitalised patients. In the context of this study, a nursing
11 surveillance improving program named VIDA (the Catalan acronym for Surveillance
12 and Identification of Acute Deterioration) started in 2013 and has evolved with a
13 multidisciplinary approach, as a daily used early warning score system, contributing to
14 assist clinical decision-making, since then.
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28 It has been described that admitted patients with COVID-19 have a substantial
29 rate of chronic conditions that may affect the complexity of medical and nursing care
30 provision, and patient health outcomes.¹⁵ Nevertheless, care complexity individual
31 factors (CCIF) are related not only to multiple comorbidities but also to mental-
32 cognitive and psychosocial patient features, which in turn are also associated with
33 increased healthcare needs during hospitalization and with selected health outcomes.¹⁶⁻
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44 Only a few studies in COVID-19 inpatients have explored the use of acute
45 deterioration risk stratification^{11,19} and to date, none has assessed CCIF as predictors of
46 poor health outcomes. The aim of this study is to determine the association between
47 acute deterioration risk (as measured with VIDA early warning system) and care
48 complexity individual factors with unfavourable outcomes in admitted patients with
49 COVID-19.
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METHODS

Setting and Study Design

A retrospective cohort study was carried out at seven public hospitals in Catalonia, Spain: three tertiary metropolitan facilities, three urban university centres and one community hospital. All patients with COVID-19 who were admitted to the hospital from March 1, 2020 to March 31, 2020 with a completed hospital minimum data set report were recruited retrospectively and followed up. Patients' directly admitted and discharged from intensive care units (ICU), as well as those who remained hospitalized after the recruitment end date, were excluded.

We defined the primary endpoint as a composite of unfavourable outcomes including in-hospital mortality and adverse events (AEs), not present on admission and occurring thereafter during hospitalization.

Patient and Public Involvement

This study was approved by The Clinical Research Ethics Committee of the Bellvitge University Hospital (reference 158/20). Informed consent was waived due to the study's retrospective design. Ethical and data protection protocols related to anonymity and data confidentiality (access to records, data encryption and archiving of information) were complied with throughout the whole research process.

Data Collection

Information regarding the demographic and clinical characteristics, continuity of care (discharged to another facility), high-tech hospital, length of hospital stay (LOS) and patient severity and mortality risk were collected from the hospital minimum data set and the clinical data warehouse of the Catalan Institute of Health. Patient severity and risk of mortality was based on the all patient refined diagnosis-related groups (APR-DRG) that categorises both measures in four groups, from low (level 1) to extreme

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3 (level 4). Severity and mortality risk were dichotomized in this study into low risk
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5 (levels 1-2) and high risk (levels 3-4).²⁰
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8 VIDA score (acute deterioration risk stratification) classifies patients into five
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10 groups: no risk (level 0), low risk (level 1), moderate risk (level 2), high risk
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12 (impending complication if not stabilized) (level 3), manifested complication initial
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14 status (level 4). For the purposes of this study, VIDA score classified into mild (levels
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16 1-2) and high (levels 3-4) risk groups. Patient progress data were extracted from
17
18 anonymised electronic health records whenever they were e-charted including:
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20 respiratory rate (breaths/min), oxygen saturation (%), temperature (°C), mental status
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22 (level of awareness; 1= aware and orientated, >1 = disturbed mental status, including
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24 disorientation, acute confusion, etc...), pulse (cardiac rate, beats/min) and systolic and
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26 diastolic blood pressure (mmHg).
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31 Care complexity individual factors (CCIF) were classified into five domains: (i)
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33 mental-cognitive, (ii) psycho-emotional, (iii) sociocultural, (iv) developmental, and (v)
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35 comorbidity/complications, as described in previous studies.^{16,18} Each CCIF domain is
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37 structured into factors and specifications. Patients were considered within any CCIF
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39 domains if they presented at least one factor or specification. These CCIF factors and
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41 specifications were obtained from the nursing assessment e-charts, as structured data
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43 based on the Architecture, Terminology, Interface, Knowledge (ATIC) terminology.²⁰
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47 **Outcome measures**

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49 The in-hospital mortality accounted the number of deceased COVID-19 patients while
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51 in a ward. The AEs included intensive care unit transfer, hospital-acquired infections
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53 (HAI) and potentially avoidable critical complications (ACC) during hospitalization.
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55 Intensive care unit (ICU) transfer was defined as the number of patient episodes with
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57 effective bed change from a general ward to an intensive care area. HAI included the
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59 number of episodes of ward patients that developed catheter-related bloodstream
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3 infection, urinary catheter-related infection, aspiration pneumonia and/or sepsis. ACC
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5 accounted for the number of episodes of ward patients that experienced a cardiac arrest,
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7 shock, thromboembolic event, acute respiratory failure, acute respiratory distress
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9 syndrome (ARDS), myocardial injury, liver injury and/or kidney failure, not present on
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11 admission.
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14 **Statistical Analysis**

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16 Descriptive analysis of data using percentage frequencies, median and interquartile
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18 range was performed to determine demographic and clinical characteristics, and
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20 patients' outcomes. For categorical variables, a comparative analysis for detecting
21
22 significant differences between groups was carried out using the chi-square test or
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24 Fisher's exact test when one or more cells had an expected frequency of five or less.
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26 For continuous variables, the Student's t-test or Mann-Whitney U test was used
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28 depending on the results of the Kolmogorov-Smirnov normality test. A logistic-
29
30 regression model of all clinical factors potentially associated with unfavourable
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32 outcome measures (AEs and in-hospital mortality) was performed including VIDA
33
34 score, clinically relevant CCIF and other potential confounders: sex, hospital level and
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36 LOS (only covariates with *p*-values less than 0.05 in the univariate analysis were
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38 entered in the multivariate model). All potential explanatory variables included in the
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40 multivariate analyses were subjected to a correlation matrix for analysis of collinearity.
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42 The discriminatory power was evaluated by the area under the receiver operating
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44 characteristic (ROC). Results of multivariate analysis was reported as odds ratios (OR)
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46 and 95% confidence intervals (CI). We also performed a descriptive analysis to
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48 compare unfavourable outcomes in patients admitted in wards with VIDA system and
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50 without this system. Statistical analysis will be performed using the SPSS software
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52 package version 25.0 (SPSS, Chicago, IL). *P* values less than 0.05 were considered
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54 statistically significant.
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RESULTS

During the study period, 1,838 patients were hospitalised with COVID-19, among them, 1,176 patients with minimum data set completed were included. The frequency of unfavourable outcomes was 42.8% (506 patients). In-hospital mortality rate was 19.6% (232 patients), and almost 41% (481 patients) experienced an AE while in a ward (2.7% transferred to ICU; 2.5% HAI; 40% ACC). Acute respiratory failure, ARDS, acute kidney failure, urinary catheter-related infection, sepsis, and thrombotic event were the most frequently AEs.

Patient Characteristics

The baseline characteristics of patients with unfavourable and favourable outcome are compared in **Table 1**. COVID-19 hospitalised patients who had an unfavourable outcome were more often male, older, and had one or more underlying chronic conditions (75.5%), mostly arterial hypertension or congestive heart failure and, diabetes or chronic kidney disease. Furthermore, they had longer LOS and high risk of severity or mortality (APR-DRG 3-4). Conversely, patients admitted in high-tech hospitals presented less frequency of unfavourable outcomes.

Regarding VIDA score, most patients with unfavourable outcomes experienced high risk of acute deterioration (41.7% in patients with unfavourable outcomes vs. 9.1% in patients with favourable outcomes).

Comorbidity, sociocultural and developmental domains were the most frequent CCIF domains identified in the studied sample. Mental-cognitive and psycho-emotional domains were less frequent. Patients with unfavourable outcomes exhibited a higher frequency of chronic disease, position impairment, anatomical and functional disorders, communication disorders, old age (>75 years) and mental status impairments, when compared to patients with favourable outcomes. The median of CCIF was also higher in patients with unfavourable outcomes (5 [IQR: 4-6] vs. 4 [IQR: 3-5]) (**Table 1**).

Risk of acute deterioration and individual complexity factors association with outcomes.

Patients' outcomes of 806 patients with low, mild or high risk of acute deterioration were compared in **Table 2**. The frequency of unfavourable outcomes was nearly 38% in patients with mild risk and almost 80% in the high risk of acute deterioration group ($p < .001$). Similarly, the frequency of in-hospital mortality and AEs rose with increasing VIDA score and reached near 60% and 80% in patients with high risk of acute deterioration, respectively ($p < .001$). Acute respiratory failure, acute kidney failure and ICU transfer were the most frequent AEs.

Among the 1,176 patients analysed in this study, those with four or more CCIF experienced unfavourable outcomes ($p < .05$) (**Table 2**).

Table 3 shows an adjusted analysis of health outcomes in 486 patients with high risk of mortality (APR-DRG 3-4) to compare patients admitted in wards where registered nurses use or do not use the VIDA early warning score system. In-hospital mortality was more frequent in patients admitted in wards where VIDA was not used (52.5% vs. 41.3%, $p < .05$). Conversely, the frequency of AEs was slightly higher in patients admitted VIDA' wards ($p < .05$).

Risk factors associated with unfavourable outcomes

The results of the multivariable analysis for risk of acute deterioration (as measured with VIDA score) and CCIF potentially associated with unfavourable outcomes, in-hospital mortality and AEs, are summarized in **Table 4**.

After adjustment of potentially confounders, the analysis shows that high risk of acute deterioration was an independent factor associated with unfavourable outcomes, in-hospital mortality, and AEs in COVID-19 ward inpatients. Furthermore, chronic disease, mental status impairments and LOS were risk factors associated with unfavourable outcomes. Conversely, high-tech hospital admission was a protective

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3 factor of unfavourable outcomes. The area under the ROC curve (AUC) was 0.81 (95%
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5 CI: 0.78-0.84).
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8 Chronic disease, mental status impairments, old age and male sex were
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10 independent risk factors associated with in-hospital mortality for studied COVID-19
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12 inpatients. (AUC 0.91 [95% CI: 0.88-0.93]). Finally, risk factors independently
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14 associated with AEs were chronic disease, mental status impairments, old age and LOS;
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16 while high-tech hospital admission was a protective factor of AEs (AUC 0.80 [95% CI:
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18 0.77-0.83]).
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DISCUSSION

In this study of a large cohort of hospitalised patients with COVID-19, the frequency of unfavourable outcomes (in-hospital mortality and AEs) reached near 80%, in patients scored as at high risk of acute deterioration. In-hospital mortality was higher in wards not using the VIDA early warning system. A wide majority of patients had four or more care complexity individual factors identified. The risk factors independently associated with unfavourable outcomes included chronic disease, mental status impairments, LOS and high risk of acute deterioration. High-tech hospital admission was a protective factor of unfavourable outcomes.

Our findings are consistent with previous COVID-19 reports which have found a similar frequency of in-hospital mortality and AEs.^{3,21} In addition, 37% of patients developed respiratory complications (acute respiratory failure or ARDS) during hospitalization. This value is within the range reported in a previous inquiry (29-42%).³

The results of this study show that high risk of acute deterioration is a significant risk factor for unfavourable outcomes, as a composite measure for in-hospital mortality, and AEs in admitted COVID-19 patients. Although previous studies have stressed that early warning systems are predictors of in-hospital mortality and health outcomes,^{22,23} only a few have evaluated warning score systems in admitted COVID-19 patients.^{11,19} These latest studies showed a fair discrimination with adverse outcomes, concluding that the evaluation of the risk for acute deterioration in the COVID-19 hospital population is a priority for the organizations.¹⁹

In-hospital mortality was more frequent in patients admitted in wards where registered nurses do not use VIDA early warning system. In this regard, other studies show that the use of early systems reinforces collaboration among the multidisciplinary team, and promotes the early identification of clinical deterioration.²⁴ Similarly,

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3 previous studies have reported less mortality and adverse events when systematic
4 nursing surveillance of patient status and progress is a daily basis practice.⁹
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8 Chronic conditions and mental status impairments were the CCIF independently
9 associated with unfavourable outcomes. Previous reports have shown that chronic
10 diseases were more frequent among deceased COVID-19 patients¹⁵ and older age was a
11 potential risk factor associated with mortality.⁶ Although our study has not identified
12 age as a risk factor associated with a composite unfavourable outcome, we acknowledge
13 that old age was an independent risk factor associated with mortality and AE.
14 Furthermore, our findings were also consistent with other studies showing that mental
15 status impairments are associated with hospital-acquired complications,²⁵ including
16 sepsis.⁴
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28 A wide majority of patients had four or more CCIF. Our findings are consistent
29 with other studies that identified an important rate of chronic conditions in COVID-19
30 patients¹⁵ and by the other hand, selected organizational issues that may impact care
31 complexity and health outcomes.²⁶ Previous inquiries have demonstrated the association
32 of CCIF and health outcomes,¹⁶ with an average of two CCIF per patient. Our
33 investigation showed that for COVID-19 inpatients, the average of CCIF is four. These
34 results are probably related to the transmissibility of this condition requiring droplet and
35 contact precautions, the pandemics management associated public health measures of
36 population confinement, preventing patients' relatives to visit admitted patients in
37 person, resulting in a lack of family caregiver support during hospitalisation, and the
38 frequency of chronic diseases in the studied sample. The organizational adaptation of
39 hospitals to this pandemic context and the required isolation precautions have been
40 associated with poor outcomes in prior studies.^{27,28}
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58 Additionally, we found that LOS was associated with unfavourable outcomes,
59 coinciding with previous studies that associated AEs with increased healthcare costs due
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3 to longer hospital stays.²⁹ Finally, high-tech hospital admission was a protective factor
4 associated to unfavourable outcomes. High-tech hospitals usually have better nurse-to-
5 patient ratios, than urban or community facilities. In this sense, a couple of recent
6 inquiries in the same context of this study conclude that, on average hospital ward
7 patients require 5.6 hours of RN care per patient day, while the average RN offered
8 hours per patient day is 2.4, and that RN understaffing is a structural issue.^{26,30}
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10 Nevertheless, to the best of our knowledge, no study on nurse staffing and COVID-19
11 inpatients' outcomes have been published. Similarly, healthcare clinical leaders and
12 managers have become key role to rapidly adapt organizations to the new reality. Fast
13 and effective decision-making and managerial responses in crisis situations with high
14 levels of uncertainty are essential at immediate and short-term however, they should be
15 accompanied by planning and executing mid-term and long-lasting improvements that
16 positively impact patient, professional and organizational outcomes, such as structural
17 RN understaffing.²⁶

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The strengths of this study include its multicentre approach, cohort design and
large sample size. It is the first research evaluating the association of the risk of acute
deterioration, along with care complexity individual factors, with COVID-19 patient
outcomes. Importantly, we identify broader health-contributors of care complexity,
including psychosocial and mental-cognitive factors. In addition, the VIDA early
warning system was developed as an evidence-based algorithm with a multidisciplinary
approach, and also according to previous studies that highlighted the importance to
adapt surveillance and screening systems to organization and cultural context.¹⁴

VIDA score and CCIF data were comprehensively collected from clinical data
warehouse of the Catalan Institute of Health and all patients included had a completed
nurse charting in the patient electronic health record. Nevertheless, there are some
limitations that should be acknowledged. We relied a properly compliance on electronic

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3 health records and administrative data, however this statement should be interpreted
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5 with caution since voluntary completion of electronic health records show close-to-
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7 reality data and information on nurses' observations on patient status and progress, but
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9 it not the reality in itself. It should be noted, no previous studies have demonstrated the
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11 effectiveness VIDA early warning system yet. Nevertheless, the results of this study had
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13 proved the significant association between the unfavourable outcomes with VIDA
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15 score. Finally, we acknowledge as a significant limitation that we did not evaluate other
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17 clinical measures such as the age-adjusted Charlson comorbidity index or patient lab
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19 values.
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23 **Conclusion**

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25 The risk of acute deterioration and the care complexity individual factors are associated
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27 with COVID-19 patient outcomes. The rate of unfavourable outcomes rose with
28
29 increasing risk of acute deterioration as measured with VIDA score. The risk factors
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31 independently associated with poor health outcomes were chronic disease, mental status
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33 impairment, length of hospital stay and high risk of acute deterioration. High-tech
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35 hospital admission was a protective factor of unfavourable outcomes. The systematic
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37 nursing surveillance of patients at risk of acute deterioration and the assessment of
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39 CCIF may contribute to reduce deleterious health outcomes in COVID-19 inpatients.
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FOOTNOTES

Author Contributions: All authors had full access to all study data and take responsibility for the integrity of the data and the accuracy of the data analysis. *Study concept and design:* Adamuz, González-Samartino, Juvé-Udina. *Coordination team:* Juvé-Udina. *Acquisition of data:* Adamuz, Tapia-Perez, López-Jiménez, Zuriguel-Pérez, Castro-Navarro. *Analysis and interpretation data:* Adamuz, González-Samartino, Jiménez-Martínez. *Drafting of the manuscript:* Adamuz, González-Samartino, Jiménez-Martínez, Juvé-Udina. *Critical revision of the manuscript for important intellectual content:* Tapia-Perez, López-Jiménez, Rodríguez-Fernández, Zuriguel-Pérez, Castro-Navarro, Carratalà. *Statistical analysis:* Adamuz and González-Samartino. *Obtained funding:* - . *Administrative, technical and material support:* López-Jiménez, Rodríguez-Fernández. *Study supervision:* Juvé-Udina, Carratalà.

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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 inquiry.

Patient consent for publication: Not required.

Ethical approval: This study is approved by the Clinical Research Ethics Committee of the Bellvitge University Hospital with a waiver of informed consent (reference 158/20).

Provenance and peer review: Not commissioned; externally peer reviewed.

Data availability statement: All data relevant to the study are included in the article.

No additional data are available.

Table 1. Baseline characteristics, VIDA score and care complexity individual factors of admitted COVID-19 patients with unfavourable and favourable outcomes.

| Characteristics | Study population n=1,176 | | Unfavourable outcome ^a n=506 (42.8%) | | Favourable outcome n=670 (57.1%) | | p value |
|---|-----------------------------|---------|--|---------|-------------------------------------|---------|---------|
| | No. | % | No. | % | No. | % | |
| Demographic characteristics | | | | | | | |
| Age (years)_ median (IQR) | 66.5 | (51-77) | 74 | (60-80) | 61 | (49-74) | <0.001 |
| Male sex | 667 | (56.7) | 192 | (37.9) | 317 | (47.3) | 0.001 |
| Clinical characteristics | | | | | | | |
| LOS_ median (IQR) | 6 | (4-8) | 7 | (4-10) | 5 | (4-7) | <0.001 |
| Continuity of care (discharged to another facility) | 165 | (14) | 58 | (11.5) | 107 | (16) | 0.02 |
| Severity (APR-GRD 3-4) | 503 | (42.8) | 450 | (88.9) | 53 | (7.9) | <0.001 |
| Mortality risk (APR-DRG 3-4) | 486 | (41.3) | 449 | (88.7) | 37 | (5.5) | <0.001 |
| High-tech hospital | 969 | (82.4) | 389 | (76.9) | 580 | (86.6) | <0.001 |
| Underlying disease | 745 | (63.4) | 382 | (75.5) | 363 | (54.4) | <0.001 |
| Arterial hypertension or chronic heart failure | 469 | (39.9) | 234 | (46.2) | 235 | (35.1) | <0.001 |
| Diabetes or chronic kidney disease | 298 | (25.3) | 165 | (32.6) | 133 | (19.9) | <0.001 |
| Chronic respiratory disease | 171 | (14.5) | 95 | (18.8) | 76 | (11.3) | <0.001 |
| Neurodegenerative disease | 63 | (5.3) | 33 | (6.5) | 39 | (4.5) | 0.15 |
| Chronic liver disease | 54 | (4.6) | 30 | (5.9) | 24 | (3.6) | 0.07 |
| Cancer | 50 | (4.3) | 31 | (6.5) | 19 | (2.8) | 0.008 |
| Immunosuppression | 49 | (4.2) | 23 | (4.5) | 26 | (3.9) | 0.66 |
| VIDA score^b | | | | | | | |
| Low risk (0) | 104 | (12.9) | 27 | (7.1) | 77 | (18) | <0.001 |
| Moderate risk (1-2) | 505 | (62.7) | 194 | (51.2) | 311 | (72.8) | <0.001 |
| High risk (3-4) | 197 | (16.7) | 158 | (41.7) | 39 | (9.1) | <0.001 |
| Care complexity individual factors (CCIF) | | | | | | | |
| Comorbidity/complications | | | | | | | |
| Transmissible infection | 1,176 | (100) | 506 | (100) | 670 | (100) | - |
| Hemodynamic instability | 910 | (77.4) | 396 | (78.3) | 514 | (76.7) | 0.57 |
| Chronic disease | 745 | (63.4) | 382 | (75.5) | 363 | (54.4) | <0.001 |
| Uncontrolled pain | 194 | (16.5) | 82 | (16.2) | 112 | (16.7) | 0.87 |
| Extreme weight | 168 | (14.3) | 82 | (16.2) | 86 | (12.8) | 0.11 |
| Position impairment | 72 | (6.1) | 52 | (10.3) | 20 | (3.0) | <0.001 |
| Urinary or faecal incontinence | 58 | (4.9) | 31 | (6.1) | 27 | (4.0) | 0.10 |
| Immunosuppression | 49 | (4.1) | | | | | |
| Anatomical and functional disorders | 41 | (3.5) | 30 | (5.9) | 11 | (1.6) | <0.001 |
| Communication disorders | 18 | (1.5) | 13 | (2.6) | 5 | (0.7) | 0.01 |
| High risk of hemorrhage | 2 | (0.2) | 1 | (0.2) | 1 | (0.1) | 0.68 |
| Vascular fragility | 6 | (0.5) | 4 | (0.8) | 2 | (0.3) | 0.41 |
| Involuntary movements | 3 | (0.3) | 3 | (0.6) | 0 | (0.0) | 0.08 |
| Dehydration | 3 | (0.3) | 1 | (0.2) | 2 | (0.3) | 0.60 |
| Oedema | 0 | (0) | 0 | (0.0) | 0 | (0.0) | - |
| Developmental | | | | | | | |
| Old age (≥75 years) | 397 | (33.8) | 244 | (48.2) | 153 | (22.8) | <0.001 |
| Psycho-emotional | | | | | | | |
| Fear/anxiety | 173 | (14.7) | 70 | (13.8) | 103 | (15.4) | 0.51 |
| Impaired adaptation | 54 | (4.6) | 17 | (3.4) | 37 | (5.5) | 0.09 |
| Aggressive behaviour | 1 | (0.1) | 1 | (0.2) | 0 | (0.0) | 0.43 |
| Mental-cognitive | | | | | | | |
| Mental status impairments | 240 | (20.4) | 184 | (36.4) | 56 | (8.4) | <0.001 |
| Agitation | 238 | (20.2) | 183 | (36.2) | 55 | (8.2) | <0.001 |
| Impaired cognitive functions | 5 | (0.4) | 4 | (0.8) | 1 | (0.1) | 0.17 |
| Perception of reality disorders | 4 | (0.3) | 3 | (0.6) | 1 | (0.1) | 0.32 |
| Perception of reality disorders | 2 | (0.2) | 0 | (0.0) | 2 | (0.3) | 0.51 |
| Sociocultural | | | | | | | |
| Lack of caregiver support | 1,176 | (100) | 506 | (100) | 670 | (100) | - |
| Belief conflict | 1,176 | (100) | 506 | (100) | 670 | (100) | - |
| Belief conflict | 1 | (0.1) | 0 | (0.0) | 1 | (0.1) | 0.57 |
| Language barriers | 1 | (0.1) | 1 | (0.2) | 0 | (0.0) | 0.43 |
| Social exclusion | 1 | (0.1) | 0 | (0.0) | 1 | (0.1) | 1 |
| Care complexity individual factors (CCIF), median (IQR) | 4 | (3-6) | 5 | (4-6) | 4 | (3-5) | <0.001 |

Abbreviations: IQR, interquartile range; LOS, length of hospital stay; ICU, intensive care unit; APR-DRG, all patient refined diagnosis-related groups; VIDA, surveillance and identification of acute deterioration.

