Hospital characteristics associated with COVID-19 mortality: data from the multicenter cohort Brazilian Registry

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Abstract

The COVID-19 pandemic caused unprecedented pressure over health care systems worldwide. Hospital-level data that may influence the prognosis in COVID-19 patients still needs to be better investigated. Therefore, this study analyzed regional socioeconomic, hospital, and intensive care units (ICU) characteristics associated with in-hospital mortality in COVID-19 patients admitted to Brazilian institutions. This multicenter retrospective cohort study is part of the Brazilian COVID-19 Registry. We enrolled patients ≥ 18 years old with laboratory-confirmed COVID-19 admitted to the participating hospitals from March to September 2020. Patients’ data were obtained through hospital records. Hospitals’ data were collected through forms filled in loco and through open national databases. Generalized linear mixed models with logit link function were used for pooling mortality and to assess the association between hospital characteristics and mortality estimates. We built two models, one tested general hospital characteristics while the other tested ICU characteristics. All analyses were
adjusted for the proportion of high-risk patients at admission. Thirty-one hospitals were included. The mean number of beds was 320.4 ± 186.6. These hospitals had eligible 6556 COVID-19 admissions during the study period. Estimated in-hospital mortality ranged from 9.0 to 48.0%. The first model included all 31 hospitals and showed that a private source of funding ($\beta = -0.37; 95\% \text{ CI } -0.71 \text{ to } -0.04; p = 0.029$) and location in areas with a high gross domestic product (GDP) per capita ($\beta = -0.40; 95\% \text{ CI } -0.72 \text{ to } -0.08; p = 0.014$) were independently associated with a lower mortality. The second model included 23 hospitals and showed that hospitals with an ICU work shift composed of more than 50% of intensivists ($\beta = -0.59; 95\% \text{ CI } -0.98 \text{ to } -0.20; p = 0.003$) had lower mortality while hospitals with a higher proportion of less experienced medical professionals had higher mortality ($\beta = 0.40; 95\% \text{ CI } 0.11-0.68; p = 0.006$). The impact of those association increased according to the proportion of high-risk patients at admission. In-hospital mortality varied significantly among Brazilian hospitals. Private-funded hospitals and those located in municipalities with a high GDP had a lower mortality. When analyzing ICU-specific characteristics, hospitals with more experienced ICU teams had a reduced mortality.

**Keywords** COVID-19 · Healthcare · Hospital · Intensive care · Mortality

**Background**

Since the World Health Organization (WHO) announced the COVID-19 pandemic, hospitals worldwide have faced the challenging task of improving their capacity to handle the unusual influx of patients. Even though COVID-19 more frequently causes mild to moderate symptoms, this novel disease significantly increased hospital resource utilization in many countries [1].

The pressure over the health care system was especially challenging in low—and middle—income countries (LMICs), such as Brazil, where the pre-pandemic resources were already scanty [2, 3]. In this country, the system struggled to adapt to the higher rate of hospitalization. Reports of a shortage of equipment and medication throughout the country increased amid the second surge in 2021 [4]. As of March 2022, Brazil remains one of the countries most affected by the pandemic, ranking third in the number of cumulative confirmed cases, and in the number of cumulative deaths [5].

Previous studies explored different factors influencing COVID-19 mortality mostly at an individual level, such as increasing age, sex, genetics, race, socioeconomic status, and the presence of certain comorbidities [6–8]. At a hospital level, it is known from pre-pandemic studies that the way a hospital system is structured and organized may affect the quality of care and the patient outcome [9–11]. In the COVID-19 pandemic, variations in mortality across hospitals and intensive care units (ICU) have been described, however, the role of hospital characteristics on the patient outcome remains unclear [12, 13]. To this moment, few observational studies have examined one or more hospital-level variables and COVID-19 mortality, and all are from high-income countries [14–16], which may not fully translate to emerging countries. In LMICs, after thoroughly literature search, we could not find detailed data analyzing hospital-level characteristics associated with the outcome of COVID-19 patients. This information is essential to identify potentially modifiable factors related to organizational characteristics.

Therefore, this study sought to analyze regional socioeconomic, hospital and ICU-specific characteristics and their association with mortality in COVID-19 patients admitted to Brazilian hospitals.

**Methods**

**Study design**

This study is part of the Brazilian COVID-19 Registry, a multicenter retrospective cohort detailed in a previous report [17]. Hospitals were invited to participate with an open call sent through email, website, and radio. The registry is being conducted according to a predefined protocol in 37 Brazilian hospitals. We followed the Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) guidelines for observational cohort studies (Supplementary Table 1) [18].

**Study participants**

We enrolled consecutive adult (≥ 18 years old) patients with laboratory-confirmed COVID-19 admitted to the participating hospitals from March 1 to September 30, 2020. Confirmatory COVID-19 diagnosis followed the World Health Organization guidance [19].

Patients transferred to step-down beds, such as hospice care, nursing homes, long-term stay care, or lower complexity hospitals, were considered discharged. We excluded patients who required transfer to a higher complexity care facility, such as larger hospitals with more infrastructure.
to deliver complex care. Between-hospital transfers were included if they occurred between participating institutions in the first three days of hospitalization, otherwise, the patient was excluded. In the case of transfer, we considered the data from the receiving institution. All other patients who had been transferred to a non-participant institution were excluded, as well as patients who developed COVID-19 symptoms while admitted for other conditions. Finally, hospitals that did not complete at least 30 consecutive patients or did not comply with the study protocol were excluded (Fig. 1).

**Patient-level data**

We used Research Electronic Data Capture (REDCap®) online tool, hosted at the Telehealth Center, University Hospital, Universidade Federal de Minas Gerais [20, 21] to collect patient’s data were obtained through hospital records. Data contained patients’ demographics, clinical, laboratory and imaging findings, treatments, complications, and outcomes during the hospital stay. To assure data quality, all data underwent a series of manual and automated verifications to identify inconsistencies and non-conforming values, as previously described [17, 22].

**Hospital-level data**

Data regarding hospitals’ characteristics were collected on forms filled by the hospital staff or managers, or on the open national database from Cadastro Nacional de Estabelecimentos da Saúde- CNES (National Registry of Health Facilities) [23] and from the Instituto Brasileiro de Geografia e Estatística-IBGE (Brazilian Institute of Geography and Statistics) [24]. We chose characteristics in accordance with the previous literature on the topic [10, 11, 25–27].

The first form contained information about hospitals’ classification, structure, and location. It included source of income (public, mixed—partly public and partly private—or private), accreditation, academic status, number of COVID-19-specific beds (ward and ICU), and whether the institution had been selected as a COVID-19 reference center. If available, the information was cross-referenced against the one available in the open database. If any disagreement between sources were identified, we asked the hospital research team to re-check the information. In addition to that, we collected variables about the hospitals’ location at a municipality-level to assess the socioeconomic characteristics of the population that attended these hospitals. For this purpose, we evaluated the size, geographic region, number of hospital beds per 1000 inhabitants, gross development product (GDP) per capita, and average human development index (HDI) of each municipality [24].

The second form contained information about ICU characteristics. Hospitals’ supervisors retrieved the requested information in loco. The variables had two domains. The first one was staff information: previous experience in critical care of the medical staff (nurses and physicians) in a COVID-19 ICU work shift, staff availability (physicians, nurses, and technicians) per shift, and the need for emergency hiring of healthcare personnel to work with COVID-19 patients. The second one contemplated organizational characteristics, such as COVID-19-specific protocol for hospital and ICU admission, training of the healthcare team, implementation of daily clinical multidisciplinary rounds, and the number of implemented clinical protocols for the management of critical patients in the ICU.

To assess the previous experience in critical care of the medical staff, we considered as “experienced” the proportion of the staff (physicians or nurses) on COVID-19 ICU work shift that were board-certified specialists in intensive care or had more than 2 years of clinical experience in critical care. To identify less experienced professionals, we considered
the proportion of medical doctors in training (residency or specialization) in the COVID-19 ICU work shift. We also created an intermediate category evaluating the proportion of staff transferred from other clinical or surgical areas to work in COVID-19 ICUs.