^a Unfavourable outcomes included: in-hospital mortality and adverse events during hospitalization.

^b VIDA score was analysed according to 806 admitted patients in wards with VIDA system.

Table 2. Patients' outcomes according to risk of acute deterioration (VIDA score) and care complexity individual factors.

| Outcomes | VIDA_score n=806 (68.5) | | | | CCIF n=1,176 | |
|--|-------------------------|------------------------------|---------------------------------|---------------------------------|------------------------|------------------------|
| | All n=1,181 | Low risk (0) n=104 (12.9) | Mild risk (1-2) n=505 (62.7) | High risk (3-4) n=197 (16.7) | CCIF<4 n=327 (27.8) | CCIF≥4 n=849 (72.2) |
| | N (%) | N (%) | N (%) | N (%) | N (%) | N (%) |
| Unfavourable outcomes | 506 (43.0) | 27 (26.0)** | 194 (38.4)* | 158 (80.2)** | 92 (28.1)** | 414 (48.8)** |
| Deceased | 232 (19.6) | 0 (0.0)** | 46 (9.1)** | 118 (59.9)** | 5 (1.5)** | 227 (26.7)** |
| Adverse event | 481 (40.9) | 27 (26.0)** | 187 (37)* | 153 (77.7)** | 91 (27.8)** | 394 (46.4)** |
| ICU transfer | 32 (2.7) | 0 (0.0)* | 12 (2.4) | 13 (6.6)* | 4 (1.2)* | 28 (3.3)* |
| HAI | 29 (2.5) | 0 (0.0)* | 10 (2.0) | 12 (6.1)* | 1 (1.5) | 24 (2.8) |
| Catheter-related bloodstream infection | 1 (0.1) | 0 (0.0) | 0 (0.0) | 1 (0.5) | 0 (0.0) | 1 (0.1) |
| HA urinary tract infection | 19 (1.6) | 0 (0.0) | 7 (1.4) | 8 (4.1)* | 3 (0.9) | 16 (1.9) |
| Aspiration pneumonia | 3 (0.3) | 0 (0.0) | 3 (0.6) | 0 (0.0) | 0 (0.0) | 3 (0.4) |
| Sepsis | 7 (0.6) | 0 (0.0) | 1 (0.2) | 3 (1.5)* | 2 (0.6) | 5 (0.6) |
| ACC | 470 (40.0) | 27 (26.0)** | 181 (35.8)** | 150 (76.1)** | 88 (26.6)** | 383 (45.1)** |
| Cardiac arrest | 5 (0.4) | 1 (1.0) | 0 (0.0)* | 3 (1.5)* | 0 (0.0) | 5 (0.6) |
| Shock | 4 (0.3) | 0 (0.0) | 2 (0.4) | 0 (0.0) | 0 (0.0) | 4 (0.5) |
| Thrombotic event | 7 (0.6) | 1 (1.0) | 1 (0.2) | 2 (1) | 1 (0.3) | 6 (0.7) |
| Acute respiratory failure ¹ | 436 (37.0) | 27 (26.0)** | 164 (32.5)** | 144 (73.1)** | 84 (25.1)** | 353 (41.6)** |
| Myocardial injury | 5 (0.4) | 0 (0) | 3 (0.6) | 1 (0.5) | 0 (0.0) | 5 (0.6) |
| Liver injury | 2 (0.2) | 0 (0) | 0 (0) | 1 (0.5) | 0 (0.0) | 2 (0.2) |
| Renal insufficiency | 83 (7.1) | 1 (1.0)* | 28 (5.5)* | 31 (15.7)** | 6 (1.8)** | 77 (9.1)** |

Abbreviations: VIDA, surveillance and identification of acute deterioration; CCIF, care complexity individual factors; ICU, intensive care unit; HAI, hospital-acquired infections; ACC, avoidable critical complications.

* *p* value >0.001 and <0.05.

** *p* value ≤0.001.

¹ Include acute respiratory distress syndrome (ARDS).

Table 3. Adjusted analysis of unfavourable outcomes according to VIDA early warning system in 486 patients with high risk of mortality (APR-DRG 3-4).

| Outcomes | Unadjusted | Adjusted | With VIDA system | Without VIDA system | <i>p value</i> |
|------------------------------|------------|--------------|------------------|---------------------|----------------|
| | n=1,181 | n=486 (41.2) | n=368 (75.7) | n=118 (24.3) | |
| | N (%) | N (%) | N (%) | N (%) | |
| Unfavourable outcomes | 506 (43.0) | 449 (92.4) | 345 (93.8) | 104 (88.1) | 0.07 |
| Deceased | 232 (19.6) | 214 (44) | 152 (41.3) | 62 (52.5) | 0.02 |
| Adverse event | 481 (40.9) | 436 (89.7) | 337 (91.6) | 99 (83.9) | 0.02 |
| ICU transfer | 32 (2.7) | 25 (5.1) | 20 (5.4) | 5 (4.2) | 0.41 |
| HAI | 29 (2.5) | 19 (3.9) | 16 (4.3) | 3 (2.5) | 0.28 |
| ACC | 470 (40.0) | 433 (89.1) | 334 (90.8) | 99 (83.9) | 0.31 |

Abbreviations: VIDA, surveillance and identification of acute deterioration; ICU, intensive care unit; HAI, hospital-acquired infections; ACC, avoidable critical.

Review only

Table 4. Multivariate analysis of VIDA score and CCIF in adult COVID-19 hospitalized patients associated with unfavourable outcomes.

| <i>Characteristics</i> | Unfavourable outcomes ¹ | | Deceased ² | | AE ³ | |
|---------------------------|------------------------------------|----------------|-----------------------|----------------|-----------------|---------------|
| | n= 379 (47) | | n= 164 (20.3) | | n=367 (45.5) | |
| | OR | (95% CI) | OR | (95% CI) | OR | (95% CI) |
| Old age (≥75 years) | 1.48 | (0.99-2.22) | 3.04 | (1.79-5.15)** | 1.52 | (1.02-2.26)* |
| Male sex | 1.21 | (0.87-1.69) | 1.86 | (1.11-3.11)* | 1.20 | (0.87-1.67) |
| LOS | 1.16 | (1.11-1.21)** | 0.97 | (0.93-1.01) | 1.17 | (1.12-1.22)** |
| High-tech hospital | 0.57 | (0.36-0.89)* | 1.88 | (0.94-3.78) | 0.61 | (0.39-0.95)* |
| VIDA score 3-4 | 4.32 | (2.83-6.60)** | 13.99 | (8.44-23.18)** | 4.21 | (2.79-6.36)** |
| Chronic disease | 1.90 | (1.32-2.72)** | 2.01 | (1.03-3.90)* | 1.81 | (1.26-2.59)** |
| Position impairment | 1.19 | (0.58-2.44) | 1.41 | (0.63-3.13) | 1.23 | (0.62-2.46) |
| Communication disorders | 0.97 | (0.24-3.96) | 0.87 | (0.22-3.41) | 0.78 | (0.21-2.95) |
| Mental status impairments | 2.31 | (1.45-23.66)** | 6.21 | (3.67-10.50)** | 1.72 | (1.09-2.69)* |

Abbreviations: AE, adverse event; LOS, length of hospital stay; VIDA, surveillance and identification of acute deterioration.

¹AUC 0.81 (CI 95%; 0.78-0.84).

²AUC 0.91 (CI 95%; 0.88-0.93).

³AUC 0.80 (CI 95%; 0.77 -0.83).

* *p* value >0.001 and <0.05.

** *p* value ≤0.001.

STROBE Statement—Checklist of items that should be included in reports of *cohort studies*

| | Item No | Recommendation | |
|------------------------------|---------|--|-----------|
| Title and abstract | 1 | (a) Indicate the study's design with a commonly used term in the title or the abstract | Pg.3 |
| | | (b) Provide in the abstract an informative and balanced summary of what was done and what was found | Pg.3-4 |
| Introduction | | | |
| Background/rationale | 2 | Explain the scientific background and rationale for the investigation being reported | Pg.5-6 |
| Objectives | 3 | State specific objectives, including any prespecified hypotheses | Pg.6 |
| Methods | | | |
| Study design | 4 | Present key elements of study design early in the paper | Pg.7 |
| Setting | 5 | Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection | Pg.7 |
| Participants | 6 | (a) Give the eligibility criteria, and the sources and methods of selection of participants. Describe methods of follow-up | Pg.7 |
| | | (b) For matched studies, give matching criteria and number of exposed and unexposed | - |
| Variables | 7 | Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable | Pg.7-8 |
| Data sources/ measurement | 8* | For each variable of interest, give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group | Pg.7-8 |
| Bias | 9 | Describe any efforts to address potential sources of bias | Pg.16 |
| Study size | 10 | Explain how the study size was arrived at | Pg.7 |
| Quantitative variables | 11 | Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why | Pg.9 |
| Statistical methods | 12 | (a) Describe all statistical methods, including those used to control for confounding | Pg.9 |
| | | (b) Describe any methods used to examine subgroups and interactions | Pg.9 |
| | | (c) Explain how missing data were addressed | - |
| | | (d) If applicable, explain how loss to follow-up was addressed | - |
| | | (e) Describe any sensitivity analyses | - |
| Results | | | |
| Participants | 13* | (a) Report numbers of individuals at each stage of study—eg numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed | Pg.10 |
| | | (b) Give reasons for non-participation at each stage | Pg.10-11 |
| | | (c) Consider use of a flow diagram | - |
| Descriptive data | 14* | (a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders | Pg.10 |
| | | (b) Indicate number of participants with missing data for each variable of interest | - |
| | | (c) Summarise follow-up time (eg, average and total amount) | Pg.10 |
| Outcome data | 15* | Report numbers of outcome events or summary measures over time | Pg10-11 |
| Main results | 16 | (a) Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (eg, 95% confidence interval). Make clear which confounders were adjusted for and why they were included | Table 1&4 |

| | | | |
|----|--------------------------|---|-----------|
| 1 | | (b) Report category boundaries when continuous variables were categorized | Table 1&4 |
| 2 | | (c) If relevant, consider translating estimates of relative risk into absolute risk for | Pg.11-12 |
| 3 | | a meaningful time period | |
| 4 | | | |
| 5 | Other analyses | 17 Report other analyses done—eg analyses of subgroups and interactions, and | Pg.11 |
| 6 | | sensitivity analyses | |
| 7 | | | |
| 8 | Discussion | | |
| 9 | Key results | 18 Summarise key results with reference to study objectives | Pg.13 |
| 10 | Limitations | 19 Discuss limitations of the study, taking into account sources of potential bias or | Pg.16 |
| 11 | | imprecision. Discuss both direction and magnitude of any potential bias | |
| 12 | | | |
| 13 | Interpretation | 20 Give a cautious overall interpretation of results considering objectives, | Pg.14-16 |
| 14 | | limitations, multiplicity of analyses, results from similar studies, and other | |
| 15 | | relevant evidence | |
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| 17 | Generalisability | 21 Discuss the generalisability (external validity) of the study results | Pg.15-16 |
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| 19 | Other information | | |
| 20 | Funding | 22 Give the source of funding and the role of the funders for the present study and, if | Pg.21. |
| 21 | | applicable, for the original study on which the present article is based | |
| 22 | | | |

*Give information separately for exposed and unexposed groups.

Note: An Explanation and Elaboration article discusses each checklist item and gives methodological background and published examples of transparent reporting. The STROBE checklist is best used in conjunction with this article (freely available on the Web sites of PLoS Medicine at <http://www.plosmedicine.org/>, Annals of Internal Medicine at <http://www.annals.org/>, and Epidemiology at <http://www.epidem.com/>). Information on the STROBE Initiative is available at <http://www.strobe-statement.org>.

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Risk of acute deterioration and care complexity individual factors associated with health outcomes in hospitalised patients with COVID-19: a multicenter cohort study.

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ORIGINAL ARTICLE

Risk of acute deterioration and care complexity individual factors associated with health outcomes in hospitalised patients with COVID-19: a multicenter cohort study.

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ABSTRACT

Background: Evidence about the impact of systematic nursing surveillance on acute deterioration risk along with care complexity individual factors on inpatient outcomes, is scarce. The study is aimed at determining the association between acute deterioration risk and care complexity individual factors with unfavourable outcomes in hospitalised patients with COVID-19.

Methods: A multicentre cohort study was conducted from March 1, 2020 to March 31, 2020 at seven hospitals in Catalonia. All COVID-19 adults patients admitted to hospitals and with completed minimum data set were recruited retrospectively. Patients were classified based on the presence or absence of a composite unfavourable outcome (in-hospital mortality and adverse events). The main measures included acute deterioration risk (as measured with VIDA early warning system) and care complexity individual factors. All data were obtained blinded from electronic health records. Multivariate logistic analysis was performed to identify VIDA score and care complexity factors associated with unfavourable outcomes.

Results: From a total of 1,176 COVID-19 patients, 506 patients (43%) experienced an unfavourable outcome during hospitalisation. The frequency of unfavourable outcomes rose with increasing risk of acute deterioration as measured with VIDA score. Risk factors independently associated with unfavourable outcomes were chronic underlying disease (OR: 1.90, 95% CI: 1.32-2.72; $p < 0.001$), mental status impairment (OR: 2.31, 95% CI: 1.45-23.66; $p < 0.001$), length of hospital stay (OR: 1.16, 95% CI: 1.11-1.21; $p < 0.001$) and high risk of acute deterioration (OR: 4.32, 95% CI: 2.83-6.60; $p < 0.001$). High-tech hospital admission was a protective factor of unfavourable outcomes (OR: 0.57, 95% CI: 0.36-0.89; $p = 0.01$). Area under the receiver-operating-characteristic curve was 0.81 (95% CI: 0.78-0.84).

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3 **Conclusion:** The systematic nursing surveillance of the status and evolution of COVID-
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5 19 inpatients, including the careful monitoring of acute deterioration risk and care
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7 complexity individual factors may contribute to reduce deleterious health outcomes in
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9 COVID-19 inpatients.
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14 **STRENGTHS AND LIMITATIONS OF THIS STUDY**

- 16 • We performed a multicentre cohort study with a large sample size in patients with
17 COVID-19.
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- 19 • This novel research assessed the impact of the risk of acute deterioration and
20 broader health contributors of care complexity with COVID-19 patient outcomes.
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- 22 • We do not evaluate other clinical measures such as the age-adjusted Charlson
23 comorbidity index or patient lab values.
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- 25 • Futures studies should validate the model.
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INTRODUCTION

Along with climate change and financial crises, pandemics are one of the major global risks for the 21st century. A 2019 report stated that, in the last decade the World Health Organization (WHO) tracked 1,483 epidemic events, including Severe Acute Respiratory Syndrome (SARS), Middle East Respiratory Syndrome (MERS), Ebola or other epidemic-prone diseases, considered harbingers of a new era of high-impact, potentially fast-spreading outbreaks.¹

The potential thread became real last December 2019, when a severe acute respiratory infection caused by the new coronavirus SARS-CoV-2 began to spread first in Wuhan (China).^{2,3} The WHO announced the Wuhan pneumonia as an outbreak of potential danger in December 31st, as an outbreak of global concern in January 31st, and finally the coronavirus disease (COVID-19) was declared a global pandemic in February 2020.

COVID-19 patients frequently require hospital admission as they may rapidly develop severe potential life-threatening complications, such as acute respiratory distress syndrome, sepsis, major thromboembolic events or cardiac injury, requiring intensive care.³⁻⁵ Recent studies have found overall in-hospital mortality rates for COVID-19 inpatients ranging from 15 to 28%.^{3,6-8} Therefore, early recognition of patient deterioration and escalation of treatment to reduce the risk of progression to critical complications is a significant issue that may impact patient and organizational outcomes. Screening for acute deterioration implies nursing surveillance, data collection, interpretation and recognition of changes in patients' status, prioritization of patients' problems and decision making on the interventions to perform in order to curb the cascade towards adverse events (AEs) and death.⁹

According to the WHO "*patients hospitalized with COVID-19 require regular monitoring of vital signs and, where possible, utilization of early warning scores that*

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3 *facilitate early recognition and escalation of treatment of the deteriorating patient.*¹⁰
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5 Early warning systems have become an important component of managing inpatient care,
6
7 as well as a clinical decision-making support stratification tool to prevent poor health
8
9 outcomes.^{11–13} Previous studies suggested the need for adaptation of these systems to each
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11 context.¹⁴ According to these recommendations, several evidence-based algorithms were
12
13 developed and used to early identify and act upon initial or impending acute deterioration
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15 among hospitalised patients. In the context of this study, a nursing surveillance improving
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17 program named VIDA (the Catalan acronym for Surveillance and Identification of Acute
18
19 Deterioration) started in 2013 and has evolved with a multidisciplinary approach, as a
20
21 daily used early warning score system, contributing to assist clinical decision-making,
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23 since then.
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28 It has been described that admitted patients with COVID-19 have a substantial
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30 rate of chronic conditions that may affect the complexity of medical and nursing care
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32 provision, and patient health outcomes.¹⁵ Nevertheless, care complexity individual factors
33
34 (CCIF) are related not only to multiple comorbidities but also to mental-cognitive and
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36 psychosocial patient features, which in turn are also associated with increased healthcare
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38 needs during hospitalization and with selected health outcomes.^{16–18}
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42 Only a few studies in COVID-19 inpatients have explored the use of acute
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44 deterioration risk stratification^{11,19} and to date, none has assessed CCIF as predictors of
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46 poor health outcomes. The aim of this study is to determine the association between acute
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48 deterioration risk (as measured with VIDA early warning system) and care complexity
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50 individual factors with unfavourable outcomes in admitted patients with COVID-19.
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METHODS

Setting and Study Design

A retrospective cohort study was carried out at seven public hospitals in Catalonia, Spain: three tertiary metropolitan facilities, three urban university centres and one community hospital. All patients with a medical diagnosis of COVID-19 infection whether they were admitted for COVID-19 or other causes from March 1, 2020 to March 31, 2020 with a completed hospital minimum data set report were recruited retrospectively and followed up during the hospitalization until discharge or deceased. Patients' directly admitted and discharged from intensive care units (ICU), as well as those who remained hospitalized after the recruitment end date, were excluded.

We defined the primary endpoint as a composite of unfavourable outcomes including in-hospital mortality or adverse events (AEs), not present on admission and occurring thereafter during hospitalization.

Patient and Public Involvement

This study was approved by The Clinical Research Ethics Committee of the Bellvitge University Hospital (reference 158/20). Informed consent was waived due to the study's retrospective design. Ethical and data protection protocols related to anonymity and data confidentiality (access to records, data encryption and archiving of information) were complied with throughout the whole research process.

Data Collection

Information regarding the demographic and clinical characteristics, continuity of care (discharged to another facility), high-tech hospital (referral centre that provides tertiary care for either open-heart surgery or major organ transplants or both, or other centre), length of hospital stay (LOS) and patient severity and mortality risk were collected from the hospital minimum data set and the clinical data warehouse of the Catalan Institute of Health. Patient severity and risk of mortality was based on the all patient refined

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3 diagnosis-related groups (APR-DRG) that categorises both measures in four groups, from
4 low (level 1) to extreme (level 4). Severity and mortality risk were dichotomized in this
5 study into low risk (levels 1-2) and high risk (levels 3-4).²⁰
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10 VIDA score (acute deterioration risk stratification) classifies automatically
11 patients into five groups according to patient progress data: no risk (level 0), low risk
12 (level 1), moderate risk (level 2), high risk (impending complication if not stabilized)
13 (level 3), manifested complication initial status (level 4). Levels 2 to 4 make an alert in
14 the electronic health records with clinical recommendations. These recommendations
15 were standardized for each context in line to intensify the measurement of vital signs and
16 notify to medical team. The health team (nurse and specialist) had the final clinical
17 decision-making. For the purposes of this study, VIDA score classified into mild (levels
18 1-2) and high (levels 3-4) risk groups. Patients were classified in each group according
19 the highest degree of VIDA score obtained during their hospitalization. Patient progress
20 data were extracted from anonymised electronic health records whenever they were e-
21 charted including: respiratory rate (breaths/min), oxygen saturation (%), temperature
22 (°C), mental status (level of awareness; 1= aware and orientated, >1 = disturbed mental
23 status, including disorientation, acute confusion, etc...), pulse (cardiac rate, beats/min)
24 and systolic and diastolic blood pressure (mmHg) (Supplementary file 1).
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44 Care complexity individual factors (CCIF) were classified into five domains: (i)
45 mental-cognitive, (ii) psycho-emotional, (iii) sociocultural, (iv) developmental, and (v)
46 comorbidity/complications, as described in previous studies.^{16,18} Each CCIF domain is
47 structured into factors and specifications. Patients were considered within any CCIF
48 domains if they presented at least one factor or specification. These CCIF factors and
49 specifications were obtained from the nursing assessment e-charts, as structured data
50 based on the Architecture, Terminology, Interface, Knowledge (ATIC) terminology²⁰
51 (Supplementary file 2).
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Outcome measures

The main end point was a composite of unfavourable outcomes including in-hospital mortality and adverse events [AEs] during hospitalization. The in-hospital mortality accounted the number of deceased COVID-19 patients while in a ward. The AEs included intensive care unit transfer, hospital-acquired infections (HAI) and potentially avoidable critical complications (ACC) during hospitalization. Intensive care unit (ICU) transfer was defined as the number of patient episodes with effective bed change from a general ward to an intensive care area. HAI included the number of episodes of ward patients that developed catheter-related bloodstream infection, urinary catheter-related infection, aspiration pneumonia and/or sepsis. ACC accounted for the number of episodes of ward patients that experienced a cardiac arrest, shock, thromboembolic event, acute respiratory failure, acute respiratory distress syndrome (ARDS), myocardial injury, liver injury and/or kidney failure, not present on admission.