For assessing staff availability, we calculated the absolute number of professionals (physicians, nurses, and nurse technicians) in a COVID-19 ICU work shift on weekdays, weekends, and holidays at the month of the peak of the pandemic. Then, we calculated the bed-to-staff ratio using the weighted average of the number of professionals in a shift divided by the total number of available beds. We compared this ratio with the minimum standards recommended by the Brazilian legislation, which are, 10 beds per physician, 10 beds per nurse, and two beds per nurse technician [28]. Emergency hiring included physicians, nurses, nurse technicians, and other allied health professionals (physical therapists, pharmacists, nutritionists, social workers, or psychologists) who were hired under emergency hiring calls due to the pandemic.

Organizational processes inquired about the implementation of general and COVID-19 specific protocols. We also evaluated the number of clinical protocols for the critically ill patients fully implemented in the COVID-19 ICU. This included ten different protocols that showed association with mortality in a pre-pandemic study in Brazilian ICUs [11]: early mobilization, sedation, sepsis, lung protective mechanical ventilation, prevention of ventilator-associated pneumonia, prevention of central line-associated bloodstream infection, cardiorespiratory arrest, acute coronary syndrome, cerebrovascular accident. In addition, we also included a protocol regarding intubation and mechanical ventilation in COVID-19 patients.

**Statistical analysis**

Hospitals’ categorical characteristics were described as absolute or relative frequency while the continuous ones were studied using central tendency statistics (mean and standard deviation, or median and quartiles according to the Shapiro–Wilk’s test).

The main outcome was COVID-19 mortality that we estimated independently for each hospital. As the outcome was an aggregated data, we used generalized linear mixed models with logit link function to assess the association between hospital characteristics and mortality estimates. First, we constructed a forest plot to show the heterogeneity among the outcome in each hospital. Second, we built two independent models, using the same methodology: one for general hospital characteristics and another for ICU characteristics. The methodology was to test each hospital characteristics individually in a bivariate model (characteristic + proportion of high-risk patients). Then, variables that achieved $p < 0.20$ in the bivariate analysis were included in a multivariate analysis in a stepwise approach, dropping variables with the poorest performance on each step. All variables analyzed in the multivariate analysis were categorical, thus collinearity was studied using cross-tabulation. A $p$ value lower than 0.05 denoted significance in the final model. To adjust for patients’ explanatory variables, we included the proportion of high-risk patients at admission. This variable was defined as those patients who scored more than 4 (“high risk” or “very high-risk”) according to the ABC2-SPH scoring system. This score predicts COVID-19 mortality using variables at hospital admission and was developed and externally validated from a sample of this cohort in a previous study, demonstrating high discriminatory capacity [22].

To calculate this score, seven variables are necessary, including age, the number of comorbidities, heart rate, FiO2/SpO2 rate, and laboratory values of serum urea, reactive C protein, and platelets [22]. Clinical and laboratory variables that had missing values were considered missing at random after a thorough analysis of missing data patterns. We used multiple imputations with chained equations (MICE) to handle these values. Ten imputed datasets were generated and combined using the mean proportion of high-risk patients per hospital in each dataset. Finally, we repeated the analysis only with the 3,728 patients who had complete information, after excluding patients with any missing (Supplementary Fig. 2).

We used the R project for statistical computing (version 4.0.3) to all analyses. Packages included dplyr (version 1.0.7), ggplot2 (version 3.3.5), meta (version 4.18-2), and metafor (version 3.0–2).

**Ethics approval and consent to participate**

The Brazilian National Commission for Research Ethics approved the study protocol (CAAE: 30350820.5.1001.0008). This commission waived off the requirement for informed consent due to the severity of the pandemic circumstances and since we used only de-identified data based solely on medical records review.