Statistical Analysis

Descriptive analysis of data using percentage frequencies, median and interquartile range was performed to determine demographic and clinical characteristics, and patients' outcomes. For categorical variables, a comparative analysis for detecting significant differences between groups was carried out using the chi-square test or Fisher's exact test when one or more cells had an expected frequency of five or less. For continuous variables, the Student's t-test or Mann-Whitney U test was used depending on the results of the Kolmogorov-Smirnov normality test. A logistic-regression model of all clinical factors potentially associated with unfavourable outcome measures (AEs and in-hospital mortality) was performed including VIDA score, clinically relevant CCIF and other potential confounders: sex, hospital level and LOS. All potential explanatory variables included in the multivariate analysis were subjected to a correlation matrix for analysis of collinearity. The discriminatory power was evaluated by the area under the receiver

operating characteristic (ROC). Results of multivariate analysis was reported as odds ratios (OR) and 95% confidence intervals (CI). We also performed an adjusted analysis to compare unfavourable outcomes in patients admitted in wards with VIDA system and without this system. Statistical analysis will be performed using the SPSS software package version 25.0 (SPSS, Chicago, IL). *P* values less than 0.05 were considered statistically significant.

RESULTS

During the study period, 1,838 patients were hospitalised with COVID-19, among them, 1,176 patients met inclusion criteria. The frequency of unfavourable outcomes was 42.8% (506 patients). In-hospital mortality rate was 19.6% (232 patients), and almost 41% (481 patients) experienced an AE while in a ward (2.7% transferred to ICU; 2.5% HAI; 40% ACC). Acute respiratory failure, ARDS, acute kidney failure, urinary catheter-related infection, sepsis, and thrombotic event were the most frequently AEs.

Patient Characteristics

The baseline characteristics of patients with unfavourable and favourable outcome are compared in **Table 1**. COVID-19 hospitalised patients who had an unfavourable outcome were more often male, older, and had one or more underlying chronic conditions (75.5%), mostly arterial hypertension or congestive heart failure and, diabetes or chronic kidney disease. Furthermore, they had longer LOS and high risk of severity or mortality (APR-DRG 3-4). Conversely, patients admitted in high-tech hospitals presented less frequency of unfavourable outcomes.

Regarding 806 patients hospitalised with VIDA early warning system, most patients with unfavourable outcomes experienced high risk of acute deterioration (41.7% in patients with unfavourable outcomes vs. 9.1% in patients with favourable outcomes).

Comorbidity, sociocultural and developmental domains were the most frequent CCIF domains identified in the studied sample. Mental-cognitive and psycho-emotional

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3 domains were less frequent. Patients with unfavourable outcomes exhibited a higher
4 frequency of chronic disease, position impairment, anatomical and functional disorders,
5 communication disorders, old age (>75 years) and mental status impairments, when
6 compared to patients with favourable outcomes. The median of CCIF was also higher in
7 patients with unfavourable outcomes (5 [IQR: 4-6] vs. 4 [IQR: 3-5]) (**Table 1**).

14 **Risk of acute deterioration and individual complexity factors association with** 15 **outcomes.**

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18 Patients' outcomes of 806 patients with low, mild or high risk of acute deterioration were
19 compared in **Table 2**. The frequency of unfavourable outcomes was nearly 38% in
20 patients with mild risk and almost 80% in the high risk of acute deterioration group (p
21 <.0001). Similarly, the frequency of in-hospital mortality and AEs rose with increasing
22 VIDA score and reached near 60% and 80% in patients with high risk of acute
23 deterioration, respectively (p <.0001). Acute respiratory failure, acute kidney failure and
24 ICU transfer were the most frequent AEs.

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Among the 1,176 patients analysed in this study, those with four or more CCIF
experienced unfavourable outcomes (p <.0.05) (**Table 2**).

Table 3 shows an adjusted analysis of health outcomes in 486 patients with high
risk of mortality (APR-DRG 3-4) to compare patients admitted in wards where registered
nurses use or do not use the VIDA early warning score system. In-hospital mortality was
more frequent in patients admitted in wards where VIDA was not used (52.5% vs. 41.3%,
 p <.0.05). Conversely, the frequency of AEs was slightly higher in patients admitted
VIDA' wards (p <.0.05).

Risk factors associated with unfavourable outcomes

The results of the multivariable analysis for risk of acute deterioration (as measured with VIDA score) and CCIF potentially associated with unfavourable outcomes, in-hospital mortality and AEs, are summarized in **Table 4**.

After adjustment of potentially confounders, the analysis shows that high risk of acute deterioration was an independent factor associated with unfavourable outcomes, in-hospital mortality, and AEs in COVID-19 ward inpatients. Furthermore, chronic disease, mental status impairments and LOS were risk factors associated with unfavourable outcomes. Conversely, high-tech hospital admission was a protective factor of unfavourable outcomes. The area under the ROC curve (AUC) was 0.81 (95% CI: 0.78-0.84).

Chronic disease, mental status impairments, old age and male sex were independent risk factors associated with in-hospital mortality for studied COVID-19 inpatients (AUC 0.91 [95% CI: 0.88-0.93]). Finally, risk factors independently associated with AEs were chronic disease, mental status impairments, old age and LOS; while high-tech hospital admission was a protective factor of AEs (AUC 0.80 [95% CI: 0.77-0.83]). The AUC of the three outcomes analysed were > 0.80 , showing a fair discriminatory power.

DISCUSSION

In this study of a large cohort of hospitalised patients with COVID-19, the frequency of in-hospital mortality and AEs reached near 60% and 80%, in patients scored as at high risk of acute deterioration, respectively. In-hospital mortality was higher in wards not using the VIDA early warning system. A wide majority of patients had four or more care complexity individual factors identified. The risk factors independently associated with unfavourable outcomes included chronic disease, mental status impairments, LOS and high risk of acute deterioration. High-tech hospital admission was a protective factor of unfavourable outcomes.

Our findings are consistent with previous COVID-19 reports which have found a similar frequency of in-hospital mortality and AEs.^{3,21} In addition, 37% of patients developed respiratory complications (acute respiratory failure or ARDS) during hospitalization. This value is within the range reported in a previous inquiry (29-42%).³

The results of this study show that high risk of acute deterioration is a significant risk factor for unfavourable outcomes, as a composite measure for in-hospital mortality, and AEs in admitted COVID-19 patients. Although previous studies have stressed that early warning systems are predictors of in-hospital mortality and health outcomes,^{22,23} only a few have evaluated warning score systems in admitted COVID-19 patients.^{11,19} These latest studies showed a fair discrimination with adverse outcomes, concluding that the evaluation of the risk for acute deterioration in the COVID-19 hospital population is a priority for the organizations.¹⁹

In-hospital mortality was more frequent in patients admitted in wards where registered nurses do not use VIDA early warning system. In this regard, other studies show that the use of early systems reinforces collaboration among the multidisciplinary team, and promotes the early identification of clinical deterioration.²⁴ Similarly, previous

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3 studies have reported less mortality and adverse events when systematic nursing
4 surveillance of patient status and progress is a daily basis practice.⁹
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8 Chronic conditions and mental status impairments were the CCIF independently
9 associated with unfavourable outcomes. Previous reports have shown that chronic
10 diseases were more frequent among deceased COVID-19 patients¹⁵ and older age was a
11 potential risk factor associated with mortality.⁶ Although our study has not identified age
12 as a risk factor associated with a composite unfavourable outcome, we acknowledge that
13 old age was an independent risk factor associated with mortality and AE. Furthermore,
14 our findings were also consistent with other studies showing that mental status
15 impairments are associated with hospital-acquired complications,²⁵ including sepsis.⁴
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26 A wide majority of patients had four or more CCIF. Our findings are consistent
27 with other studies that identified an important rate of chronic conditions in COVID-19
28 patients¹⁵ and by the other hand, selected organizational issues that may impact care
29 complexity and health outcomes.²⁶ Previous inquires have demonstrated the association
30 of CCIF and health outcomes,¹⁶ with an average of two CCIF per patient. Our
31 investigation showed that for COVID-19 inpatients, the average of CCIF is four. These
32 results are probably related to the transmissibility of this condition requiring droplet and
33 contact precautions, the pandemics management associated public health measures of
34 population confinement, preventing patients' relatives to visit admitted patients in person,
35 resulting in a lack of family caregiver support during hospitalisation, and the frequency
36 of chronic diseases in the studied sample. The organizational adaptation of hospitals to
37 this pandemic context and the required isolation precautions have been associated with
38 poor outcomes in prior studies.^{27,28}
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56 Additionally, we found that LOS was associated with unfavourable outcomes,
57 coinciding with previous studies that associated AEs with increased healthcare costs due
58 to longer hospital stays.²⁹ Finally, high-tech hospital admission was a protective factor
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3 associated to unfavourable outcomes. High-tech hospitals usually have better nurse-to-
4 patient ratios, than urban or community facilities. In this sense, a couple of recent
5 inquiries in the same context of this study conclude that, on average hospital ward patients
6 require 5.6 hours of RN care per patient day, while the average RN offered hours per
7 patient day is 2.4, and that RN understaffing is a structural issue.^{26,30} Nevertheless, to the
8 best of our knowledge, no study on nurse staffing and COVID-19 inpatients' outcomes
9 have been published. Similarly, healthcare clinical leaders and managers have become
10 key role to rapidly adapt organizations to the new reality. Fast and effective decision-
11 making and managerial responses in crisis situations with high levels of uncertainty are
12 essential at immediate and short-term however, they should be accompanied by planning
13 and executing mid-term and long-lasting improvements that positively impact patient,
14 professional and organizational outcomes, such as structural RN understaffing.²⁶

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The strengths of this study include its multicentre approach, cohort design and large sample size. It is the first research evaluating the association of the risk of acute deterioration, along with care complexity individual factors, with COVID-19 patient outcomes. Importantly, we identify broader health-contributors of care complexity, including psychosocial and mental-cognitive factors. In addition, the VIDA early warning system was developed as an evidence-based algorithm with a multidisciplinary approach, and also according to previous studies that highlighted the importance to adapt surveillance and screening systems to organization and cultural context.¹⁴

VIDA score and CCIF data were comprehensively collected from clinical data warehouse of the Catalan Institute of Health and all patients included had a completed nurse charting in the patient electronic health record. Nevertheless, there are some limitations that should be acknowledged. We relied a properly compliance on electronic health records and administrative data, however this statement should be interpreted with caution since voluntary completion of electronic health records show close-to-reality data

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3 and information on nurses' observations on patient status and progress, but it not the
4 reality in itself. It should be noted, no previous studies have demonstrated the
5 effectiveness VIDA early warning system yet. Nevertheless, the results of this study had
6 proved the significant association between the unfavourable outcomes with VIDA score
7 and CCIF, although a validate the model in external samples is still needed. Finally, we
8 acknowledge as a significant limitation that we did not evaluate other clinical measures
9 such as the age-adjusted Charlson comorbidity index or patient lab values.

19 **Conclusion**

21 The risk of acute deterioration and the care complexity individual factors are associated
22 with COVID-19 patient outcomes. The rate of unfavourable outcomes rose with
23 increasing risk of acute deterioration as measured with VIDA score. The risk factors
24 independently associated with poor health outcomes were chronic disease, mental status
25 impairment, length of hospital stay and high risk of acute deterioration. High-tech hospital
26 admission was a protective factor of unfavourable outcomes. The systematic nursing
27 surveillance of patients at risk of acute deterioration and the assessment of CCIF may
28 contribute to reduce deleterious health outcomes in COVID-19 inpatients.
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FOOTNOTES

Author Contributions: All authors had full access to all study data and take responsibility for the integrity of the data and the accuracy of the data analysis. *Study concept and design:* Adamuz, González-Samartino, Juvé-Udina. *Coordination team:* Juvé-Udina. *Acquisition of data:* Adamuz, Tapia-Perez, López-Jiménez, Zuriguel-Pérez, Castro-Navarro. *Analysis and interpretation data:* Adamuz, González-Samartino, Jiménez-Martínez. *Drafting of the manuscript:* Adamuz, González-Samartino, Jiménez-Martínez, Juvé-Udina. *Critical revision of the manuscript for important intellectual content:* Tapia-Perez, López-Jiménez, Rodríguez-Fernández, Zuriguel-Pérez, Castro-Navarro, Carratalà. *Statistical analysis:* Adamuz and González-Samartino. *Obtained funding:* - . *Administrative, technical and material support:* López-Jiménez, Rodríguez-Fernández. *Study supervision:* Juvé-Udina, Carratalà.

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Patient consent for publication: Not required.

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Provenance and peer review: Not commissioned; externally peer reviewed.

Data availability statement: All data relevant to the study are included in the article.

No additional data are available.

Table 1. Baseline characteristics, VIDA score and care complexity individual factors of admitted COVID-19 patients with unfavourable and favourable outcomes.

| Characteristics | Study population n=1,176 | | Unfavourable outcome ^a n=506 (42.8%) | | Favourable outcome n=670 (57.1%) | | p value |
|---|-----------------------------|---------|--|---------|-------------------------------------|---------|---------|
| | No. | % | No. | % | No. | % | |
| Demographic characteristics | | | | | | | |
| Age (years)_ median (IQR) | 66.5 | (51-77) | 74 | (60-80) | 61 | (49-74) | <0.001 |
| Male sex | 667 | (56.7) | 192 | (37.9) | 317 | (47.3) | 0.001 |
| Clinical characteristics | | | | | | | |
| LOS_ median (IQR) | 6 | (4-8) | 7 | (4-10) | 5 | (4-7) | <0.001 |
| Continuity of care (discharged to another facility) | 165 | (14) | 58 | (11.5) | 107 | (16) | 0.02 |
| Severity (APR-GRD 3-4) | 503 | (42.8) | 450 | (88.9) | 53 | (7.9) | <0.001 |
| Mortality risk (APR-DRG 3-4) | 486 | (41.3) | 449 | (88.7) | 37 | (5.5) | <0.001 |
| High-tech hospital | 969 | (82.4) | 389 | (76.9) | 580 | (86.6) | <0.001 |
| Underlying disease | 745 | (63.4) | 382 | (75.5) | 363 | (54.4) | <0.001 |
| Arterial hypertension or chronic heart failure | 469 | (39.9) | 234 | (46.2) | 235 | (35.1) | <0.001 |
| Diabetes or chronic kidney disease | 298 | (25.3) | 165 | (32.6) | 133 | (19.9) | <0.001 |
| Chronic respiratory disease | 171 | (14.5) | 95 | (18.8) | 76 | (11.3) | <0.001 |
| Neurodegenerative disease | 63 | (5.3) | 33 | (6.5) | 39 | (4.5) | 0.15 |
| Chronic liver disease | 54 | (4.6) | 30 | (5.9) | 24 | (3.6) | 0.07 |
| Cancer | 50 | (4.3) | 31 | (6.5) | 19 | (2.8) | 0.008 |
| Immunosuppression | 49 | (4.2) | 23 | (4.5) | 26 | (3.9) | 0.66 |
| VIDA score^b | | | | | | | |
| Low risk (0) | 104 | (12.9) | 27 | (7.1) | 77 | (18) | <0.001 |
| Moderate risk (1-2) | 505 | (62.7) | 194 | (51.2) | 311 | (72.8) | <0.001 |
| High risk (3-4) | 197 | (16.7) | 158 | (41.7) | 39 | (9.1) | <0.001 |
| Care complexity individual factors (CCIF) | | | | | | | |
| Comorbidity/complications | | | | | | | |
| Transmissible infection | 1,176 | (100) | 506 | (100) | 670 | (100) | - |
| Hemodynamic instability | 910 | (77.4) | 396 | (78.3) | 514 | (76.7) | 0.57 |
| Chronic disease | 745 | (63.4) | 382 | (75.5) | 363 | (54.4) | <0.001 |
| Uncontrolled pain | 194 | (16.5) | 82 | (16.2) | 112 | (16.7) | 0.87 |
| Extreme weight | 168 | (14.3) | 82 | (16.2) | 86 | (12.8) | 0.11 |
| Position impairment | 72 | (6.1) | 52 | (10.3) | 20 | (3.0) | <0.001 |
| Urinary or faecal incontinence | 58 | (4.9) | 31 | (6.1) | 27 | (4.0) | 0.10 |
| Immunosuppression | 49 | (4.1) | | | | | |
| Anatomical and functional disorders | 41 | (3.5) | 30 | (5.9) | 11 | (1.6) | <0.001 |
| Communication disorders | 18 | (1.5) | 13 | (2.6) | 5 | (0.7) | 0.01 |
| High risk of hemorrhage | 2 | (0.2) | 1 | (0.2) | 1 | (0.1) | 0.68 |
| Vascular fragility | 6 | (0.5) | 4 | (0.8) | 2 | (0.3) | 0.41 |
| Involuntary movements | 3 | (0.3) | 3 | (0.6) | 0 | (0.0) | 0.08 |
| Dehydration | 3 | (0.3) | 1 | (0.2) | 2 | (0.3) | 0.60 |
| Oedema | 0 | (0) | 0 | (0.0) | 0 | (0.0) | - |
| Developmental | | | | | | | |
| Old age (≥75 years) | 397 | (33.8) | 244 | (48.2) | 153 | (22.8) | <0.001 |
| Psycho-emotional | | | | | | | |
| Fear/anxiety | 173 | (14.7) | 70 | (13.8) | 103 | (15.4) | 0.51 |
| Impaired adaptation | 54 | (4.6) | 17 | (3.4) | 37 | (5.5) | 0.09 |
| Aggressive behaviour | 1 | (0.1) | 1 | (0.2) | 0 | (0.0) | 0.43 |
| Mental-cognitive | | | | | | | |
| Mental status impairments | 240 | (20.4) | 184 | (36.4) | 56 | (8.4) | <0.001 |
| Agitation | 238 | (20.2) | 183 | (36.2) | 55 | (8.2) | <0.001 |
| Impaired cognitive functions | 5 | (0.4) | 4 | (0.8) | 1 | (0.1) | 0.17 |
| Perception of reality disorders | 4 | (0.3) | 3 | (0.6) | 1 | (0.1) | 0.32 |
| Perception of reality disorders | 2 | (0.2) | 0 | (0.0) | 2 | (0.3) | 0.51 |
| Sociocultural | | | | | | | |
| Lack of caregiver support | 1,176 | (100) | 506 | (100) | 670 | (100) | - |
| Belief conflict | 1,176 | (100) | 506 | (100) | 670 | (100) | - |
| Belief conflict | 1 | (0.1) | 0 | (0.0) | 1 | (0.1) | 0.57 |
| Language barriers | 1 | (0.1) | 1 | (0.2) | 0 | (0.0) | 0.43 |
| Social exclusion | 1 | (0.1) | 0 | (0.0) | 1 | (0.1) | 1 |
| Care complexity individual factors (CCIF), median (IQR) | 4 | (3-6) | 5 | (4-6) | 4 | (3-5) | <0.001 |

Abbreviations: IQR, interquartile range; LOS, length of hospital stay; ICU, intensive care unit; APR-DRG, all patient refined diagnosis-related groups; VIDA, surveillance and identification of acute deterioration.

^a Unfavourable outcomes included: in-hospital mortality and adverse events during hospitalization.

^b VIDA score was analysed according to 806 admitted patients in wards with VIDA system.

Table 2. Patients' outcomes according to risk of acute deterioration (VIDA score) and care complexity individual factors.

| Outcomes | VIDA_score n=806 (68.5) | | | | CCIF n=1,176 | |
|--|-------------------------|-----------------------|-----------------------|-----------------------|-----------------------|-----------------------|
| | All | Low risk (0) | Mild risk (1-2) | High risk (3-4) | CCIF<4 | CCIF≥4 |
| | n=1,1176 N (%) | n=104 (12.9) N (%) | n=505 (62.7) N (%) | n=197 (16.7) N (%) | n=327 (27.8) N (%) | n=849 (72.2) N (%) |
| Unfavourable outcomes | 506 (43.0) | 27 (26.0)** | 194 (38.4)* | 158 (80.2)** | 92 (28.1)** | 414 (48.8)** |
| Deceased | 232 (19.6) | 0 (0.0)** | 46 (9.1)** | 118 (59.9)** | 5 (1.5)** | 227 (26.7)** |
| Adverse event | 481 (40.9) | 27 (26.0)** | 187 (37)* | 153 (77.7)** | 91 (27.8)** | 394 (46.4)** |
| ICU transfer | 32 (2.7) | 0 (0.0)* | 12 (2.4) | 13 (6.6)* | 4 (1.2)* | 28 (3.3)* |
| HAI | 29 (2.5) | 0 (0.0)* | 10 (2.0) | 12 (6.1)* | 1 (1.5) | 24 (2.8) |
| Catheter-related bloodstream infection | 1 (0.1) | 0 (0.0) | 0 (0.0) | 1 (0.5) | 0 (0.0) | 1 (0.1) |
| HA urinary tract infection | 19 (1.6) | 0 (0.0) | 7 (1.4) | 8 (4.1)* | 3 (0.9) | 16 (1.9) |
| Aspiration pneumonia | 3 (0.3) | 0 (0.0) | 3 (0.6) | 0 (0.0) | 0 (0.0) | 3 (0.4) |
| Sepsis | 7 (0.6) | 0 (0.0) | 1 (0.2) | 3 (1.5)* | 2 (0.6) | 5 (0.6) |
| ACC | 470 (40.0) | 27 (26.0)** | 181 (35.8)** | 150 (76.1)** | 88 (26.6)** | 383 (45.1)** |
| Cardiac arrest | 5 (0.4) | 1 (1.0) | 0 (0.0)* | 3 (1.5)* | 0 (0.0) | 5 (0.6) |
| Shock | 4 (0.3) | 0 (0.0) | 2 (0.4) | 0 (0.0) | 0 (0.0) | 4 (0.5) |
| Thrombotic event | 7 (0.6) | 1 (1.0) | 1 (0.2) | 2 (1) | 1 (0.3) | 6 (0.7) |
| Acute respiratory failure ¹ | 436 (37.0) | 27 (26.0)** | 164 (32.5)** | 144 (73.1)** | 84 (25.1)** | 353 (41.6)** |
| Myocardial injury | 5 (0.4) | 0 (0) | 3 (0.6) | 1 (0.5) | 0 (0.0) | 5 (0.6) |
| Liver injury | 2 (0.2) | 0 (0) | 0 (0) | 1 (0.5) | 0 (0.0) | 2 (0.2) |
| Renal insufficiency | 83 (7.1) | 1 (1.0)* | 28 (5.5)* | 31 (15.7)** | 6 (1.8)** | 77 (9.1)** |

Abbreviations: VIDA, surveillance and identification of acute deterioration; CCIF, care complexity individual factors; ICU, intensive care unit; HAI, hospital-acquired infections; ACC, avoidable critical complications.