**Results**

Thirty-one hospitals from 16 Brazilian cities in 4 states were included (Supplementary Fig. 2). These hospitals received COVID-19 patients from 370 municipalities across 12 different states (Supplementary Fig. 2).
General and ICU characteristics stratified by the hospital main source of income (public or private) are summarized in Tables 1 and 2. For ICU characteristics, 23 hospitals answered the form (15 provided complete information and 8 partial information). Regarding the characteristics of the studied population, 6556 patients were eligible. Overall, 54.6% were male and the median age was 61 (IQR 48–72) years old. Hypertension (54.8%), diabetes mellitus (29.2%) and obesity (17.8%) were the most frequent comorbidities. Of all admitted patients, 38.1% needed critical care support, 28.0% required invasive mechanical ventilation and 20.8% (CI 95% 18.0 to 24.0%) died (Supplementary Table 1).

### Mortality estimation

Mortality was 21.0% (95% CI 18.0–24.0%) with high heterogeneity ($I^2 = 87\%$; $p < 0.01$) in the mortality estimates among hospitals (between 9.0 and 48.0%). Hospitals with the lowest mortality were private, but also had a lower proportion of high-risk patients, whilst the eight hospitals with higher mortality were public, but had a higher proportion of high-risk patients (Fig. 2). A positive, linear, and significant ($p < 0.001$) correlation was found between the proportion of high-risk patients and the logit of the mortality (Supplementary Fig. 2B).

### Association between general hospital characteristics and mortality estimates

A total of 31 hospitals were included in this analysis. Five from the 15 general hospital characteristics tested in the bivariate model achieved a $p < 0.20$ and were included in the multivariate analysis (Table 3). After a stepwise exclusion, two variables remained independently associated with mortality. Hospitals with a private source of income had a lower mortality compared to a public one ($\beta = -0.37$; 95% CI –0.71 to –0.04; $p = 0.029$). Hospitals located in municipalities with a GDP per capita lower than the Brazilian average had a higher mortality compared to locations with a
GDP higher than the country’s average ($\beta = -0.40$; 95% CI $-0.72$ to $-0.08$; $p = 0.014$).

**Association between ICU characteristics and mortality estimates**

A total of 23 hospitals were included in this analysis. Four from the 11 ICU-specific characteristics tested in the bivariate model achieved a $p < 0.20$ and were included in the multivariate analysis (Table 3). The variables "daily multidisciplinary rounds" and "staff training" could not be tested, because all hospitals gave the same answer. Two variables remained independently associated with mortality. Hospitals with more than 50% of experienced medical professionals on the COVID-19 ICU team had lower mortality ($\beta = -0.59$; 95% CI $-0.98$ to $-0.20$; $p = 0.003$) while hospitals with less experienced medical professionals (> 10% of medical residents or trainees) on COVID-19 ICU duty had higher mortality ($\beta = 0.40$; 95% CI 0.11–0.68; $p = 0.006$). The $\beta$'s estimates are in the logit scale of mortality. Negative values mean reduced mortality while positive ones mean an increased mortality. Also, higher values in modulus mean greater impact (Table 4).

Supplementary Figs. 3 and 4, and Supplementary Table 2 show the results of the multivariate model in the mortality scale. Mortality increased with the proportion of high-risk patients. Furthermore, regardless of the proportion of high-risk patients, mortality was lower depending on whether a hospital has less than 50% of intensivists and more than 10% of medical residents. For example, if the proportion of high-risk patients estimated in a hospital was 40%, mortality was estimated as 14.4% for scenario 1 (high experience: < 10% residents and > 50% intensivists), 20.0% for scenario 2 (moderate experience: > 10% residents and > 50% intensivists), 23.3% for scenario 3 (low experience: < 10% residents and < 50% intensivists) and 31.1% for scenario 4 (very low experience: > 10% residents and < 50% intensivists) (Supplementary Fig. 4).

**Discussion**

In this study, we investigated whether regional socioeconomic, general and ICU hospital characteristics were associated with mortality in a Brazilian multicenter study of COVID-19 patients. Mortality varied significantly across the institutions, ranging from 9.0 to 48.0%. Private hospitals, as
well as those located in areas with a high GDP per capita, had lower mortality. In the analysis of ICU characteristics, hospitals with a less experienced critical care team had higher mortality.

The association between hospital characteristics with COVID-19 mortality have not been previously extensively explored. Most studies on this topic focused on limited aspects of care. For instance, two studies explored the association between the pressure on hospital capacity imposed by the pandemic and the increased mortality but did not assess other topics such as resource availability and other organizational aspects [14, 16]. A French study found that in-hospital mortality of COVID-19 patients was higher during weekends, which could be partially explained by the lower availability of staff on weekends, although this parameter was not directly measured by the authors [15]. This study also evaluated the ICU team experience on critical care and mortality in COVID-19 patients, but did not find an association, which contrasted with our finding. These discordant results, however, might be related to the different definition of staff experience used in that study and ours. While Rimmelé et al. [15] considered staff experience as the number of COVID-19 patients admitted by the ICU team during the study period, we assessed the professional background of each staff on COVID-19 ICU duty. As for the other variables analyzed, we did not find any study assessing those detailed metrics, such as the implementation of protocols, clinical rounds, or staff training, which could be associated with in-hospital mortality according to pre-pandemic evidence [9, 15, 29]. On top of that, it is noteworthy that all studies on this topic were from high-income countries and no studies analyzed the association of hospital-level characteristics and COVID-19 mortality in LMICs.

In this study, mortality varied remarkably between hospitals. Although previous studies reported the overall COVID-19 mortality in Brazil ranging from 22.0 to 38.0% [17, 30], at a hospital-level, we observed a wider variation, with mortality estimates reaching up to 48.0%. Earlier patient-level analyses of this cohort showed considerable differences in patient’s characteristics depending on the hospital’s main source of funding, such as advanced age and a higher number of comorbidities that were observed in public hospitals [17]. Conversely, in the present study, the analysis of the patient’s explanatory variables at a hospital-level showed that public hospitals had a higher proportion of high-risk patients. We hypothesize that patients admitted to public hospitals tend to present a more severe condition when compared to patients from private hospitals due to the unequal provision of hospital beds between the two healthcare systems, with private hospitals having more beds available [31, 32]. However, even after adjusting for disease severity, the increased mortality observed in public hospitals persisted, indicating that aspects other than those related to the patient influenced COVID-19 mortality.

Previous studies showed that socioeconomic status is an independent risk factor for COVID-19 mortality [8, 33–35].
In Brazil, there are reports of higher mortality in socioeconomically deprived populations, residents in the Brazilian poorest regions (North and Northeast of the country), and in black and pardo people [30, 33]. Our findings reiterate those associations, public hospitals and in the municipalities with a GDP per capita lower than the Brazilian average presented higher mortality. In this country, public hospitals are managed by the Brazilian Unified Health System (SUS—Sistema Único de Saúde) which is a universal health system implemented since the 1988 healthcare reform [36]. Currently, approximately 77% of the Brazilian population depends exclusively on this modality of health system. Private healthcare is represented by out-of-pocket services and paid by health insurance. This modality covers about 23% of the population, and, as it is a paid system, most of the insured people are in the wealthiest areas of the country [37]. Although SUS is paramount for the goal of achieving universal healthcare for the Brazilian population, this system has been underfunded and understaffed for years [36, 38]. When the COVID-19 pandemic struck, there was immediate concern about how the public health system would respond to the overwhelming demand. The situation was particularly pressing for hospitals and ICUs because of the low availability and uneven distribution of critical care resources across the country [32].

The second analysis provided detailed information on ICU characteristics showing that a higher medical staff experience in critical care was associated with lower mortality. As the pandemic evolved, countries needed to expand hospital and ICU capacity to supply the demands. However, creating new hospital beds, especially in the ICU, is a complex process that requires infrastructure expansion, new equipment, medications, and qualified professionals [39–41]. To meet the health care needs in an emergency scenario, such as the COVID-19 pandemic, increasing the number of personnel is one of the most intricate adaptations, especially where the number of skilled professionals had already been scarce before the event [2].