* p value >0.001 and <0.05 .

** p value ≤ 0.001 .

¹ Include acute respiratory distress syndrome (ARDS).

Table 3. Adjusted analysis of unfavourable outcomes according to VIDA early warning system in 486 patients with high risk of mortality (APR-DRG 3-4).

| Outcomes | Unadjusted n=1,1176 | | Adjusted n=486 (41.2) | | With VIDA_system n=368 (75.7) | | Without VIDA_system n=118 (24.3) | | <i>p value</i> ¹ |
|------------------------------|------------------------|--------|--------------------------|--------|----------------------------------|--------|-------------------------------------|--------|-----------------------------|
| | N | (%) | N | (%) | N | (%) | N | (%) | |
| Unfavourable outcomes | 506 | (43.0) | 449 | (92.4) | 345 | (93.8) | 104 | (88.1) | 0.07 |
| Deceased | 232 | (19.6) | 214 | (44) | 152 | (41.3) | 62 | (52.5) | 0.02 |
| Adverse event | 481 | (40.9) | 436 | (89.7) | 337 | (91.6) | 99 | (83.9) | 0.02 |
| ICU transfer | 32 | (2.7) | 25 | (5.1) | 20 | (5.4) | 5 | (4.2) | 0.41 |
| HAI | 29 | (2.5) | 19 | (3.9) | 16 | (4.3) | 3 | (2.5) | 0.28 |
| ACC | 470 | (40.0) | 433 | (89.1) | 334 | (90.8) | 99 | (83.9) | 0.31 |

Abbreviations: VIDA, surveillance and identification of acute deterioration; ICU, intensive care unit; HAI, hospital-acquired infections; ACC, avoidable critical.

¹All variables were compared using the Fisher exact test.

Review only

Table 4. Multivariate analysis of VIDA score and CCIF in 806 adult COVID-19 hospitalized patients associated with unfavourable outcomes, deceased and AE.

| <i>Characteristics</i> | Unfavourable outcomes ¹ | | Deceased ² | | AE ³ | |
|---------------------------|------------------------------------|----------------|-----------------------|----------------|-------------------|---------------|
| | n= 379/806 (47%) | | n= 164/806 (20.3%) | | n=367/806 (45.5%) | |
| | OR | (95% CI) | OR | (95% CI) | OR | (95% CI) |
| Old age (≥75 years) | 1.48 | (0.99-2.22) | 3.04 | (1.79-5.15)** | 1.52 | (1.02-2.26)* |
| Male sex | 1.21 | (0.87-1.69) | 1.86 | (1.11-3.11)* | 1.20 | (0.87-1.67) |
| LOS | 1.16 | (1.11-1.21)** | 0.97 | (0.93-1.01) | 1.17 | (1.12-1.22)** |
| High-tech hospital | 0.57 | (0.36-0.89)* | 1.88 | (0.94-3.78) | 0.61 | (0.39-0.95)* |
| VIDA score 3-4 | 4.32 | (2.83-6.60)** | 13.99 | (8.44-23.18)** | 4.21 | (2.79-6.36)** |
| Chronic disease | 1.90 | (1.32-2.72)** | 2.01 | (1.03-3.90)* | 1.81 | (1.26-2.59)** |
| Position impairment | 1.19 | (0.58-2.44) | 1.41 | (0.63-3.13) | 1.23 | (0.62-2.46) |
| Communication disorders | 0.97 | (0.24-3.96) | 0.87 | (0.22-3.41) | 0.78 | (0.21-2.95) |
| Mental status impairments | 2.31 | (1.45-23.66)** | 6.21 | (3.67-10.50)** | 1.72 | (1.09-2.69)* |

Abbreviations: AE, adverse event; LOS, length of hospital stay; VIDA, surveillance and identification of acute deterioration. Multivariate analysis included: high risk of acute deterioration (VIDA score 3-4), clinically relevant care complexity individual factors (old age, chronic disease, position impairment, communication disorders and mental status impairments) and potential confounders (sex, hospital level and LOS).

¹AUC 0.81 (CI 95%; 0.78-0.84).

²AUC 0.91 (CI 95%; 0.88-0.93).

³AUC 0.80 (CI 95%; 0.77 -0.83).

* *p* value >0.001 and <0.05.

** *p* value ≤0.001.

only

Supplementary file 1. Juvé-Udina ME. VIDA score for acute deterioration in the current human algorithm.

| H1, H2, H3 | | |
|--------------------|-------------------|---|
| Punctuation | Risk score | Definition |
| 0 – 1 | 0 | No risk of complication (at that particular moment) |
| 2 – 3 | 1 | Low risk |
| 4 | 2 | Moderate risk (very probable complication) |
| 5 – 6 | 3 | High risk (imminent complication if not stabilized) |
| >= 7 | 4 | Critical complication status |
| H4 | | |
| Punctuation | Risk score | Definition |
| 0 – 1 | 0 | No risk of complication (at that particular moment) |
| 2 – 3 | 1 | Low risk |
| 4 – 6 | 2 | Moderate risk (very probable complication) |
| 7 – 9 | 3 | High risk (imminent complication if not stabilized) |
| >= 10 | 4 | Critical complication status |
| H5 | | |
| Punctuation | Risk score | Definition |
| 0 – 2 | 0 | No risk of complication (at that particular moment) |
| 3 – 4 | 1 | Low risk |
| 5 – 6 | 2 | Moderate risk (very probable complication) |
| 7 – 8 | 3 | High risk (imminent complication if not stabilized) |
| >= 9 | 4 | Critical complication status |
| H6 | | |
| Punctuation | Risk score | Definition |
| 0 – 2 | 0 | No risk of complication (at that particular moment) |
| 3 – 4 | 1 | Low risk |
| 5 – 6 | 2 | Moderate risk (very probable complication) |
| 7 – 9 | 3 | High risk (imminent complication if not stabilized) |
| >= 10 | 4 | Critical complication status |
| H7 | | |
| Punctuation | Risk score | Definition |
| <= 3 | 1 | Low risk |
| 4 – 6 | 2 | Moderate risk (very probable complication) |
| 7 – 8 | 3 | High risk (imminent complication if not stabilized) |
| >= 9 | 4 | Critical complication status |

Abbreviations: H, hospital.

Supplementary file 2. Care complexity individual factors.

| Domains | Factors | Specifications |
|-------------------------------|--|--|
| Comorbidity/ Complications | Transmissible infection | Isolation measures |
| | Hemodynamic instability | Intensive control of vital signs or state of shock |
| | Chronic disease | Conditions (organ failure, degenerative process or oncological disease) that require ongoing medical attention and limit activities of daily living. |
| | Uncontrolled pain | Verbal numerical rating scale above three points |
| | Extreme weight | Low weight, obesity |
| | Position impairment | Includes any position impairment |
| | Urinary or faecal incontinence | Loss of bladder control or failure to control bowel movements |
| | Immunosuppression | Neutropenia, immunodeficiency or immunosuppressive therapy |
| | Anatomical and functional disorders | Amputation, deformities, joint stiffness |
| | Communication disorders | Aphasia, dysphasia, dysarthria, laryngectomy, tracheostomy |
| | High risk of haemorrhage | Coagulation disorders, thrombocytopenia, anticoagulant therapy |
| | Vascular fragility | Capillary fragility, tortuous veins |
| | Involuntary movements | Continuous involuntary movements |
| Dehydration | Skin turgor | |
| Oedema | An accumulation of an excessive amount of watery fluid in cells, tissues, or serous cavities | |
| Developmental | Old age | ≥75 years |
| Psycho- emotional | Fear/anxiety | Fear or anxiety (moderate or intense) |
| | Impaired adaptation | Disruptive behaviour, hopelessness or surrender |
| | Aggressive behaviour | Physical or verbal aggressive behaviour (moderate or intense) |
| Mental- cognitive | Mental status impairments | Confusion, disorientation, stupor, transient loss of consciousness |
| | Agitation | Psychomotor agitation |
| | Impaired cognitive functions | Intellectual disability, amnesia |
| | Perception of reality disorders | Delirium, hallucinations, disconnection from reality |
| Sociocultural | Lack of caregiver support | Without caregiver support or caregiver burnout |
| | Belief conflict | Spiritual distress |
| | Language barriers | Barrier to communication resulting from speaking different languages than Spanish or Catalan without translator. |
| | Social exclusion | Extreme poverty |

STROBE Statement—Checklist of items that should be included in reports of *cohort studies*

| | Item No | Recommendation | |
|------------------------------|---------|--|-----------|
| Title and abstract | 1 | (a) Indicate the study's design with a commonly used term in the title or the abstract | Pg.3 |
| | | (b) Provide in the abstract an informative and balanced summary of what was done and what was found | Pg.3-4 |
| Introduction | | | |
| Background/rationale | 2 | Explain the scientific background and rationale for the investigation being reported | Pg.5-6 |
| Objectives | 3 | State specific objectives, including any prespecified hypotheses | Pg.6 |
| Methods | | | |
| Study design | 4 | Present key elements of study design early in the paper | Pg.7 |
| Setting | 5 | Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection | Pg.7 |
| Participants | 6 | (a) Give the eligibility criteria, and the sources and methods of selection of participants. Describe methods of follow-up | Pg.7 |
| | | (b) For matched studies, give matching criteria and number of exposed and unexposed | - |
| Variables | 7 | Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable | Pg.7-8 |
| Data sources/ measurement | 8* | For each variable of interest, give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group | Pg.7-8 |
| Bias | 9 | Describe any efforts to address potential sources of bias | Pg.16 |
| Study size | 10 | Explain how the study size was arrived at | Pg.7 |
| Quantitative variables | 11 | Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why | Pg.9 |
| Statistical methods | 12 | (a) Describe all statistical methods, including those used to control for confounding | Pg.9 |
| | | (b) Describe any methods used to examine subgroups and interactions | Pg.9 |
| | | (c) Explain how missing data were addressed | - |
| | | (d) If applicable, explain how loss to follow-up was addressed | - |
| | | (e) Describe any sensitivity analyses | - |
| Results | | | |
| Participants | 13* | (a) Report numbers of individuals at each stage of study—eg numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed | Pg.10 |
| | | (b) Give reasons for non-participation at each stage | Pg.10-11 |
| | | (c) Consider use of a flow diagram | - |
| Descriptive data | 14* | (a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders | Pg.10 |
| | | (b) Indicate number of participants with missing data for each variable of interest | - |
| | | (c) Summarise follow-up time (eg, average and total amount) | Pg.10 |
| Outcome data | 15* | Report numbers of outcome events or summary measures over time | Pg10-11 |
| Main results | 16 | (a) Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (eg, 95% confidence interval). Make clear which confounders were adjusted for and why they were included | Table 1&4 |

| | | | |
|--------------------------|----|--|-----------|
| | | (b) Report category boundaries when continuous variables were categorized | Table 1&4 |
| | | (c) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period | Pg.11-12 |
| Other analyses | 17 | Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses | Pg.11 |
| Discussion | | | |
| Key results | 18 | Summarise key results with reference to study objectives | Pg.13 |
| Limitations | 19 | Discuss limitations of the study, taking into account sources of potential bias or imprecision. Discuss both direction and magnitude of any potential bias | Pg.16 |
| Interpretation | 20 | Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence | Pg.14-16 |
| Generalisability | 21 | Discuss the generalisability (external validity) of the study results | Pg.15-16 |
| Other information | | | |
| Funding | 22 | Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based | Pg.21. |

*Give information separately for exposed and unexposed groups.

Note: An Explanation and Elaboration article discusses each checklist item and gives methodological background and published examples of transparent reporting. The STROBE checklist is best used in conjunction with this article (freely available on the Web sites of PLoS Medicine at <http://www.plosmedicine.org/>, Annals of Internal Medicine at <http://www.annals.org/>, and Epidemiology at <http://www.epidem.com/>). Information on the STROBE Initiative is available at <http://www.strobe-statement.org>.

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Risk of acute deterioration and care complexity individual factors associated with health outcomes in hospitalised patients with COVID-19: a multicenter cohort study.

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ORIGINAL ARTICLE

Risk of acute deterioration and care complexity individual factors associated with health outcomes in hospitalised patients with COVID-19: a multicenter cohort study.

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ABSTRACT

Background: Evidence about the impact of systematic nursing surveillance on acute deterioration risk along with care complexity individual factors on inpatient outcomes, is scarce. The study is aimed at determining the association between acute deterioration risk and care complexity individual factors with unfavourable outcomes in hospitalised patients with COVID-19.

Methods: A multicentre cohort study was conducted from March 1, 2020 to March 31, 2020 at seven hospitals in Catalonia. All COVID-19 adults patients admitted to hospitals and with completed minimum data set were recruited retrospectively. Patients were classified based on the presence or absence of a composite unfavourable outcome (in-hospital mortality and adverse events). The main measures included acute deterioration risk (as measured with VIDA early warning system) and care complexity individual factors. All data were obtained blinded from electronic health records. Multivariate logistic analysis was performed to identify VIDA score and care complexity factors associated with unfavourable outcomes.

Results: From a total of 1,176 COVID-19 patients, 506 patients (43%) experienced an unfavourable outcome during hospitalisation. The frequency of unfavourable outcomes rose with increasing risk of acute deterioration as measured with VIDA score. Risk factors independently associated with unfavourable outcomes were chronic underlying disease (OR: 1.90, 95% CI: 1.32-2.72; $p < 0.001$), mental status impairment (OR: 2.31, 95% CI: 1.45-23.66; $p < 0.001$), length of hospital stay (OR: 1.16, 95% CI: 1.11-1.21; $p < 0.001$) and high risk of acute deterioration (OR: 4.32, 95% CI: 2.83-6.60; $p < 0.001$). High-tech hospital admission was a protective factor of unfavourable outcomes (OR: 0.57, 95% CI: 0.36-0.89; $p = 0.01$).

Conclusion: The systematic nursing surveillance of the status and evolution of COVID-19 inpatients, including the careful monitoring of acute deterioration risk and care

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3 complexity individual factors may contribute to reduce deleterious health outcomes in
4
5 COVID-19 inpatients.
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10 **STRENGTHS AND LIMITATIONS OF THIS STUDY**

- 12 • We performed a multicentre cohort study with a large sample size in patients
13 with COVID-19.
 - 14
15 • This novel research assessed the impact of the risk of acute deterioration and
16
17 broader health contributors of care complexity with COVID-19 patient
18
19 outcomes.
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21
 - 22 • We do not evaluate other clinical measures such as the age-adjusted Charlson
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24 comorbidity index or patient lab values.
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 - 27 • Futures studies should validate the model.
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INTRODUCTION

Along with climate change and financial crises, pandemics are one of the major global risks for the 21st century. A 2019 report stated that, in the last decade the World Health Organization (WHO) tracked 1,483 epidemic events, including Severe Acute Respiratory Syndrome (SARS), Middle East Respiratory Syndrome (MERS), Ebola or other epidemic-prone diseases, considered harbingers of a new era of high-impact, potentially fast-spreading outbreaks.¹

The potential thread became real last December 2019, when a severe acute respiratory infection caused by the new coronavirus SARS-CoV-2 began to spread first in Wuhan (China).^{2,3} The WHO announced the Wuhan pneumonia as an outbreak of potential danger in December 31st, as an outbreak of global concern in January 31st, and finally the coronavirus disease (COVID-19) was declared a global pandemic in February 2020.

COVID-19 patients frequently require hospital admission as they may rapidly develop severe potential life-threatening complications, such as acute respiratory distress syndrome, sepsis, major thromboembolic events or cardiac injury, requiring intensive care.³⁻⁵ Recent studies have found overall in-hospital mortality rates for COVID-19 inpatients ranging from 15 to 28%.^{3,6-8} Therefore, early recognition of patient deterioration and escalation of treatment to reduce the risk of progression to critical complications is a significant issue that may impact patient and organizational outcomes. Screening for acute deterioration implies nursing surveillance, data collection, interpretation and recognition of changes in patients' status, prioritization of patients' problems and decision making on the interventions to perform in order to curb the cascade towards adverse events (AEs) and death.⁹

According to the WHO "*patients hospitalized with COVID-19 require regular monitoring of vital signs and, where possible, utilization of early warning scores that*

1
2
3 *facilitate early recognition and escalation of treatment of the deteriorating patient.*¹⁰
4

5 Early warning systems have become an important component of managing inpatient
6 care, as well as a clinical decision-making support stratification tool to prevent poor
7 health outcomes.¹¹⁻¹³ Previous studies suggested the need for adaptation of these
8 systems to each context.¹⁴ According to these recommendations, several evidence-based
9 algorithms were developed and used to early identify and act upon initial or impending
10 acute deterioration among hospitalised patients. In the context of this study, a nursing
11 surveillance improving program named VIDA (the Catalan acronym for Surveillance
12 and Identification of Acute Deterioration) started in 2013 and has evolved with a
13 multidisciplinary approach, as a daily used early warning score system, contributing to
14 assist clinical decision-making, since then.
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28 It has been described that admitted patients with COVID-19 have a substantial
29 rate of chronic conditions that may affect the complexity of medical and nursing care
30 provision, and patient health outcomes.¹⁵ Nevertheless, care complexity individual
31 factors (CCIF) are related not only to multiple comorbidities but also to mental-
32 cognitive and psychosocial patient features, which in turn are also associated with
33 increased healthcare needs during hospitalization and with selected health outcomes.¹⁶⁻
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44 Only a few studies in COVID-19 inpatients have explored the use of acute
45 deterioration risk stratification^{11,19} and to date, none has assessed CCIF as predictors of
46 poor health outcomes. The aim of this study is to determine the association between
47 acute deterioration risk (as measured with VIDA early warning system) and care
48 complexity individual factors with unfavourable outcomes in admitted patients with
49 COVID-19.
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METHODS

Setting and Study Design

A retrospective cohort study was carried out at seven public hospitals in Catalonia, Spain: three tertiary metropolitan facilities, three urban university centres and one community hospital. All patients with a medical diagnosis of COVID-19 infection whether they were admitted to a ward or intermediate unit for COVID-19 or other causes from March 1, 2020 to March 31, 2020 with a completed hospital minimum data set report were recruited retrospectively and followed up during the hospitalization until discharge or deceased. Patients' directly admitted and discharged from intensive care units (ICU) were excluded because VIDA early warning system was not implemented on ICU. Also patients who remained hospitalized after the recruitment end date were excluded due the data of hospital minimum data set was not available.

We defined the primary endpoint as a composite of unfavourable outcomes including in-hospital mortality or adverse events (AEs), not present on admission and occurring thereafter during hospitalization.

Patient and Public Involvement

This study was approved by The Clinical Research Ethics Committee of the Bellvitge University Hospital (reference 158/20). Informed consent was waived due to the study's retrospective design. Ethical and data protection protocols related to anonymity and data confidentiality (access to records, data encryption and archiving of information) were complied with throughout the whole research process.