Table 3 General hospital characteristics and city-level variables associated with mortality in the bivariate and multivariate analysis (n = 31)

| Variables                                | Bivariate analysis | Multivariate analysis |
|------------------------------------------|--------------------|-----------------------|
|                                          | β* (95% CI)        | p value               | β* (95% CI)        | p value               |
| GDP per capita higher than the Brazilian average | −0.39 (−0.72; −0.06) | 0.019 | −0.40 (−0.72; −0.08) | 0.014 |
| Source of income                         |                    |                       |                    |                       |
| Private                                  | −0.37 (−0.73; −0.01) | 0.044 | −0.37 (−0.71; −0.04) | 0.029 |
| Mixed (public and private)              | −0.20 (−0.48; 0.07) | 0.148 | −0.20 (−0.46; 0.06) | 0.127 |
| Public                                   | Reference category | NA | Reference category | NA |
| > 50% Patients admitted from other municipalities | 0.25 (−0.02; 0.51) | 0.070 | 0.14 (−0.14; 0.43) | 0.324 |
| Academic hospitals                       | 0.17 (−0.07; 0.41) | 0.168 | 0.07 (−0.19; 0.34) | 0.584 |
| COVID-19 reference center                | −0.10 (−0.22; 0.41) | 0.556 |                       |                       |
| Accreditation                            | −0.03 (−0.28; 0.21) | 0.805 |                       |                       |
| Hospital size                            |                    |                       |                    |                       |
| 150–500 beds                             | −0.04 (−0.32; 0.24) | 0.771 |                       |                       |
| > 500 beds                               | 0.16 (−0.18; 0.50) | 0.348 |                       |                       |
| 50–150 beds                              | Reference category | NA | Reference category | NA |
| Proportion COVID-19 ICU beds             | 0.23 (−0.36; 0.82) | 0.440 |                       |                       |
| Number of COVID-19 ICU beds              | 0.002 (−0.007; 0.01) | 0.719 |                       |                       |
| Number of COVID-19 ward beds             | −0.001 (−0.004;0.002) | 0.421 |                       |                       |
| Volume of COVID-19 patients              | 0.0002 (−0.0004; 0.0004) | 0.909 |                       |                       |
| Geographic region                        |                    |                       |                    |                       |
| South region                             | 0.09 (-0.17; 0.35) | 0.503 |                       |                       |
| Southeast region                         | Reference category | NA | Reference category | NA |
| Metropolitan                             | −0.13 (−0.40; 0.15) | 0.371 |                       |                       |
| HDI per capita less than the Brazilian average | −0.05 (−0.37; 0.27) | 0.762 |                       |                       |
| Beds per 1000 inhabitants                | 0.06 (−0.07; 0.19) | 0.339 |                       |                       |

GDP gross development product, ICU intensive care unit, Analyses were adjusted by the proportion of high-risk patients. HDI human development index

*Estimates are reported in the logit scale of the in-hospital mortality.
redeploying staff from other sectors, hiring new staff, having volunteers from other states or countries, and calling upon retired professionals [39, 40]. Implementing these strategies, however, create a situation where professionals may lack the ideal training to deal with the novel situation, which can compromise the quality of care [40, 42]. This is especially true for environments such as ICUs where practical skills to perform invasive procedures are often needed [40, 42]. In addition to that, taking into consideration, the worker’s perspective, training is a way to support and make them more confident [43, 44]. In a systematic review that analyzed the workers’ experiences and views during the pandemic, frontline staff reported the feeling of not being prepared and having insufficient training and support to deal with the novel situation [43]. In our cohort, even though hospitals that had a less experienced ICU medical team had a worse outcome, hospitals managers answered that all frontline workers had training for the management of COVID-19 patients. More studies are needed to investigate how and how often they trained, and even what training strategy is more effective.

This study provided a detailed examination of the variability in the COVID-19 in-hospital mortality in a Brazilian cohort. As the pandemic continues to spread around the world due to the surge of new variants of concern and low immunization coverage due to vaccine hesitancy in several countries, it is paramount to continue the investigation of potentially modifiable factors that can help to reduce mortality. As this study showed that the professional experience of the medical team was associated with lower mortality, investing in training and senior supervision of the medical team could improve outcomes in emergency situations, such as the COVID-19 pandemic. Different training and organizational strategies could be employed, such as supervision from senior staff, the use of simulators for training, and implementing tele-strategies in the ICU, and the use of daily checklists and multidisciplinary rounds [42, 45, 47, 48].

Some pre-pandemic studies, including one in Brazilian ICUs, found an association between the implementation of clinical protocols in the ICU and mortality [10, 11, 45]. In the present study, even though the number of protocols implemented in ICUs was included in the multivariate analysis, this variable did not remain in the final model. We believe that could be because most hospitals in our cohort reported a high number of protocols implemented, hampering the analysis of a possible association in our sample. This same situation applies to the analysis of staff availability, with a high number of hospitals complying with the Brazilian recommendation guidelines [28]. In addition to that, the evidence from previous studies of an association of staff availability with mortality showed mixed results, and the optimal bed-to-staff ratio is yet to be determined [27, 46].

### Table 4: ICU-specific characteristics associated with in-hospital mortality

| Variables                          | N   | Bivariate models | Multivariate model |
|-----------------------------------|-----|------------------|--------------------|
|                                   |     | β* (CI 95%)      | p value            | β* (CI 95%)      | p value            |
| > 50% of intensivists             | 16  | −0.69 (−1.17; −0.20) | 0.005             | −0.59 (−0.98; −0.20) | 0.003             |
| > 10% medical residents           | 17  | 0.45 (0.12; 0.79)  | 0.008             | 0.40 (0.11; 0.68)  | 0.006             |
| > 50% intensivist nurses           | 15  | 0.15 (−0.32; 0.62) | 0.520             |                   |                   |
| > 50% redeployed physicians        | 16  | 0.15 (−0.36; 0.67) | 0.559             |                   |                   |
| > 50% redeployed nurses            | 15  | 0.19 (−0.41; 0.79) | 0.537             |                   |                   |
| < 10 protocols implemented        | 21  | −0.30 (−0.63; 0.04) | 0.080             | 0.03 (−0.34; 0.40) | 0.8635            |
| Bed to nurse ratio ≤ 10            | 19  | −0.10 (−0.84; 0.63) | 0.788             |                   |                   |
| Bed to nurse technician ≤ 2        | 19  | −0.23 (−0.63; 0.16) | 0.250             |                   |                   |
| Hospital admission protocol        | 22  | −0.18 (−0.66; 0.30) | 0.457             |                   |                   |
| ICU admission protocol             | 22  | 0.12 (−0.33; 0.57)  | 0.593             |                   |                   |
| Emergency contract of staff        | 20  | 0.35 (−0.14; 0.84)  | 0.157             | 0.08 (−0.40; 0.55) | 0.7519            |

*Estimates are reported in the logit scale of the in-hospital mortality. ICU intensive care unit; Analyses are adjusted by the proportion of high-risk patients.
Conclusion

In-hospital mortality varied significantly among Brazilian hospitals. Private-funded hospitals located in cities with high GDP per capita had lower mortality. In the ICU, a more experienced critical care medical team assisting COVID-19 patients were associated with lower mortality.

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Declarations

Conflict of interest  The author(s) declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

Human and animal rights statement  This study is in accordance with the Declaration of Helsinki. The study protocol was approved by the Brazilian National Commission for Research Ethics (CAAE: 30350820.5.1001.0008).

Ethical approval and consent to participate  This study followed the STROBE guidelines for reporting observational studies, and it is in accordance with the Declaration of Helsinki. The study protocol was approved by the Brazilian National Commission for Research Ethics (CAAE: 30350820.5.1001.0008). Individual informed consent was waived due to the severity of the pandemic situation and the use of de-identified data, based on medical chart review only.

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