Data Collection

Information regarding the demographic and clinical characteristics, continuity of care (discharged to another facility), high-tech hospital (referral centre that provides tertiary care for either open-heart surgery or major organ transplants or both), length of hospital stay (LOS) and patient severity and mortality risk were collected from the hospital

1
2
3 minimum data set and the clinical data warehouse of the Catalan Institute of Health.
4
5 Patient severity and risk of mortality was based on the all patient refined diagnosis-
6
7 related groups (APR-DRG) that categorises both measures in four groups, from low
8
9 (level 1) to extreme (level 4). Severity and mortality risk were dichotomized in this
10
11 study into low risk (levels 1-2) and high risk (levels 3-4).²⁰ All variables were collected
12
13 during hospitalisation.
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16
17 VIDA score (acute deterioration risk stratification) classifies automatically
18
19 patients into five groups according to patient progress data: no risk (level 0), low risk
20
21 (level 1), moderate risk (level 2), high risk (impending complication if not stabilized)
22
23 (level 3), manifested complication initial status (level 4). Levels 2 to 4 make an alert in
24
25 the electronic health records with clinical recommendations. These recommendations
26
27 were standardized for each context in line to intensify the measurement of patients
28
29 status surveillance and notify to medical team. The health team (nurse and specialist)
30
31 had the final clinical decision-making. For the purposes of this study, VIDA score
32
33 classified into mild (levels 1-2) and high (levels 3-4) risk groups. Patients were
34
35 classified in each group according the highest degree of VIDA score obtained during
36
37 their hospitalization. Patient progress data were extracted from anonymised electronic
38
39 health records whenever they were e-charted including: respiratory rate (breaths/min),
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41 oxygen saturation (%), temperature (°C), mental status (level of awareness; 1= aware
42
43 and orientated, >1 = disturbed mental status, including disorientation, acute confusion,
44
45 etc...), pulse (cardiac rate, beats/min) and systolic and diastolic blood pressure (mmHg)
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47 (Supplementary file 1).
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54 Care complexity individual factors (CCIF) were classified into five domains: (i)
55
56 mental-cognitive, (ii) psycho-emotional, (iii) sociocultural, (iv) developmental, and (v)
57
58 comorbidity/complications, as described in previous studies.^{16,18} Each CCIF domain is
59
60 structured into factors and specifications. Patients were considered within any CCIF

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2
3 domains if they presented at least one factor or specification during their hospitalisation.
4
5 These CCIF factors and specifications were obtained from the nursing assessment e-
6
7 charts, as structured data based on the Architecture, Terminology, Interface, Knowledge
8
9 (ATIC) terminology²⁰ (Supplementary file 2).
10
11

12 **Outcome measures**

13
14 The main end point was a composite of unfavourable outcomes including in-hospital
15
16 mortality and adverse events [AEs] during hospitalization. The in-hospital mortality
17
18 accounted the number of deceased COVID-19 patients while in a ward. The AEs
19
20 included intensive care unit transfer, hospital-acquired infections (HAI) and potentially
21
22 avoidable critical complications (ACC) during hospitalization. Intensive care unit (ICU)
23
24 transfer was defined as the number of patient episodes with effective bed change from a
25
26 general ward to an intensive care area. HAI included the number of episodes of ward
27
28 patients that developed catheter-related bloodstream infection, urinary catheter-related
29
30 infection, aspiration pneumonia and/or sepsis. ACC accounted for the number of
31
32 episodes of ward patients that experienced a cardiac arrest, shock, thromboembolic
33
34 event, acute respiratory failure, acute respiratory distress syndrome (ARDS), myocardial
35
36 injury, liver injury and/or kidney failure, not present on admission.
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42 **Statistical Analysis**

43
44 Descriptive analysis of data using percentage frequencies, median and interquartile
45
46 range was performed to determine demographic and clinical characteristics, and
47
48 patients' outcomes. For categorical variables, a comparative analysis for detecting
49
50 significant differences between groups was carried out using the chi-square test or
51
52 Fisher's exact test when one or more cells had an expected frequency of five or less.
53
54 For continuous variables, the Student's t-test or Mann-Whitney U test was used
55
56 depending on the results of the Kolmogorov-Smirnov normality test. A logistic-
57
58 regression model of all clinical factors potentially associated with unfavourable
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3 outcome measures (AEs and in-hospital mortality) was performed including VIDA
4 score, clinically relevant CCIF and other potential confounders: sex, hospital level and
5
6 LOS. All potential explanatory variables included in the multivariate analysis were
7
8 subjected to a correlation matrix for analysis of collinearity. The discriminatory power
9
10 was evaluated by the area under the receiver operating characteristic (ROC). Results of
11
12 multivariate analysis was reported as odds ratios (OR) and 95% confidence intervals
13
14 (CI). We also performed an adjusted analysis to compare unfavourable outcomes in
15
16 patients admitted in wards with VIDA system and without this system. Statistical
17
18 analysis will be performed using the SPSS software package version 25.0 (SPSS,
19
20 Chicago, IL). *P* values less than 0.05 were considered statistically significant.
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27 RESULTS

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29 During the study period, 1,838 patients were hospitalised with COVID-19, among them,
30
31 1,176 patients met inclusion criteria (**Figure 1**). The frequency of unfavourable
32
33 outcomes was 42.8% (506 patients). In-hospital mortality rate was 19.6% (232 patients),
34
35 and almost 41% (481 patients) experienced an AE while in a ward (2.7% transferred to
36
37 ICU; 2.5% HAI; 40% ACC). Acute respiratory failure, ARDS, acute kidney failure,
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39 urinary catheter-related infection, sepsis, and thrombotic event were the most frequently
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41 AEs.
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45 Patient Characteristics

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47 The baseline characteristics of patients with unfavourable and favourable outcome are
48
49 compared in **Table 1**. COVID-19 hospitalised patients who had an unfavourable
50
51 outcome were more often male, older, and had one or more underlying chronic
52
53 conditions (75.5%), mostly arterial hypertension or congestive heart failure and,
54
55 diabetes or chronic kidney disease. Furthermore, they had longer LOS and high risk of
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57 severity or mortality (APR-DRG 3-4). Conversely, patients admitted in high-tech
58
59 hospitals presented less frequency of unfavourable outcomes.
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3 Regarding 806 patients hospitalised with VIDA early warning system, most
4 patients with unfavourable outcomes experienced high risk of acute deterioration
5 (41.7% in patients with unfavourable outcomes vs. 9.1% in patients with favourable
6 outcomes).
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11
12 Comorbidity, sociocultural and developmental domains were the most frequent
13 CCIF domains identified in the studied sample. Mental-cognitive and psycho-emotional
14 domains were less frequent. Patients with unfavourable outcomes exhibited a higher
15 frequency of chronic disease, position impairment, anatomical and functional disorders,
16 communication disorders, old age (>75 years) and mental status impairments, when
17 compared to patients with favourable outcomes. The median of CCIF was also higher in
18 patients with unfavourable outcomes (5 [IQR: 4-6] vs. 4 [IQR: 3-5]) (**Table 1**).
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28 **Risk of acute deterioration and individual complexity factors association with** 29 **outcomes.** 30 31

32 Patients' outcomes of 806 patients with low, mild or high risk of acute deterioration
33 were compared in **Table 2**. The frequency of unfavourable outcomes was nearly 38%
34 in patients with mild risk and almost 80% in the high risk of acute deterioration group
35 ($p < 0.001$). Similarly, the frequency of in-hospital mortality and AEs rose with
36 increasing VIDA score and reached near 60% and 80% in patients with high risk of
37 acute deterioration, respectively ($p < 0.001$). Acute respiratory failure, acute kidney
38 failure and ICU transfer were the most frequent AEs.
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49 Among the 1,176 patients analysed in this study, those with four or more CCIF
50 experienced unfavourable outcomes ($p < 0.05$) (**Table 2**).
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54 **Table 3** shows an adjusted analysis of health outcomes in 486 patients with high
55 risk of mortality (APR-DRG 3-4) to compare patients admitted in wards where
56 registered nurses use or do not use the VIDA early warning score system. In-hospital
57 mortality was more frequent in patients admitted in wards where VIDA was not used
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3 (52.5% vs. 41.3%, $p < 0.05$). Conversely, the frequency of AEs was slightly higher in
4
5 patients admitted in VIDA' wards ($p < 0.05$).
6

7 **Risk factors associated with unfavourable outcomes**

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10 The results of the multivariate analysis for risk of acute deterioration (as measured with
11
12 VIDA score) and CCIF potentially associated with unfavourable outcomes, in-hospital
13
14 mortality and AEs are summarized in **Table 4**.
15

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17 After adjustment of potentially confounders, the analysis shows that high risk of
18
19 acute deterioration was an independent factor associated with unfavourable outcomes,
20
21 in-hospital mortality and AEs in COVID-19 ward inpatients. Furthermore, chronic
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23 disease, mental status impairments and LOS were risk factors associated with
24
25 unfavourable outcomes. Conversely, high-tech hospital admission was a protective
26
27 factor of unfavourable outcomes. The area under the ROC curve (AUC) was 0.81 (95%
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29 CI: 0.78-0.84).
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33 Chronic disease, mental status impairments, old age and male sex were
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35 independent risk factors associated with in-hospital mortality for studied COVID-19
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37 inpatients (AUC 0.91 [95% CI: 0.88-0.93]). Finally, risk factors independently
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39 associated with AEs were chronic disease, mental status impairments, old age and LOS;
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41 while high-tech hospital admission was a protective factor of AEs (AUC 0.80 [95% CI:
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43 0.77-0.83]). The AUC of the three outcomes analysed were > 0.80 , showing a fair
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45 discriminatory power.
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DISCUSSION

In this study of a large cohort of hospitalised patients with COVID-19, the frequency of in-hospital mortality and AEs reached near 60% and 80%, in patients scored as at high risk of acute deterioration respectively. In-hospital mortality was higher in wards not using the VIDA early warning system. A wide majority of patients had four or more care complexity individual factors identified. The risk factors independently associated with unfavourable outcomes included chronic disease, mental status impairments, LOS and high risk of acute deterioration. High-tech hospital admission was a protective factor of unfavourable outcomes.

Our findings are consistent with previous COVID-19 reports which have found a similar frequency of in-hospital mortality and AEs.^{3,21} In addition, 37% of patients developed respiratory complications (acute respiratory failure or ARDS) during hospitalization. This value is within the range reported in a previous inquiry (29-42%).³

The results of this study show that high risk of acute deterioration is a significant risk factor for unfavourable outcomes, as a composite measure for in-hospital mortality, and AEs in admitted COVID-19 patients. Although previous studies have stressed that early warning systems are predictors of in-hospital mortality and health outcomes,^{22,23} only a few have evaluated warning score systems in admitted COVID-19 patients.^{11,19} These latest studies showed a fair discrimination with adverse outcomes, concluding that the evaluation of the risk for acute deterioration in the COVID-19 hospital population is a priority for the organizations.¹⁹

In-hospital mortality was more frequent in patients admitted in wards where registered nurses do not use VIDA early warning system. In this regard, other studies showed that the use of early systems reinforces collaboration among the multidisciplinary team, and promotes the early identification of clinical deterioration.²⁴

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3 Similarly, previous studies have reported less mortality and adverse events when
4 systematic nursing surveillance of patient status and progress is a daily basis practice.⁹
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8 Chronic conditions and mental status impairments were the CCIF independently
9 associated with unfavourable outcomes. Previous reports have shown that chronic
10 diseases were more frequent among deceased COVID-19 patients¹⁵ and aging was a
11 potential risk factor associated with mortality.⁶ Although our study has not identified
12 age as a risk factor associated with a composite unfavourable outcome, we acknowledge
13 that old age was an independent risk factor associated with mortality and AE.
14 Furthermore, our findings were also consistent with other studies demonstrating that
15 mental status impairments are associated with hospital-acquired complications,²⁵
16 including sepsis.⁴
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28 A wide majority of patients had four or more CCIF. Our findings are consistent
29 with other studies that identified a significant rate of chronic conditions in COVID-19
30 patients¹⁵ and by the other hand, selected organizational issues that may impact care
31 complexity and health outcomes.²⁶ Previous inquires have demonstrated the association
32 of CCIF and health outcomes,¹⁶ with an average of two CCIF per patient. Our
33 investigation showed that for COVID-19 inpatients, the average of CCIF is four. These
34 results are probably related to the transmissibility of this condition requiring droplet and
35 contact precautions, the pandemics management associated public health measures of
36 population confinement, preventing patients' relatives to visit admitted patients in
37 person, resulting in a lack of family caregiver support during hospitalisation, and the
38 frequency of chronic diseases in the studied sample. The organizational adaptation of
39 hospitals to this pandemic context and the required isolation precautions have been
40 associated with poor outcomes in prior studies.^{27,28}
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58 Additionally, we found that LOS was associated with unfavourable outcomes,
59 coinciding with previous studies that associated AEs with increased healthcare costs due
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3 to longer hospital stays.²⁹ Finally, high-tech hospital admission was a protective factor
4 associated to unfavourable outcomes. High-tech hospitals usually have better nurse-to-
5 patient ratios, than urban or community facilities. In this sense, a couple of recent
6 inquiries in the same study setting conclude that on average, hospital ward patients
7 require 5.6 hours of RN care per patient day, while the average of available RN hours
8 per patient day is 2.4, and that RN understaffing is a structural issue.^{26,30} Nevertheless,
9 to the best of our knowledge, no study on nurse staffing and COVID-19 inpatients'
10 outcomes have been published. Similarly, healthcare clinical leaders and managers have
11 become key role to rapidly adapt organizations to the new reality. Fast and effective
12 decision-making and managerial responses in crisis situations with high levels of
13 uncertainty are essential at immediate and short-term however, they should be
14 accompanied by planning and executing mid-term and long-lasting improvements that
15 positively impact patient, professional and organizational outcomes, such as structural
16 RN understaffing.²⁶

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The strengths of this study include its multicentre approach, cohort design and
large sample size. It is the first research evaluating the association of the risk of acute
deterioration, along with care complexity individual factors, with COVID-19 patient
outcomes. Importantly, we identify broader health-contributors of care complexity,
including psychosocial and mental-cognitive factors. In addition, the VIDA early
warning system was developed as an evidence-based algorithm with a multidisciplinary
approach, and also according to previous studies that highlighted the importance to
adapt surveillance and screening systems to organization and cultural context.¹⁴

This study is not exempt of some limitations. First, VIDA score and CCIF data
were comprehensively collected from clinical data warehouse of the Catalan Institute of
Health and all patients included had a completed nurse charting in the patient electronic
health record but we relied a proper compliance of electronic health records and

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3 administrative data. This is acknowledged as a significant limitation since voluntary
4 completion of patient electronic documentation during the initial weeks of COVID-19
5 first wave in our country, might have been negatively influenced by the peak rising
6 hospital system burden, the need for patient direct care activity prioritization, as well as
7 the physical and emotional stress experienced by bedside healthcare professionals.
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10 Second, regarding the study selection criteria, patients directly admitted and discharged
11 from intensive care unit were excluded, since no early warning system was use at the
12 critical care setting at the outset of the pandemics in our context. In this sense, the
13 results of this study only apply to adult ward and intermediate care inpatients. Third, it
14 should be noted that unpublished face validity studies have demonstrated the
15 effectiveness VIDA early warning system. A full evaluation of its psychometric
16 properties, in general medical-surgical inpatients, is pending and this must be
17 acknowledged as a significant limitation. To minimize the potential effect of this
18 limitation, this inquiry considered an adjusted analysis performed with patients in
19 higher risk mortality (APR-DRG 3-4) comparing the ones admitted in wards with VIDA
20 fully implemented and those being treated in units with no VIDA early warning system.
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22 The results proved a significant association of VIDA score and CCIF with unfavourable
23 outcomes. Finally, we acknowledge as a potential limitation that other clinical measures
24 such as the age-adjusted Charlson comorbidity index or patient lab values were not
25 assessed. Selected lab values such as lactate, ferritin or calciferol have been studied as
26 indicators of COVID-19 prognosis and severity. Combining point of care lab data with
27 clinical data from nurses' observations and judgments on patient complexity factors,
28 status and progress would probably result in a improved system for early detection and
29 prevention of critical complications and other unfavourable outcomes in COVID-19
30 inpatients.
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Conclusion

The risk of acute deterioration and the care complexity individual factors are associated with COVID-19 patient outcomes. The rate of unfavourable outcomes rose with increasing risk of acute deterioration as measured with VIDA score. The risk factors independently associated with poor health outcomes were chronic disease, mental status impairment, length of hospital stay and high risk of acute deterioration. High-tech hospital admission was a protective factor of unfavourable outcomes. The systematic nursing surveillance of patients at risk of acute deterioration and the assessment of CCIF may contribute to reduce deleterious health outcomes in COVID-19 adult inpatients.

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FOOTNOTES

Author Contributions: All authors had full access to all study data and take responsibility for the integrity of the data and the accuracy of the data analysis. *Study concept and design:* Adamuz, González-Samartino, Juvé-Udina. *Coordination team:* Juvé-Udina. *Acquisition of data:* Adamuz, Tapia-Perez, López-Jiménez, Zuriguel-Pérez, Castro-Navarro. *Analysis and interpretation data:* Adamuz, González-Samartino, Jiménez-Martínez. *Drafting of the manuscript:* Adamuz, González-Samartino, Jiménez-Martínez, Juvé-Udina. *Critical revision of the manuscript for important intellectual content:* Tapia-Perez, López-Jiménez, Rodríguez-Fernández, Zuriguel-Pérez, Castro-Navarro, Carratalà. *Statistical analysis:* Adamuz and González-Samartino. *Obtained funding:* - . *Administrative, technical and material support:* López-Jiménez, Rodríguez-Fernández. *Study supervision:* Juvé-Udina, Carratalà.

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Patient consent for publication: Not required.

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Provenance and peer review: Not commissioned; externally peer reviewed.

Data availability statement: All data relevant to the study are included in the article.

No additional data are available.

Table 1. Baseline characteristics, VIDA score and care complexity individual factors of admitted COVID-19 patients with unfavourable and favourable outcomes.

| Characteristics | Study population n=1,176 | | Unfavourable outcome ^a n=506 (42.8%) | | Favourable outcome n=670 (57.1%) | | p value |
|---|-----------------------------|---------|--|---------|-------------------------------------|---------|---------|
| | No. | % | No. | % | No. | % | |
| Demographic characteristics | | | | | | | |
| Age (years)_ median (IQR) | 66.5 | (51-77) | 74 | (60-80) | 61 | (49-74) | <0.001 |
| Male sex | 667 | (56.7) | 192 | (37.9) | 317 | (47.3) | 0.001 |
| Clinical characteristics | | | | | | | |
| LOS_ median (IQR) | 6 | (4-8) | 7 | (4-10) | 5 | (4-7) | <0.001 |
| Continuity of care (discharged to another facility) | 165 | (14) | 58 | (11.5) | 107 | (16) | 0.02 |
| Severity (APR-GRD 3-4) | 503 | (42.8) | 450 | (88.9) | 53 | (7.9) | <0.001 |
| Mortality risk (APR-DRG 3-4) | 486 | (41.3) | 449 | (88.7) | 37 | (5.5) | <0.001 |
| High-tech hospital | 969 | (82.4) | 389 | (76.9) | 580 | (86.6) | <0.001 |
| Underlying disease | 745 | (63.4) | 382 | (75.5) | 363 | (54.4) | <0.001 |
| Arterial hypertension or chronic heart failure | 469 | (39.9) | 234 | (46.2) | 235 | (35.1) | <0.001 |
| Diabetes or chronic kidney disease | 298 | (25.3) | 165 | (32.6) | 133 | (19.9) | <0.001 |
| Chronic respiratory disease | 171 | (14.5) | 95 | (18.8) | 76 | (11.3) | <0.001 |
| Neurodegenerative disease | 63 | (5.3) | 33 | (6.5) | 39 | (4.5) | 0.15 |
| Chronic liver disease | 54 | (4.6) | 30 | (5.9) | 24 | (3.6) | 0.07 |
| Cancer | 50 | (4.3) | 31 | (6.5) | 19 | (2.8) | 0.008 |
| Immunosuppression | 49 | (4.2) | 23 | (4.5) | 26 | (3.9) | 0.66 |
| VIDA score^b | | | | | | | |
| Low risk (0) | 104 | (12.9) | 27 | (7.1) | 77 | (18) | <0.001 |
| Moderate risk (1-2) | 505 | (62.7) | 194 | (51.2) | 311 | (72.8) | <0.001 |
| High risk (3-4) | 197 | (16.7) | 158 | (41.7) | 39 | (9.1) | <0.001 |
| Care complexity individual factors (CCIF) | | | | | | | |
| Comorbidity/complications | | | | | | | |
| Transmissible infection | 1,176 | (100) | 506 | (100) | 670 | (100) | - |
| Hemodynamic instability | 910 | (77.4) | 396 | (78.3) | 514 | (76.7) | 0.57 |
| Chronic disease | 745 | (63.4) | 382 | (75.5) | 363 | (54.4) | <0.001 |
| Uncontrolled pain | 194 | (16.5) | 82 | (16.2) | 112 | (16.7) | 0.87 |
| Extreme weight | 168 | (14.3) | 82 | (16.2) | 86 | (12.8) | 0.11 |
| Position impairment | 72 | (6.1) | 52 | (10.3) | 20 | (3.0) | <0.001 |
| Urinary or faecal incontinence | 58 | (4.9) | 31 | (6.1) | 27 | (4.0) | 0.10 |
| Immunosuppression | 49 | (4.1) | | | | | |
| Anatomical and functional disorders | 41 | (3.5) | 30 | (5.9) | 11 | (1.6) | <0.001 |
| Communication disorders | 18 | (1.5) | 13 | (2.6) | 5 | (0.7) | 0.01 |
| High risk of hemorrhage | 2 | (0.2) | 1 | (0.2) | 1 | (0.1) | 0.68 |
| Vascular fragility | 6 | (0.5) | 4 | (0.8) | 2 | (0.3) | 0.41 |
| Involuntary movements | 3 | (0.3) | 3 | (0.6) | 0 | (0.0) | 0.08 |
| Dehydration | 3 | (0.3) | 1 | (0.2) | 2 | (0.3) | 0.60 |
| Oedema | 0 | (0) | 0 | (0.0) | 0 | (0.0) | - |
| Developmental | | | | | | | |
| Old age (≥75 years) | 397 | (33.8) | 244 | (48.2) | 153 | (22.8) | <0.001 |
| Psycho-emotional | | | | | | | |
| Fear/anxiety | 173 | (14.7) | 70 | (13.8) | 103 | (15.4) | 0.51 |
| Impaired adaptation | 54 | (4.6) | 17 | (3.4) | 37 | (5.5) | 0.09 |
| Aggressive behaviour | 1 | (0.1) | 1 | (0.2) | 0 | (0.0) | 0.43 |
| Mental-cognitive | | | | | | | |
| Mental status impairments | 240 | (20.4) | 184 | (36.4) | 56 | (8.4) | <0.001 |
| Agitation | 238 | (20.2) | 183 | (36.2) | 55 | (8.2) | <0.001 |
| Impaired cognitive functions | 5 | (0.4) | 4 | (0.8) | 1 | (0.1) | 0.17 |
| Perception of reality disorders | 4 | (0.3) | 3 | (0.6) | 1 | (0.1) | 0.32 |
| Perception of reality disorders | 2 | (0.2) | 0 | (0.0) | 2 | (0.3) | 0.51 |
| Sociocultural | | | | | | | |
| Lack of caregiver support | 1,176 | (100) | 506 | (100) | 670 | (100) | - |
| Belief conflict | 1,176 | (100) | 506 | (100) | 670 | (100) | - |
| Belief conflict | 1 | (0.1) | 0 | (0.0) | 1 | (0.1) | 0.57 |
| Language barriers | 1 | (0.1) | 1 | (0.2) | 0 | (0.0) | 0.43 |
| Social exclusion | 1 | (0.1) | 0 | (0.0) | 1 | (0.1) | 1 |
| Care complexity individual factors (CCIF), median (IQR) | 4 | (3-6) | 5 | (4-6) | 4 | (3-5) | <0.001 |

Abbreviations: IQR, interquartile range; LOS, length of hospital stay; ICU, intensive care unit; APR-DRG, all patient refined diagnosis-related groups; VIDA, surveillance and identification of acute deterioration.

^a Unfavourable outcomes included: in-hospital mortality and adverse events during hospitalization.

^b VIDA score was analysed according to 806 admitted patients in wards with VIDA system.

Table 2. Patients' outcomes according to risk of acute deterioration (VIDA score) and care complexity individual factors.

| Outcomes | All n=1,176 N (%) | VIDA_score n=806 (68.5) | | | CCIF n=1,176 | |
|--|-------------------------|---------------------------------------|--|--|---------------------------------|---------------------------------|
| | | Low risk (0) n=104 (12.9) N (%) | Mild risk (1-2) n=505 (62.7) N (%) | High risk (3-4) n=197 (16.7) N (%) | CCIF<4 n=327 (27.8) N (%) | CCIF≥4 n=849 (72.2) N (%) |
| Unfavourable outcomes | 506 (43.0) | 27 (26.0)** | 194 (38.4)* | 158 (80.2)** | 92 (28.1)** | 414 (48.8)** |
| Deceased | 232 (19.6) | 0 (0.0)** | 46 (9.1)** | 118 (59.9)** | 5 (1.5)** | 227 (26.7)** |
| Adverse event | 481 (40.9) | 27 (26.0)** | 187 (37)* | 153 (77.7)** | 91 (27.8)** | 394 (46.4)** |
| ICU transfer | 32 (2.7) | 0 (0.0)* | 12 (2.4) | 13 (6.6)* | 4 (1.2)* | 28 (3.3)* |
| HAI | 29 (2.5) | 0 (0.0)* | 10 (2.0) | 12 (6.1)* | 1 (1.5) | 24 (2.8) |
| Catheter-related bloodstream infection | 1 (0.1) | 0 (0.0) | 0 (0.0) | 1 (0.5) | 0 (0.0) | 1 (0.1) |
| HA urinary tract infection | 19 (1.6) | 0 (0.0) | 7 (1.4) | 8 (4.1)* | 3 (0.9) | 16 (1.9) |
| Aspiration pneumonia | 3 (0.3) | 0 (0.0) | 3 (0.6) | 0 (0.0) | 0 (0.0) | 3 (0.4) |
| Sepsis | 7 (0.6) | 0 (0.0) | 1 (0.2) | 3 (1.5)* | 2 (0.6) | 5 (0.6) |
| ACC | 470 (40.0) | 27 (26.0)** | 181 (35.8)** | 150 (76.1)** | 88 (26.6)** | 383 (45.1)** |
| Cardiac arrest | 5 (0.4) | 1 (1.0) | 0 (0.0)* | 3 (1.5)* | 0 (0.0) | 5 (0.6) |
| Shock | 4 (0.3) | 0 (0.0) | 2 (0.4) | 0 (0.0) | 0 (0.0) | 4 (0.5) |
| Thrombotic event | 7 (0.6) | 1 (1.0) | 1 (0.2) | 2 (1) | 1 (0.3) | 6 (0.7) |
| Acute respiratory failure ¹ | 436 (37.0) | 27 (26.0)** | 164 (32.5)** | 144 (73.1)** | 84 (25.1)** | 353 (41.6)** |
| Myocardial injury | 5 (0.4) | 0 (0) | 3 (0.6) | 1 (0.5) | 0 (0.0) | 5 (0.6) |
| Liver injury | 2 (0.2) | 0 (0) | 0 (0) | 1 (0.5) | 0 (0.0) | 2 (0.2) |
| Renal insufficiency | 83 (7.1) | 1 (1.0)* | 28 (5.5)* | 31 (15.7)** | 6 (1.8)** | 77 (9.1)** |

Abbreviations: VIDA, surveillance and identification of acute deterioration; CCIF, care complexity individual factors; ICU, intensive care unit; HAI, hospital-acquired infections; ACC, avoidable critical complications.

* *p* value >0.001 and <0.05.

** *p* value ≤0.001.

¹ Include acute respiratory distress syndrome (ARDS).

Table 3. Adjusted analysis of unfavourable outcomes according to VIDA early warning system in 486 patients with high risk of mortality (APR-DRG 3-4).

| Outcomes | Unadjusted | Adjusted | With VIDA system | Without VIDA system | <i>p value</i> ¹ |
|------------------------------|------------|--------------|------------------|---------------------|-----------------------------|
| | n=1,176 | n=486 (41.2) | n=368 (75.7) | n=118 (24.3) | |
| | N (%) | N (%) | N (%) | N (%) | |
| Unfavourable outcomes | 506 (43.0) | 449 (92.4) | 345 (93.8) | 104 (88.1) | 0.07 |
| Deceased | 232 (19.6) | 214 (44) | 152 (41.3) | 62 (52.5) | 0.02 |
| Adverse event | 481 (40.9) | 436 (89.7) | 337 (91.6) | 99 (83.9) | 0.02 |
| ICU transfer | 32 (2.7) | 25 (5.1) | 20 (5.4) | 5 (4.2) | 0.41 |
| HAI | 29 (2.5) | 19 (3.9) | 16 (4.3) | 3 (2.5) | 0.28 |
| ACC | 470 (40.0) | 433 (89.1) | 334 (90.8) | 99 (83.9) | 0.31 |

Abbreviations: VIDA, surveillance and identification of acute deterioration; ICU, intensive care unit; HAI, hospital-acquired infections; ACC, avoidable critical.

¹All variables were compared using the Fisher exact test.

Table 4. Multivariate analysis of VIDA score and CCIF in 806 adult COVID-19 hospitalized patients associated with unfavourable outcomes, deceased and AE.

| <i>Characteristics</i> | Unfavourable outcomes ¹ | | Deceased ² | | AE ³ | |
|---------------------------|------------------------------------|----------------|-----------------------|----------------|-------------------|---------------|
| | n= 379/806 (47%) | | n= 164/806 (20.3%) | | n=367/806 (45.5%) | |
| | OR | (95% CI) | OR | (95% CI) | OR | (95% CI) |
| Old age (≥75 years) | 1.48 | (0.99-2.22) | 3.04 | (1.79-5.15)** | 1.52 | (1.02-2.26)* |
| Male sex | 1.21 | (0.87-1.69) | 1.86 | (1.11-3.11)* | 1.20 | (0.87-1.67) |
| LOS | 1.16 | (1.11-1.21)** | 0.97 | (0.93-1.01) | 1.17 | (1.12-1.22)** |
| High-tech hospital | 0.57 | (0.36-0.89)* | 1.88 | (0.94-3.78) | 0.61 | (0.39-0.95)* |
| VIDA score 3-4 | 4.32 | (2.83-6.60)** | 13.99 | (8.44-23.18)** | 4.21 | (2.79-6.36)** |
| Chronic disease | 1.90 | (1.32-2.72)** | 2.01 | (1.03-3.90)* | 1.81 | (1.26-2.59)** |
| Position impairment | 1.19 | (0.58-2.44) | 1.41 | (0.63-3.13) | 1.23 | (0.62-2.46) |
| Communication disorders | 0.97 | (0.24-3.96) | 0.87 | (0.22-3.41) | 0.78 | (0.21-2.95) |
| Mental status impairments | 2.31 | (1.45-23.66)** | 6.21 | (3.67-10.50)** | 1.72 | (1.09-2.69)* |

Abbreviations: AE, adverse event; LOS, length of hospital stay; VIDA, surveillance and identification of acute deterioration. Multivariate analysis included: high risk of acute deterioration (VIDA score 3-4), clinically relevant care complexity individual factors (old age, chronic disease, position impairment, communication disorders and mental status impairments) and potential confounders (sex, hospital level and LOS).

¹AUC 0.81 (CI 95%; 0.78-0.84).

²AUC 0.91 (CI 95%; 0.88-0.93).

³AUC 0.80 (CI 95%; 0.77 -0.83).

* *p* value >0.001 and <0.05.

** *p* value ≤0.001.

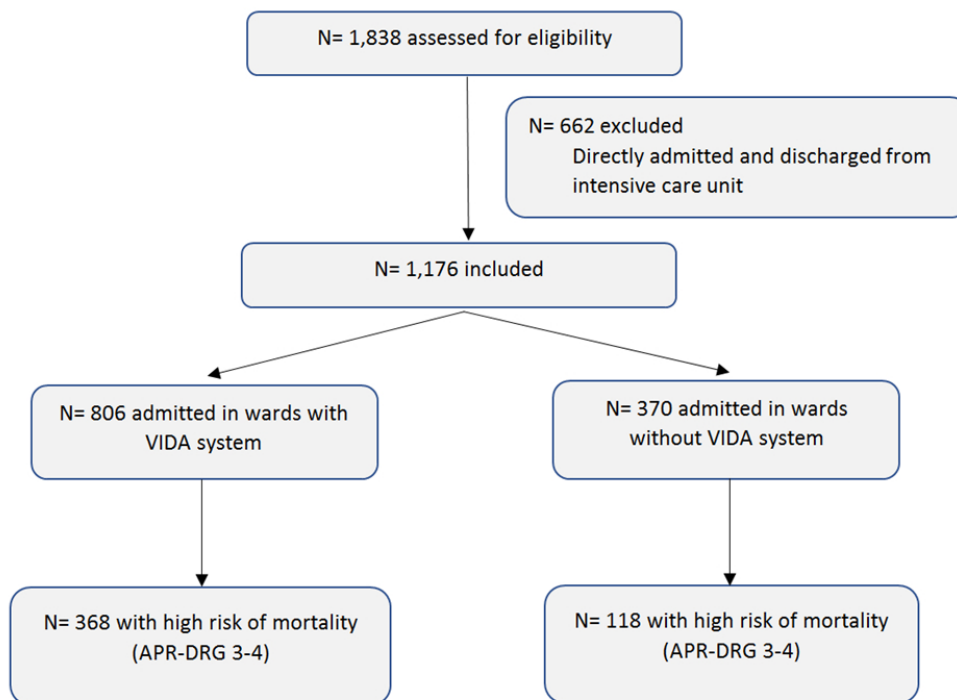


Figure 1. Flow-chart of patient selection process.

Supplementary file 1. Juvé-Udina ME. VIDA score for acute deterioration in the current human algorithm.

| H1, H2, H3 | | |
|--------------------|-------------------|---|
| Punctuation | Risk score | Definition |
| 0 – 1 | 0 | No risk of complication (at that particular moment) |
| 2 – 3 | 1 | Low risk |
| 4 | 2 | Moderate risk (very probable complication) |
| 5 – 6 | 3 | High risk (imminent complication if not stabilized) |
| >= 7 | 4 | Critical complication status |
| H4 | | |
| Punctuation | Risk score | Definition |
| 0 – 1 | 0 | No risk of complication (at that particular moment) |
| 2 – 3 | 1 | Low risk |
| 4 – 6 | 2 | Moderate risk (very probable complication) |
| 7 – 9 | 3 | High risk (imminent complication if not stabilized) |
| >= 10 | 4 | Critical complication status |
| H5 | | |
| Punctuation | Risk score | Definition |
| 0 – 2 | 0 | No risk of complication (at that particular moment) |
| 3 – 4 | 1 | Low risk |
| 5 – 6 | 2 | Moderate risk (very probable complication) |
| 7 – 8 | 3 | High risk (imminent complication if not stabilized) |
| >= 9 | 4 | Critical complication status |
| H6 | | |
| Punctuation | Risk score | Definition |
| 0 – 2 | 0 | No risk of complication (at that particular moment) |
| 3 – 4 | 1 | Low risk |
| 5 – 6 | 2 | Moderate risk (very probable complication) |
| 7 – 9 | 3 | High risk (imminent complication if not stabilized) |
| >= 10 | 4 | Critical complication status |
| H7 | | |
| Punctuation | Risk score | Definition |
| <= 3 | 1 | Low risk |
| 4 – 6 | 2 | Moderate risk (very probable complication) |
| 7 – 8 | 3 | High risk (imminent complication if not stabilized) |
| >= 9 | 4 | Critical complication status |

Abbreviations: H, hospital.

Supplementary file 2. Care complexity individual factors.

| Domains | Factors | Specifications |
|-------------------------------|--|--|
| Comorbidity/ Complications | Transmissible infection | Isolation measures |
| | Hemodynamic instability | Intensive control of vital signs or state of shock |
| | Chronic disease | Conditions (organ failure, degenerative process or oncological disease) that require ongoing medical attention and limit activities of daily living. |
| | Uncontrolled pain | Verbal numerical rating scale above three points |
| | Extreme weight | Low weight, obesity |
| | Position impairment | Includes any position impairment |
| | Urinary or faecal incontinence | Loss of bladder control or failure to control bowel movements |
| | Immunosuppression | Neutropenia, immunodeficiency or immunosuppressive therapy |
| | Anatomical and functional disorders | Amputation, deformities, joint stiffness |
| | Communication disorders | Aphasia, dysphasia, dysarthria, laryngectomy, tracheostomy |
| | High risk of haemorrhage | Coagulation disorders, thrombocytopenia, anticoagulant therapy |
| | Vascular fragility | Capillary fragility, tortuous veins |
| | Involuntary movements | Continuous involuntary movements |
| Dehydration | Skin turgor | |
| Oedema | An accumulation of an excessive amount of watery fluid in cells, tissues, or serous cavities | |
| Developmental | Old age | ≥75 years |
| Psycho- emotional | Fear/anxiety | Fear or anxiety (moderate or intense) |
| | Impaired adaptation | Disruptive behaviour, hopelessness or surrender |
| | Aggressive behaviour | Physical or verbal aggressive behaviour (moderate or intense) |
| Mental- cognitive | Mental status impairments | Confusion, disorientation, stupor, transient loss of consciousness |
| | Agitation | Psychomotor agitation |
| | Impaired cognitive functions | Intellectual disability, amnesia |
| | Perception of reality disorders | Delirium, hallucinations, disconnection from reality |
| Sociocultural | Lack of caregiver support | Without caregiver support or caregiver burnout |
| | Belief conflict | Spiritual distress |
| | Language barriers | Barrier to communication resulting from speaking different languages than Spanish or Catalan without translator. |
| | Social exclusion | Extreme poverty |

STROBE Statement—Checklist of items that should be included in reports of *cohort studies*

| | Item No | Recommendation | |
|------------------------------|---------|--|-----------|
| Title and abstract | 1 | (a) Indicate the study's design with a commonly used term in the title or the abstract | Pg.3 |
| | | (b) Provide in the abstract an informative and balanced summary of what was done and what was found | Pg.3-4 |
| Introduction | | | |
| Background/rationale | 2 | Explain the scientific background and rationale for the investigation being reported | Pg.5-6 |
| Objectives | 3 | State specific objectives, including any prespecified hypotheses | Pg.6 |
| Methods | | | |
| Study design | 4 | Present key elements of study design early in the paper | Pg.7 |
| Setting | 5 | Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection | Pg.7 |
| Participants | 6 | (a) Give the eligibility criteria, and the sources and methods of selection of participants. Describe methods of follow-up | Pg.7 |
| | | (b) For matched studies, give matching criteria and number of exposed and unexposed | - |
| Variables | 7 | Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable | Pg.7-8 |
| Data sources/ measurement | 8* | For each variable of interest, give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group | Pg.7-8 |
| Bias | 9 | Describe any efforts to address potential sources of bias | Pg.16 |
| Study size | 10 | Explain how the study size was arrived at | Pg.7 |
| Quantitative variables | 11 | Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why | Pg.9 |
| Statistical methods | 12 | (a) Describe all statistical methods, including those used to control for confounding | Pg.9 |
| | | (b) Describe any methods used to examine subgroups and interactions | Pg.9 |
| | | (c) Explain how missing data were addressed | - |
| | | (d) If applicable, explain how loss to follow-up was addressed | - |
| | | (e) Describe any sensitivity analyses | - |
| Results | | | |
| Participants | 13* | (a) Report numbers of individuals at each stage of study—eg numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed | Pg.10 |
| | | (b) Give reasons for non-participation at each stage | Pg.10-11 |
| | | (c) Consider use of a flow diagram | - |
| Descriptive data | 14* | (a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders | Pg.10 |
| | | (b) Indicate number of participants with missing data for each variable of interest | - |
| | | (c) Summarise follow-up time (eg, average and total amount) | Pg.10 |
| Outcome data | 15* | Report numbers of outcome events or summary measures over time | Pg10-11 |
| Main results | 16 | (a) Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (eg, 95% confidence interval). Make clear which confounders were adjusted for and why they were included | Table 1&4 |

| | | | |
|--------------------------|----|--|-----------|
| | | (b) Report category boundaries when continuous variables were categorized | Table 1&4 |
| | | (c) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period | Pg.11-12 |
| Other analyses | 17 | Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses | Pg.11 |
| Discussion | | | |
| Key results | 18 | Summarise key results with reference to study objectives | Pg.13 |
| Limitations | 19 | Discuss limitations of the study, taking into account sources of potential bias or imprecision. Discuss both direction and magnitude of any potential bias | Pg.16 |
| Interpretation | 20 | Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence | Pg.14-16 |
| Generalisability | 21 | Discuss the generalisability (external validity) of the study results | Pg.15-16 |
| Other information | | | |
| Funding | 22 | Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based | Pg.21. |

*Give information separately for exposed and unexposed groups.

Note: An Explanation and Elaboration article discusses each checklist item and gives methodological background and published examples of transparent reporting. The STROBE checklist is best used in conjunction with this article (freely available on the Web sites of PLoS Medicine at <http://www.plosmedicine.org/>, Annals of Internal Medicine at <http://www.annals.org/>, and Epidemiology at <http://www.epidem.com/>). Information on the STROBE Initiative is available at <http://www.strobe-statement.org>.

BMJ Open

Risk of acute deterioration and care complexity individual factors associated with health outcomes in hospitalised patients with COVID-19: a multicenter cohort study.

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ORIGINAL ARTICLE

Risk of acute deterioration and care complexity individual factors associated with health outcomes in hospitalised patients with COVID-19: a multicenter cohort study.

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ABSTRACT

Background: Evidence about the impact of systematic nursing surveillance on risk of acute deterioration of patients with COVID-19 and the effects of care complexity factors on inpatient outcomes is scarce. The aim of this study was to determine the association between acute deterioration risk, care complexity factors and unfavourable outcomes in hospitalised patients with COVID-19.

Methods: A multicentre cohort study was conducted from March 1, 2020 to March 31, 2020 at seven hospitals in Catalonia. All adult COVID-19 patients admitted to hospitals and with a complete minimum data set were recruited retrospectively. Patients were classified based on the presence or absence of a composite unfavourable outcome (in-hospital mortality and adverse events). The main measures included risk of acute deterioration (as measured using the VIDA early warning system) and care complexity factors. All data were obtained blinded from electronic health records. Multivariate logistic analysis was performed to identify the VIDA score and complexity factors associated with unfavourable outcomes.

Results: Out of a total of 1,176 COVID-19 patients, 506 patients (43%) experienced an unfavourable outcome during hospitalisation. The frequency of unfavourable outcomes rose with increasing risk of acute deterioration as measured by the VIDA score. Risk factors independently associated with unfavourable outcomes were chronic underlying disease (OR: 1.90, 95% CI: 1.32–2.72; $p < 0.001$), mental status impairment (OR: 2.31, 95% CI: 1.45–23.66; $p < 0.001$), length of hospital stay (OR: 1.16, 95% CI: 1.11–1.21; $p < 0.001$) and high risk of acute deterioration (OR: 4.32, 95% CI: 2.83–6.60; $p < 0.001$). High-tech hospital admission was a protective factor against unfavourable outcomes (OR: 0.57, 95% CI: 0.36–0.89; $p = 0.01$).

Conclusion: The systematic nursing surveillance of the status and evolution of COVID-19 inpatients, including the careful monitoring of acute deterioration risk and care

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3 complexity factors may help reduce deleterious health outcomes in COVID-19
4
5 inpatients.
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10 **STRENGTHS AND LIMITATIONS OF THIS STUDY**

- 12 • We performed a multicentre cohort study with a large sample of patients with
13 COVID-19.
14
- 15 • This novel research assessed the impact of the risk of acute deterioration and
16 broader contributors to care complexity on COVID-19 patient outcomes.
17
- 18 • We did not evaluate other clinical measures such as the age-adjusted Charlson
19 comorbidity index or patient lab values.
20
- 21 • The results of this study only apply to adult wards and intermediate care
22 inpatients.
23
- 24 • The risk of acute deterioration was measured using VIDA, an early warning
25 system not yet fully implemented in all hospitals wards.
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INTRODUCTION

Along with climate change and financial crises, pandemics are a major global risk in the 21st century. A 2019 report stated that, in the last decade, the World Health Organization (WHO) had tracked 1,483 epidemic events, including Severe Acute Respiratory Syndrome (SARS), Middle East Respiratory Syndrome (MERS), Ebola and other epidemic-prone diseases, considered harbingers of a new era of high-impact, potentially fast-spreading outbreaks.¹

The potential threat became real in December 2019, when a severe acute respiratory infection caused by the new coronavirus SARS-CoV-2 first began to spread in Wuhan (China).^{2,3} The WHO described the ‘Wuhan pneumonia’ as an outbreak of potential danger on December 31st, and as an outbreak of global concern on January 31st. This coronavirus disease (named COVID-19) was declared a global pandemic in February 2020.

COVID-19 patients frequently require hospital admission as they may rapidly develop severe potentially life-threatening complications, such as acute respiratory distress syndrome, sepsis, major thromboembolic events or cardiac injury, requiring intensive care.³⁻⁵ Recent studies have found overall in-hospital mortality rates for COVID-19 inpatients ranging from 15 to 28%.^{3,6-8} Therefore, early recognition of patient deterioration and escalation of treatment to reduce the risk of progression to critical complications is a significant issue that may impact patient and organizational outcomes. Screening for acute deterioration implies nursing surveillance, data collection, interpretation and recognition of changes in patients’ status, prioritization of patients’ problems and decision-making on the interventions needed in order to curb the cascade towards adverse events (AEs) and death.⁹

According to the WHO “*patients hospitalized with COVID-19 require regular monitoring of vital signs and, where possible, utilization of early warning scores that*

1
2
3 *facilitate early recognition and escalation of treatment of the deteriorating patient.*"¹⁰

4
5 Early warning systems have become an important component of managing inpatient
6 care, and are a clinical decision-making support stratification tool used to prevent poor
7 health outcomes.¹¹⁻¹³ Previous studies suggested the need for adaptation of these
8 systems to each context.¹⁴ According to these recommendations, several evidence-based
9 algorithms have been developed and used to identify and act upon initial or impending
10 acute deterioration among hospitalised patients in a timely fashion. In the context of this
11 study, a nursing surveillance improvement programme named VIDA (the Catalan
12 acronym for Surveillance and Identification of Acute Deterioration) was first
13 implemented in 2013 and, through a multidisciplinary approach, has evolved into an
14 early warning score system that is used on a daily basis to assist clinical decision-
15 making.

16
17 It has been reported that patients hospitalised with COVID-19 have a substantial
18 rate of chronic conditions that may affect the complexity of medical and nursing care
19 provision and patient health outcomes.¹⁵ Nevertheless, care complexity individual
20 factors (CCIF) are related not only to multiple comorbidities but also to mental-
21 cognitive and psychosocial patient features, which in turn are also associated with
22 increased healthcare needs during hospitalisation and with selected health outcomes.¹⁶⁻
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Only a few studies in COVID-19 inpatients have explored the use of acute deterioration risk stratification^{11,19} and to date, none has assessed CCIF as predictors of poor health outcomes. The aim of this study was to determine the association between the risk of acute deterioration (as measured using the VIDA early warning system), care complexity individual factors and unfavourable outcomes in patients hospitalised with COVID-19.

METHODS

Setting and Study Design

A retrospective cohort study was carried out at seven public hospitals in Catalonia, Spain: three tertiary metropolitan facilities, three urban university centres and one community hospital. All patients with a medical diagnosis of COVID-19 infection admitted to a ward or intermediate unit for COVID-19 or other causes from March 1, 2020 to March 31, 2020 with a completed hospital minimum data set report were recruited retrospectively and followed up during hospitalisation until discharge or death. Patients' directly admitted and discharged from intensive care units (ICU) were excluded because the VIDA early warning system is not used in the ICU. Patients who remained hospitalised after the recruitment end date were also excluded as the hospital minimum data set was not available.

We defined the primary endpoint as a composite of unfavourable outcomes including in-hospital mortality or adverse events (AEs), not present on admission and occurring thereafter during hospitalisation.

This study was approved by The Clinical Research Ethics Committee of the Bellvitge University Hospital (reference 158/20). Informed consent was waived due to the study's retrospective design. Ethical and data protection protocols related to anonymity and data confidentiality (access to records, data encryption and archiving of information) were complied with throughout the study.

Patient and Public Involvement

Patients were not involved in the design, conduct, or reporting of this study.

Data Collection

Information regarding the demographic and clinical characteristics, continuity of care (discharged to another facility), high-tech hospital (referral centre that provides tertiary care for either open-heart surgery or major organ transplants or both), length of hospital

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2
3 stay (LOS) and patient severity and mortality risk were collected from the hospital
4
5 minimum data set and the clinical data warehouse of the Catalan Institute of Health.
6
7 Patient severity and risk of mortality were based on the all patient refined diagnosis-
8
9 related group (APR-DRG), which categorises both measures from low (level 1) to
10
11 extreme (level 4). Severity and mortality risk were dichotomised in this study into low
12
13 risk (levels 1–2) and high risk (levels 3–4).²⁰ All variables were collected during
14
15 hospitalisation.
16
17

18
19 The VIDA score (acute deterioration risk stratification) automatically classifies
20
21 patients into five groups according to patient progress data: no risk (level 0), low risk
22
23 (level 1), moderate risk (level 2), high risk (impending complication if not stabilised)
24
25 (level 3), manifested complication initial status (level 4). Levels 2 to 4 create an alert in
26
27 the electronic health records and require action in response to clinical recommendations.
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29 These recommendations are standardised for each context and involve intensifying the
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31 surveillance of the patients' status and notifying the medical team. The health team
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33 (nurse and specialist) are responsible for the final clinical decision-making. For the
34
35 purposes of this study, the VIDA score was classified as mild (levels 1–2) or high
36
37 (levels 3–4) risk. Patients were classified according to the highest VIDA score obtained
38
39 during their hospitalisation. Patient progress data were extracted from anonymised
40
41 electronic health records whenever they were e-charted, and included: respiratory rate
42
43 (breaths/min), oxygen saturation (%), temperature (°C), mental status (level of
44
45 awareness; 1= aware and orientated, >1 = disturbed mental status, including
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47 disorientation, acute confusion, etc.), pulse (cardiac rate, beats/min) and systolic and
48
49 diastolic blood pressure (mmHg) (Supplementary file 1).
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56 Care complexity individual factors (CCIF) were classified into five domains: (i)
57
58 mental-cognitive, (ii) psycho-emotional, (iii) sociocultural, (iv) developmental, and (v)
59
60 comorbidity/complications, as described in previous studies.^{16,18} Each CCIF domain is

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3 structured into factors and specifications. Patients were considered to fall within any
4
5 CCIF domains if they presented at least one factor or specification during their
6
7 hospitalisation. These CCIF factors and specifications were obtained from the nursing
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9 assessment e-charts as structured data based on the Architecture, Terminology,
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11 Interface, Knowledge (ATIC) terminology²⁰ (Supplementary file 2).
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14 **Outcome measures**

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16 The main end point was a composite of unfavourable outcomes including in-hospital
17
18 mortality and adverse events (AEs) during hospitalisation. The in-hospital mortality
19
20 counted the number of COVID-19 patients dying while in a ward. The AEs included
21
22 intensive care unit transfer, hospital-acquired infections (HAI) and potentially avoidable
23
24 critical complications (ACC) during hospitalisation. Intensive care unit (ICU) transfer
25
26 was defined as the number of patient episodes with effective bed change from a general
27
28 ward to an intensive care area. HAI included the number of episodes of ward patients
29
30 that developed catheter-related bloodstream infection, urinary catheter-related infection,
31
32 aspiration pneumonia and/or sepsis. ACC accounted for the number of episodes of ward
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34 patients that experienced a cardiac arrest, shock, thromboembolic event, acute
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36 respiratory failure, acute respiratory distress syndrome (ARDS), myocardial injury, liver
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38 injury and/or kidney failure, not present on admission.
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44 **Statistical Analysis**

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46 Descriptive analysis of data using percentage frequencies, median and interquartile
47
48 range was performed to determine demographic and clinical characteristics, and
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50 patients' outcomes. For categorical variables, a comparative analysis for detecting
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52 significant differences between groups was carried out using the chi-square test or
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54 Fisher's exact test when one or more cells had an expected frequency of five or less.
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56 For continuous variables, the Student's t-test or Mann-Whitney U test was used
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58 depending on the results of the Kolmogorov-Smirnov normality test. A logistic-
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3 regression model of all clinical factors potentially associated with unfavourable
4 outcome measures (AEs and in-hospital mortality) was performed including the VIDA
5 score, clinically relevant CCIF and other potential confounders: sex, hospital level and
6 LOS. All potential explanatory variables included in the multivariate analysis were
7 subjected to a correlation matrix for analysis of collinearity. The discriminatory power
8 was evaluated by the area under the receiver operating characteristic (ROC) curve. The
9 results of the multivariate analysis were reported as odds ratios (OR) and 95%
10 confidence intervals (CI). We also performed an adjusted analysis to compare
11 unfavourable outcomes in patients admitted to wards with and without the VIDA
12 system. Statistical analysis was performed using the SPSS software package version
13 25.0 (SPSS, Chicago, IL). *P* values less than 0.05 were considered statistically
14 significant.

31 RESULTS

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33 During the study period, 1,838 patients were hospitalised with COVID-19, of which
34 1,176 patients met the inclusion criteria (**Figure 1**). The frequency of unfavourable
35 outcomes was 42.8% (506 patients). The in-hospital mortality rate was 19.6% (232
36 patients), and almost 41% (481 patients) experienced an AE while in a ward (2.7%
37 transferred to ICU; 2.5% HAI; 40% ACC). Acute respiratory failure, ARDS, acute
38 kidney failure, urinary catheter-related infection, sepsis, and thrombotic events were the
39 most frequent AEs.

50 Patient Characteristics

51
52 The baseline characteristics of patients with an unfavourable and favourable outcome
53 are compared in **Table 1**. Hospitalised COVID-19 patients who had an unfavourable
54 outcome were more often male, older, and had one or more underlying chronic
55 conditions (75.5%), mostly arterial hypertension or congestive heart failure, and
56 diabetes or chronic kidney disease. Furthermore, they had a longer LOS and a high risk
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3 of severity or mortality (APR-DRG 3-4). Conversely, patients admitted to high-tech
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5 hospitals presented a lower frequency of unfavourable outcomes.
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8 Among the 806 patients in wards where the VIDA early warning system was in
9
10 use, most patients with unfavourable outcomes experienced a high risk of acute
11
12 deterioration (41.7% in patients with unfavourable outcomes vs. 9.1% in patients with
13
14 favourable outcomes).
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17 Comorbidity, sociocultural and developmental domains were the most frequent
18
19 CCIF domains identified in the studied sample. Mental-cognitive and psycho-emotional
20
21 domains were less frequent. Patients with unfavourable outcomes exhibited a higher
22
23 frequency of chronic disease, position impairment, anatomical and functional disorders,
24
25 communication disorders, old age (>75 years) and mental status impairment, when
26
27 compared with patients with favourable outcomes. The median CCIF was also higher in
28
29 patients with unfavourable outcomes (5 [IQR: 4–6] vs. 4 [IQR: 3–5]) (**Table 1**).
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32 **Association of outcomes with risk of acute deterioration and care complexity** 33 **factors.** 34 35

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37 The outcomes of 806 patients with low, mild or high risk of acute deterioration are
38
39 compared in **Table 2**. The frequency of unfavourable outcomes was almost 38% in
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41 patients with mild risk and almost 80% in those at high risk of acute deterioration (p
42
43 $<.0.001$). Similarly, the frequency of in-hospital mortality and AEs rose with increasing
44
45 VIDA score and were around 60% and 80%, respectively, in patients with a high risk of
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47 acute deterioration ($p <.0.001$). Acute respiratory failure, acute kidney failure and ICU
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49 transfer were the most frequent AEs.
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53 Among the 1,176 patients analysed in this study, those with four or more CCIF
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55 experienced unfavourable outcomes ($p <.0.05$) (**Table 2**).
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58 **Table 3** shows an adjusted analysis of health outcomes in 486 patients with a
59
60 high risk of mortality (APR-DRG 3-4). In-hospital mortality was more frequent in

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3 patients admitted to wards where VIDA was not used (52.5% vs. 41.3%, $p < 0.05$).
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5 Conversely, the frequency of AEs was slightly higher in patients admitted to wards
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7 using VIDA ($p < 0.05$).
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10 **Risk factors associated with unfavourable outcomes**

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12 The results of the multivariate analysis for risk of acute deterioration (as measured using
13
14 the VIDA score) and CCIF potentially associated with unfavourable outcomes, in-
15
16 hospital mortality and AEs are summarized in **Table 4**.
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19 After adjustment for potential confounders, the analysis showed that a high risk
20
21 of acute deterioration was an independent factor associated with unfavourable
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23 outcomes, in-hospital mortality and AEs in COVID-19 inpatients. Furthermore, chronic
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25 disease, mental status impairment and LOS were risk factors associated with
26
27 unfavourable outcomes. Conversely, high-tech hospital admission was a protective
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29 factor against unfavourable outcomes. The area under the ROC curve (AUC) was 0.81
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31 (95% CI: 0.78–0.84).
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35 Chronic disease, mental status impairment, old age and male sex were
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37 independent risk factors associated with in-hospital mortality in the studied COVID-19
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39 inpatients (AUC 0.91 [95% CI: 0.88–0.93]). Finally, risk factors independently
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41 associated with AEs were chronic disease, mental status impairment, old age and LOS,
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43 whereas high-tech hospital admission was a protective factor against AEs (AUC 0.80
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45 [95% CI: 0.77–0.83]). The AUCs of the three outcomes analysed were > 0.80 , showing
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47 a fair discriminatory power.
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DISCUSSION

In this study of a large cohort of hospitalised patients with COVID-19, the frequency of in-hospital mortality and AEs was around 60% and 80%, respectively, in patients scored as at high risk of acute deterioration. In-hospital mortality was higher in wards not using the VIDA early warning system. The majority of patients had four or more care complexity factors identified. The risk factors independently associated with unfavourable outcomes included chronic disease, mental status impairment, LOS and a high risk of acute deterioration. High-tech hospital admission was a protective factor against unfavourable outcomes.

Our findings are consistent with previous COVID-19 reports that found a similar frequency of in-hospital mortality and AEs.^{3,21} In addition, 37% of patients developed respiratory complications (acute respiratory failure or ARDS) during hospitalisation. This value is within the range reported in a previous study (29–42%).³

The results of this study show that a high risk of acute deterioration is a significant risk factor for unfavourable outcomes, as a composite measure for in-hospital mortality and AEs in COVID-19 inpatients. Although previous studies have stressed that early warning systems are predictors of in-hospital mortality and health outcomes,^{22,23} only a few have evaluated warning score systems in COVID-19 inpatients.^{11,19} These latest studies showed a fair discrimination with adverse outcomes, illustrating that evaluating the risk for acute deterioration in the COVID-19 hospital population is a priority for healthcare organizations.¹⁹

In-hospital mortality was more frequent in patients admitted to wards where registered nurses were not using the VIDA early warning system. In this regard, other studies have shown that the use of early warning systems reinforces collaboration among the multidisciplinary team, and promotes the early identification of clinical deterioration.²⁴ Similarly, previous studies have reported lower mortality and fewer

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3 adverse events when systematic nursing surveillance of patient status and progress is
4 part of the daily routine.⁹
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8 Chronic conditions and mental status impairments were the CCIF independently
9 associated with unfavourable outcomes. Previous reports have shown that chronic
10 diseases were more frequent among deceased COVID-19 patients¹⁵ and that aging was
11 a potential risk factor associated with mortality.⁶ Although our study did not identify
12 age as a risk factor associated with a composite unfavourable outcome, we acknowledge
13 that old age was an independent risk factor associated with mortality and AEs.
14 Furthermore, our findings are also consistent with other studies demonstrating that
15 mental status impairment is associated with hospital-acquired complications,²⁵ including
16 sepsis.⁴
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28 The majority of patients had four or more CCIF. Our findings are consistent with
29 other studies that identified a significant rate of chronic conditions in COVID-19
30 patients¹⁵ along with various organizational issues that may impact care complexity and
31 health outcomes.²⁶ Previous studies have demonstrated the association of CCIF and
32 health outcomes,¹⁶ with an average of two CCIF per patient. In our study of COVID-19
33 inpatients, the average number of CCIF was four. These results are probably related to
34 the transmissibility of this condition, which require droplet and contact precautions; the
35 public health measures of population confinement for pandemic management, which
36 prevent patients' relatives visiting them in person, resulting in a lack of family caregiver
37 support during hospitalisation; and the frequency of chronic diseases in the studied
38 sample. The organisational adaptation of hospitals to this pandemic context and the
39 required isolation precautions have been associated with poor outcomes in prior
40 studies.^{27,28}
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58 We also found that LOS was associated with unfavourable outcomes, consistent
59 with previous studies that associated AEs with increased healthcare costs due to longer
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3 hospital stays.²⁹ Finally, high-tech hospital admission was a protective factor against
4 unfavourable outcomes. High-tech hospitals usually have better nurse-to-patient ratios
5 than urban or community facilities. In this sense, several recent studies in the same
6 study setting concluded that on average, hospital ward patients require 5.6 hours of RN
7 care per patient day, while the average of available RN hours per patient day is 2.4, and
8 that RN understaffing is a structural issue.^{26,30} Nevertheless, to the best of our
9 knowledge, no study on nurse staffing and COVID-19 inpatients' outcomes has been
10 published. Similarly, clinical leaders and healthcare managers have a key role to play in
11 rapidly adapting organizations to the new reality. Fast and effective decision-making
12 and managerial responses in crisis situations with high levels of uncertainty are essential
13 both immediately and in the short-term; however, they should be accompanied by
14 planning and executing mid-term and long-lasting improvements that positively impact
15 patient, professional and organisational outcomes, such as structural RN understaffing.²⁶

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33 The strengths of this study include its multicentre approach, cohort design and
34 large sample size. It is the first study evaluating the association of the risk of acute
35 deterioration, along with care complexity factors, with COVID-19 patient outcomes.
36 Importantly, we identify the importance of a range of contributors to care complexity,
37 including psychosocial and mental-cognitive factors. In addition, the VIDA early
38 warning system was developed as an evidence-based algorithm using a
39 multidisciplinary approach, based on previous studies that highlighted the importance of
40 adapting surveillance and screening systems to the organizational and cultural context.¹⁴

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51 This study is not exempt from limitations. First, the VIDA score and CCIF data
52 were comprehensively collected from the clinical data warehouse of the Catalan
53 Institute of Health and all patients included had a completed nurse chart in the patient
54 electronic health record, but we were still reliant on proper compliance with electronic
55 record-keeping and the collection of administrative data. This is acknowledged as a
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3 significant limitation since voluntary completion of patient electronic documentation
4 during the initial weeks of the first wave of COVID-19 in our country might have been
5 negatively influenced by the rising hospital burden, the understandable prioritization of
6 direct patient care, as well as the physical and emotional stress experienced by bedside
7 healthcare professionals. Second, regarding the study selection criteria, patients directly
8 admitted and discharged from the intensive care unit were excluded, since no early
9 warning system was in use in the critical care setting at the outset of the pandemic in
10 our study area. In this sense, the results of this study only apply to adult ward and
11 intermediate care inpatients. Third, it should be noted that of the 1,176 patients included
12 only 806 were hospitalised in wards with a fully implemented VIDA system. Therefore,
13 patients admitted to wards without the VIDA system did not have data available on risk
14 of acute deterioration (VIDA score). This is a significant limitation. The VIDA system
15 was under development in hospitals belonging to the Catalan Institute of Health during
16 the data collection period. Therefore, future studies should corroborate the current
17 results in centres where VIDA has been fully implemented. However, due to the high
18 number of daily admissions the patients' unplanned assignment to the different wards
19 (with or without the VIDA system) means that the patients' clinical characteristics were
20 similar between wards with and without the VIDA system. Fourth, although an
21 unpublished face validity study has demonstrated the effectiveness the VIDA early
22 warning system, full evaluation of its psychometric properties is still pending. To
23 minimize the potential effect of this limitation, we conducted an adjusted analysis
24 performed with 486 patients with a similar higher risk of mortality (APR-DRG 3-4),
25 comparing those admitted to wards using VIDA with those being treated in units with
26 no VIDA early warning system. The results show that in-hospital mortality was more
27 frequent in patients admitted to wards where VIDA had not yet been implemented. This
28 result should be interpreted with caution because this analysis only included patients
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3 with a high risk of mortality and could have been influenced by other variables such as
4 the differences in sample sizes. Finally, we acknowledge as a potential limitation that
5 other clinical measures such as the age-adjusted Charlson comorbidity index or patient
6 lab values were not assessed. Selected lab values such as lactate, ferritin or calciferol
7 have been studied as indicators of COVID-19 prognosis and severity. Combining point
8 of care lab data with clinical data from nurses' observations and judgments on patient
9 complexity factors, status and progress would probably result in an improved system for
10 the early detection and prevention of critical complications and other unfavourable
11 outcomes in COVID-19 inpatients.
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26 **Conclusion**

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28 The risk of acute deterioration and care complexity individual factors are associated
29 with COVID-19 patient outcomes. The rate of unfavourable outcomes rose with
30 increasing risk of acute deterioration as measured using the VIDA score. The risk
31 factors independently associated with poor health outcomes were chronic disease,
32 mental status impairment, length of hospital stay and high risk of acute deterioration.
33 High-tech hospital admission was a protective factor against unfavourable outcomes.
34 The systematic nursing surveillance of patients at risk of acute deterioration and the
35 assessment of CCIF may help to reduce deleterious health outcomes in adult COVID-19
36 inpatients.
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50 Figure 1. Flow-chart of patient selection process.

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FOOTNOTES

Author Contributions: All authors had full access to all study data and take responsibility for the integrity of the data and the accuracy of the data analysis. *Study concept and design:* Adamuz, González-Samartino, Juvé-Udina. *Coordination team:* Juvé-Udina. *Acquisition of data:* Adamuz, Tapia-Perez, López-Jiménez, Zuriguel-Pérez, Castro-Navarro. *Analysis and interpretation of data:* Adamuz, González-Samartino, Jiménez-Martínez. *Drafting of the manuscript:* Adamuz, González-Samartino, Jiménez-Martínez, Juvé-Udina. *Critical revision of the manuscript for important intellectual content:* Tapia-Perez, López-Jiménez, Rodríguez-Fernández, Zuriguel-Pérez, Castro-Navarro, Carratalà. *Statistical analysis:* Adamuz and González-Samartino. *Obtained funding:* - . *Administrative, technical and material support:* López-Jiménez, Rodríguez-Fernández. *Study supervision:* Juvé-Udina, Carratalà.

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Patient consent for publication: Not required.

Ethical approval: This study was approved by the Clinical Research Ethics Committee of the Bellvitge University Hospital with a waiver of informed consent (reference 158/20).

Provenance and peer review: Not commissioned; externally peer reviewed.

Data availability statement: All data relevant to the study are included in the article.

No additional data are available.

Table 1. Baseline characteristics, VIDA score and care complexity factors of admitted COVID-19 inpatients with unfavourable and favourable outcomes.

| Characteristics | Study population n=1,176 | | Unfavourable outcome ^a n=506 (42.8%) | | Favourable outcome n=670 (57.1%) | | p value |
|---|-----------------------------|---------|--|---------|-------------------------------------|---------|---------|
| | No. | % | No. | % | No. | % | |
| Demographic characteristics | | | | | | | |
| Age (years)_ median (IQR) | 66.5 | (51-77) | 74 | (60-80) | 61 | (49-74) | <0.001 |
| Male sex | 667 | (56.7) | 192 | (37.9) | 317 | (47.3) | 0.001 |
| Clinical characteristics | | | | | | | |
| LOS_ median (IQR) | 6 | (4-8) | 7 | (4-10) | 5 | (4-7) | <0.001 |
| Continuity of care (discharged to another facility) | 165 | (14) | 58 | (11.5) | 107 | (16) | 0.02 |
| Severity (APR-GRD 3-4) | 503 | (42.8) | 450 | (88.9) | 53 | (7.9) | <0.001 |
| Mortality risk (APR-DRG 3-4) | 486 | (41.3) | 449 | (88.7) | 37 | (5.5) | <0.001 |
| High-tech hospital | 969 | (82.4) | 389 | (76.9) | 580 | (86.6) | <0.001 |
| Underlying disease | 745 | (63.4) | 382 | (75.5) | 363 | (54.4) | <0.001 |
| Arterial hypertension or chronic heart failure | 469 | (39.9) | 234 | (46.2) | 235 | (35.1) | <0.001 |
| Diabetes or chronic kidney disease | 298 | (25.3) | 165 | (32.6) | 133 | (19.9) | <0.001 |
| Chronic respiratory disease | 171 | (14.5) | 95 | (18.8) | 76 | (11.3) | <0.001 |
| Neurodegenerative disease | 63 | (5.3) | 33 | (6.5) | 39 | (4.5) | 0.15 |
| Chronic liver disease | 54 | (4.6) | 30 | (5.9) | 24 | (3.6) | 0.07 |
| Cancer | 50 | (4.3) | 31 | (6.5) | 19 | (2.8) | 0.008 |
| Immunosuppression | 49 | (4.2) | 23 | (4.5) | 26 | (3.9) | 0.66 |
| VIDA score^b | | | | | | | |
| Low risk (0) | 104 | (12.9) | 27 | (7.1) | 77 | (18) | <0.001 |
| Moderate risk (1-2) | 505 | (62.7) | 194 | (51.2) | 311 | (72.8) | <0.001 |
| High risk (3-4) | 197 | (16.7) | 158 | (41.7) | 39 | (9.1) | <0.001 |
| Care complexity individual factors (CCIF) | | | | | | | |
| Comorbidity/complications | | | | | | | |
| Transmissible infection | 1,176 | (100) | 506 | (100) | 670 | (100) | - |
| Hemodynamic instability | 910 | (77.4) | 396 | (78.3) | 514 | (76.7) | 0.57 |
| Chronic disease | 745 | (63.4) | 382 | (75.5) | 363 | (54.4) | <0.001 |
| Uncontrolled pain | 194 | (16.5) | 82 | (16.2) | 112 | (16.7) | 0.87 |
| Extreme weight | 168 | (14.3) | 82 | (16.2) | 86 | (12.8) | 0.11 |
| Position impairment | 72 | (6.1) | 52 | (10.3) | 20 | (3.0) | <0.001 |
| Urinary or faecal incontinence | 58 | (4.9) | 31 | (6.1) | 27 | (4.0) | 0.10 |
| Immunosuppression | 49 | (4.1) | | | | | |
| Anatomical and functional disorders | 41 | (3.5) | 30 | (5.9) | 11 | (1.6) | <0.001 |
| Communication disorders | 18 | (1.5) | 13 | (2.6) | 5 | (0.7) | 0.01 |
| High risk of haemorrhage | 2 | (0.2) | 1 | (0.2) | 1 | (0.1) | 0.68 |
| Vascular fragility | 6 | (0.5) | 4 | (0.8) | 2 | (0.3) | 0.41 |
| Involuntary movements | 3 | (0.3) | 3 | (0.6) | 0 | (0.0) | 0.08 |
| Dehydration | 3 | (0.3) | 1 | (0.2) | 2 | (0.3) | 0.60 |
| Oedema | 0 | (0) | 0 | (0.0) | 0 | (0.0) | - |
| Developmental | | | | | | | |
| Old age (≥75 years) | 397 | (33.8) | 244 | (48.2) | 153 | (22.8) | <0.001 |
| Psycho-emotional | | | | | | | |
| Fear/anxiety | 173 | (14.7) | 70 | (13.8) | 103 | (15.4) | 0.51 |
| Impaired adaptation | 54 | (4.6) | 17 | (3.4) | 37 | (5.5) | 0.09 |
| Aggressive behaviour | 1 | (0.1) | 1 | (0.2) | 0 | (0.0) | 0.43 |
| Mental-cognitive | | | | | | | |
| Mental status impairments | 240 | (20.4) | 184 | (36.4) | 56 | (8.4) | <0.001 |
| Agitation | 238 | (20.2) | 183 | (36.2) | 55 | (8.2) | <0.001 |
| Impaired cognitive functions | 5 | (0.4) | 4 | (0.8) | 1 | (0.1) | 0.17 |
| Perception of reality disorders | 4 | (0.3) | 3 | (0.6) | 1 | (0.1) | 0.32 |
| Perception of reality disorders | 2 | (0.2) | 0 | (0.0) | 2 | (0.3) | 0.51 |
| Sociocultural | | | | | | | |
| Lack of caregiver support | 1,176 | (100) | 506 | (100) | 670 | (100) | - |
| Belief conflict | 1,176 | (100) | 506 | (100) | 670 | (100) | - |
| Belief conflict | 1 | (0.1) | 0 | (0.0) | 1 | (0.1) | 0.57 |
| Language barriers | 1 | (0.1) | 1 | (0.2) | 0 | (0.0) | 0.43 |
| Social exclusion | 1 | (0.1) | 0 | (0.0) | 1 | (0.1) | 1 |
| Care complexity individual factors (CCIF), median (IQR) | 4 | (3-6) | 5 | (4-6) | 4 | (3-5) | <0.001 |

Abbreviations: IQR, interquartile range; LOS, length of hospital stay; ICU, intensive care unit; APR-DRG, all patient refined diagnosis-related groups; VIDA, surveillance and identification of acute deterioration.

^a Unfavourable outcomes included: in-hospital mortality and adverse events during hospitalisation.

^b VIDA score was analysed according to 806 patients admitted to wards using the VIDA system.

Table 2. Patients' outcomes according to risk of acute deterioration (VIDA score) and care complexity factors.

| Outcomes | VIDA_score n=806 (68.5) | | | | CCIF n=1,176 | |
|--|-------------------------|-----------------------|-----------------------|-----------------------|-----------------------|-----------------------|
| | All | Low risk (0) | Mild risk (1-2) | High risk (3-4) | CCIF<4 | CCIF≥4 |
| | n=1,176 N (%) | n=104 (12.9) N (%) | n=505 (62.7) N (%) | n=197 (16.7) N (%) | n=327 (27.8) N (%) | n=849 (72.2) N (%) |
| Unfavourable outcomes | 506 (43.0) | 27 (26.0)** | 194 (38.4)* | 158 (80.2)** | 92 (28.1)** | 414 (48.8)** |
| Deceased | 232 (19.6) | 0 (0.0)** | 46 (9.1)** | 118 (59.9)** | 5 (1.5)** | 227 (26.7)** |
| Adverse event | 481 (40.9) | 27 (26.0)** | 187 (37)* | 153 (77.7)** | 91 (27.8)** | 394 (46.4)** |
| ICU transfer | 32 (2.7) | 0 (0.0)* | 12 (2.4) | 13 (6.6)* | 4 (1.2)* | 28 (3.3)* |
| HAI | 29 (2.5) | 0 (0.0)* | 10 (2.0) | 12 (6.1)* | 1 (1.5) | 24 (2.8) |
| Catheter-related bloodstream infection | 1 (0.1) | 0 (0.0) | 0 (0.0) | 1 (0.5) | 0 (0.0) | 1 (0.1) |
| HA urinary tract infection | 19 (1.6) | 0 (0.0) | 7 (1.4) | 8 (4.1)* | 3 (0.9) | 16 (1.9) |
| Aspiration pneumonia | 3 (0.3) | 0 (0.0) | 3 (0.6) | 0 (0.0) | 0 (0.0) | 3 (0.4) |
| Sepsis | 7 (0.6) | 0 (0.0) | 1 (0.2) | 3 (1.5)* | 2 (0.6) | 5 (0.6) |
| ACC | 470 (40.0) | 27 (26.0)** | 181 (35.8)** | 150 (76.1)** | 88 (26.6)** | 383 (45.1)** |
| Cardiac arrest | 5 (0.4) | 1 (1.0) | 0 (0.0)* | 3 (1.5)* | 0 (0.0) | 5 (0.6) |
| Shock | 4 (0.3) | 0 (0.0) | 2 (0.4) | 0 (0.0) | 0 (0.0) | 4 (0.5) |
| Thrombotic event | 7 (0.6) | 1 (1.0) | 1 (0.2) | 2 (1) | 1 (0.3) | 6 (0.7) |
| Acute respiratory failure ¹ | 436 (37.0) | 27 (26.0)** | 164 (32.5)** | 144 (73.1)** | 84 (25.1)** | 353 (41.6)** |
| Myocardial injury | 5 (0.4) | 0 (0) | 3 (0.6) | 1 (0.5) | 0 (0.0) | 5 (0.6) |
| Liver injury | 2 (0.2) | 0 (0) | 0 (0) | 1 (0.5) | 0 (0.0) | 2 (0.2) |
| Renal insufficiency | 83 (7.1) | 1 (1.0)* | 28 (5.5)* | 31 (15.7)** | 6 (1.8)** | 77 (9.1)** |

Abbreviations: VIDA, surveillance and identification of acute deterioration; CCIF, care complexity individual factors; ICU, intensive care unit; HAI, hospital-acquired infections; ACC, avoidable critical complications.

* p value >0.001 and <0.05.

** p value ≤0.001.

¹ Include acute respiratory distress syndrome (ARDS).

Table 3. Adjusted analysis of unfavourable outcomes according to VIDA early warning system in 486 patients with high risk of mortality (APR-DRG 3-4).

| Outcomes | Unadjusted | Adjusted | With VIDA system | Without VIDA system | <i>p value</i> ¹ |
|------------------------------|------------|--------------|------------------|---------------------|-----------------------------|
| | n=1,176 | n=486 (41.2) | n=368 (75.7) | n=118 (24.3) | |
| | N (%) | N (%) | N (%) | N (%) | |
| Unfavourable outcomes | 506 (43.0) | 449 (92.4) | 345 (93.8) | 104 (88.1) | 0.07 |
| Deceased | 232 (19.6) | 214 (44) | 152 (41.3) | 62 (52.5) | 0.02 |
| Adverse event | 481 (40.9) | 436 (89.7) | 337 (91.6) | 99 (83.9) | 0.02 |
| ICU transfer | 32 (2.7) | 25 (5.1) | 20 (5.4) | 5 (4.2) | 0.41 |
| HAI | 29 (2.5) | 19 (3.9) | 16 (4.3) | 3 (2.5) | 0.28 |
| ACC | 470 (40.0) | 433 (89.1) | 334 (90.8) | 99 (83.9) | 0.31 |

Abbreviations: VIDA, surveillance and identification of acute deterioration; ICU, intensive care unit; HAI, hospital-acquired infections; ACC, avoidable critical complications.

¹All variables were compared using the Fisher exact test.

Table 4. Multivariate analysis of VIDA score and CCIF in 806 adult COVID-19 inpatients associated with unfavourable outcomes, death and AEs.

| <i>Characteristics</i> | Unfavourable outcomes ¹ | | Deceased ² | | AEs ³ | |
|---------------------------|------------------------------------|----------------|-----------------------|----------------|-------------------|---------------|
| | n= 379/806 (47%) | | n= 164/806 (20.3%) | | n=367/806 (45.5%) | |
| | OR | (95% CI) | OR | (95% CI) | OR | (95% CI) |
| Old age (≥75 years) | 1.48 | (0.99-2.22) | 3.04 | (1.79-5.15)** | 1.52 | (1.02-2.26)* |
| Male sex | 1.21 | (0.87-1.69) | 1.86 | (1.11-3.11)* | 1.20 | (0.87-1.67) |
| LOS | 1.16 | (1.11-1.21)** | 0.97 | (0.93-1.01) | 1.17 | (1.12-1.22)** |
| High-tech hospital | 0.57 | (0.36-0.89)* | 1.88 | (0.94-3.78) | 0.61 | (0.39-0.95)* |
| VIDA score 3-4 | 4.32 | (2.83-6.60)** | 13.99 | (8.44-23.18)** | 4.21 | (2.79-6.36)** |
| Chronic disease | 1.90 | (1.32-2.72)** | 2.01 | (1.03-3.90)* | 1.81 | (1.26-2.59)** |
| Position impairment | 1.19 | (0.58-2.44) | 1.41 | (0.63-3.13) | 1.23 | (0.62-2.46) |
| Communication disorders | 0.97 | (0.24-3.96) | 0.87 | (0.22-3.41) | 0.78 | (0.21-2.95) |
| Mental status impairments | 2.31 | (1.45-23.66)** | 6.21 | (3.67-10.50)** | 1.72 | (1.09-2.69)* |

Abbreviations: AE, adverse event; LOS, length of hospital stay; VIDA, surveillance and identification of acute deterioration. Multivariate analysis included: high risk of acute deterioration (VIDA score 3–4), clinically relevant care complexity factors (old age, chronic disease, position impairment, communication disorders and mental status impairments) and potential confounders (sex, hospital level and LOS).

¹AUC 0.81 (CI 95%; 0.78–0.84).

²AUC 0.91 (CI 95%; 0.88–0.93).

³AUC 0.80 (CI 95%; 0.77–0.83).

* *p* value >0.001 and <0.05.

** *p* value ≤0.001.

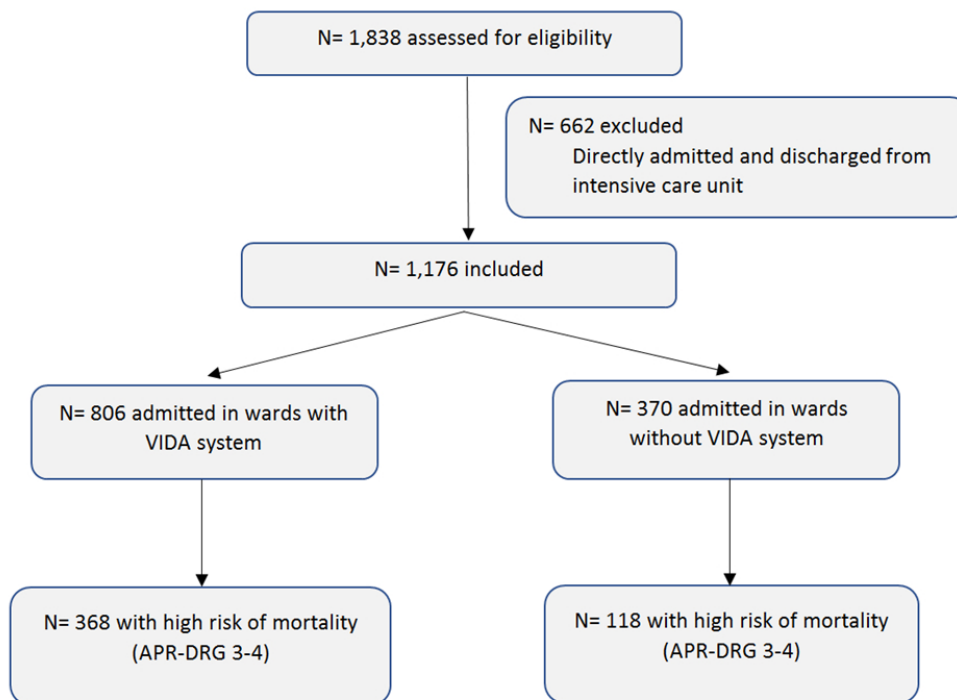


Figure 1. Flow-chart of patient selection process.

Supplementary file 1. Juvé-Udina ME. VIDA score for acute deterioration in the current human algorithm.

| H1, H2, H3 | | |
|--------------------|-------------------|---|
| Punctuation | Risk score | Definition |
| 0 – 1 | 0 | No risk of complication (at that particular moment) |
| 2 – 3 | 1 | Low risk |
| 4 | 2 | Moderate risk (very probable complication) |
| 5 – 6 | 3 | High risk (imminent complication if not stabilized) |
| >= 7 | 4 | Critical complication status |
| H4 | | |
| Punctuation | Risk score | Definition |
| 0 – 1 | 0 | No risk of complication (at that particular moment) |
| 2 – 3 | 1 | Low risk |
| 4 – 6 | 2 | Moderate risk (very probable complication) |
| 7 – 9 | 3 | High risk (imminent complication if not stabilized) |
| >= 10 | 4 | Critical complication status |
| H5 | | |
| Punctuation | Risk score | Definition |
| 0 – 2 | 0 | No risk of complication (at that particular moment) |
| 3 – 4 | 1 | Low risk |
| 5 – 6 | 2 | Moderate risk (very probable complication) |
| 7 – 8 | 3 | High risk (imminent complication if not stabilized) |
| >= 9 | 4 | Critical complication status |
| H6 | | |
| Punctuation | Risk score | Definition |
| 0 – 2 | 0 | No risk of complication (at that particular moment) |
| 3 – 4 | 1 | Low risk |
| 5 – 6 | 2 | Moderate risk (very probable complication) |
| 7 – 9 | 3 | High risk (imminent complication if not stabilized) |
| >= 10 | 4 | Critical complication status |
| H7 | | |
| Punctuation | Risk score | Definition |
| <= 3 | 1 | Low risk |
| 4 – 6 | 2 | Moderate risk (very probable complication) |
| 7 – 8 | 3 | High risk (imminent complication if not stabilized) |
| >= 9 | 4 | Critical complication status |

Abbreviations: H, hospital.

Supplementary file 2. Care complexity individual factors.

| Domains | Factors | Specifications |
|-------------------------------|--|--|
| Comorbidity/ Complications | Transmissible infection | Isolation measures |
| | Hemodynamic instability | Intensive control of vital signs or state of shock |
| | Chronic disease | Conditions (organ failure, degenerative process or oncological disease) that require ongoing medical attention and limit activities of daily living. |
| | Uncontrolled pain | Verbal numerical rating scale above three points |
| | Extreme weight | Low weight, obesity |
| | Position impairment | Includes any position impairment |
| | Urinary or faecal incontinence | Loss of bladder control or failure to control bowel movements |
| | Immunosuppression | Neutropenia, immunodeficiency or immunosuppressive therapy |
| | Anatomical and functional disorders | Amputation, deformities, joint stiffness |
| | Communication disorders | Aphasia, dysphasia, dysarthria, laryngectomy, tracheostomy |
| | High risk of haemorrhage | Coagulation disorders, thrombocytopenia, anticoagulant therapy |
| | Vascular fragility | Capillary fragility, tortuous veins |
| | Involuntary movements | Continuous involuntary movements |
| Dehydration | Skin turgor | |
| Oedema | An accumulation of an excessive amount of watery fluid in cells, tissues, or serous cavities | |
| Developmental | Old age | ≥75 years |
| Psycho- emotional | Fear/anxiety | Fear or anxiety (moderate or intense) |
| | Impaired adaptation | Disruptive behaviour, hopelessness or surrender |
| | Aggressive behaviour | Physical or verbal aggressive behaviour (moderate or intense) |
| Mental- cognitive | Mental status impairments | Confusion, disorientation, stupor, transient loss of consciousness |
| | Agitation | Psychomotor agitation |
| | Impaired cognitive functions | Intellectual disability, amnesia |
| | Perception of reality disorders | Delirium, hallucinations, disconnection from reality |
| Sociocultural | Lack of caregiver support | Without caregiver support or caregiver burnout |
| | Belief conflict | Spiritual distress |
| | Language barriers | Barrier to communication resulting from speaking different languages than Spanish or Catalan without translator. |
| | Social exclusion | Extreme poverty |

STROBE Statement—Checklist of items that should be included in reports of *cohort studies*

| | Item No | Recommendation | |
|------------------------------|---------|--|-----------|
| Title and abstract | 1 | (a) Indicate the study's design with a commonly used term in the title or the abstract | Pg.3 |
| | | (b) Provide in the abstract an informative and balanced summary of what was done and what was found | Pg.3-4 |
| Introduction | | | |
| Background/rationale | 2 | Explain the scientific background and rationale for the investigation being reported | Pg.5-6 |
| Objectives | 3 | State specific objectives, including any prespecified hypotheses | Pg.6 |
| Methods | | | |
| Study design | 4 | Present key elements of study design early in the paper | Pg.7 |
| Setting | 5 | Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection | Pg.7 |
| Participants | 6 | (a) Give the eligibility criteria, and the sources and methods of selection of participants. Describe methods of follow-up | Pg.7 |
| | | (b) For matched studies, give matching criteria and number of exposed and unexposed | - |
| Variables | 7 | Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable | Pg.7-8 |
| Data sources/ measurement | 8* | For each variable of interest, give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group | Pg.7-8 |
| Bias | 9 | Describe any efforts to address potential sources of bias | Pg.16 |
| Study size | 10 | Explain how the study size was arrived at | Pg.7 |
| Quantitative variables | 11 | Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why | Pg.9 |
| Statistical methods | 12 | (a) Describe all statistical methods, including those used to control for confounding | Pg.9 |
| | | (b) Describe any methods used to examine subgroups and interactions | Pg.9 |
| | | (c) Explain how missing data were addressed | - |
| | | (d) If applicable, explain how loss to follow-up was addressed | - |
| | | (e) Describe any sensitivity analyses | - |
| Results | | | |
| Participants | 13* | (a) Report numbers of individuals at each stage of study—eg numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed | Pg.10 |
| | | (b) Give reasons for non-participation at each stage | Pg.10-11 |
| | | (c) Consider use of a flow diagram | - |
| Descriptive data | 14* | (a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders | Pg.10 |
| | | (b) Indicate number of participants with missing data for each variable of interest | - |
| | | (c) Summarise follow-up time (eg, average and total amount) | Pg.10 |
| Outcome data | 15* | Report numbers of outcome events or summary measures over time | Pg10-11 |
| Main results | 16 | (a) Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (eg, 95% confidence interval). Make clear which confounders were adjusted for and why they were included | Table 1&4 |

| | | | |
|--------------------------|----|--|-----------|
| | | (b) Report category boundaries when continuous variables were categorized | Table 1&4 |
| | | (c) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period | Pg.11-12 |
| Other analyses | 17 | Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses | Pg.11 |
| Discussion | | | |
| Key results | 18 | Summarise key results with reference to study objectives | Pg.13 |
| Limitations | 19 | Discuss limitations of the study, taking into account sources of potential bias or imprecision. Discuss both direction and magnitude of any potential bias | Pg.16 |
| Interpretation | 20 | Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence | Pg.14-16 |
| Generalisability | 21 | Discuss the generalisability (external validity) of the study results | Pg.15-16 |
| Other information | | | |
| Funding | 22 | Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based | Pg.21. |

*Give information separately for exposed and unexposed groups.

Note: An Explanation and Elaboration article discusses each checklist item and gives methodological background and published examples of transparent reporting. The STROBE checklist is best used in conjunction with this article (freely available on the Web sites of PLoS Medicine at <http://www.plosmedicine.org/>, Annals of Internal Medicine at <http://www.annals.org/>, and Epidemiology at <http://www.epidem.com/>). Information on the STROBE Initiative is available at <http://www.strobe-statement.org>.