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Impact of the local care environment and social characteristics on aggregated hospital fatality rate from COVID-19 in France: a nationwide observational study

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ABSTRACT

Objectives: We aimed to investigate possible differences in the aggregated hospital fatality rate from coronavirus disease 2019 (COVID-19) in France at the early phase of the outbreak and to determine whether factors related to population or healthcare supply before the pandemic could be associated with outcome differences.

Study design: This is a nationwide observational study including all French hospitals from January 24, 2020, to April 11, 2020.

Methods: We analyzed the aggregated hospital fatality rate. A Poisson regression was performed to investigate associations between characteristics pertaining to populational health, socio-economic context and local healthcare supply at baseline, and the chosen outcome.

Results: On April 11, 2020, a total number of 30,960 patients were hospitalized among the 3046 French healthcare facilities, including 6832 patients in the intensive care unit (ICU). A total of 8581 deaths due to COVID-19 had been recorded, with a median mortality rate per 10,000 people per department of 0.53 (interquartile range: 0.29–1.90). There were significant variations between the 95 French departments even after adjusting for outbreak inception ($P < 0.001$). After multivariable analysis, four factors were independently associated with a significantly higher aggregated hospital fatality rate: a higher ICU capacity at baseline (estimate = 1.47; $P = 0.00791$), a lower density of general practitioners (estimate = 0.95; $P = 0.0205$), a lower fraction of activity from the for-profit private sector (estimate = 0.99; $P < 0.001$), and the ratio of people older than 75 years (estimate = $0.91; P = 0.0023$).

Conclusions: The aggregated hospital fatality rate from COVID-19 in France seems to vary among geographic areas, with some factors pertaining to local healthcare supply being associated with the outcome.

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19 was confirmed divided by the total number of COVID-19 cases, seems to vary among countries. Italian reports have shown a case fatality rate ranging from approximately 7% to 10%, whereas other countries such as South Korea have observed much lower figures. Even if there is uncertainty due to variations in case recording, we lack definitive explanations for possible differences in case fatality rates between countries. The number of tests that could be made to screen and insulate patients has been raised as a possible factor contributing to differences. In addition, it is not known whether this outcome varies within a country. Several factors can likely explain differences such as the affected population profile, healthcare environment, and quality of care. There has been concern in France with regard to critical care capacity with respect to the probable high number of simultaneous severe cases during the outbreak peak. It has been estimated by the French Ministry of Health that there were approximately 5000 intensive care unit (ICU) beds in France yet with differences between regions. Estimates forecasted that this capacity would be exceeded.

Therefore, we sought to measure the aggregated hospital fatality rate from COVID-19 in France and to examine the association between populational and local healthcare supply characteristics and this outcome.

**Methods**

**Data sources**

We used official and publicly available sources to retrieve and gather the needed data: the Ministry of Health, the National Institute of Statistics and Economic Studies (Institut National de la Statistique et des Etudes Economiques), the Directorate for Research, Studies, Evaluation, and Statistics (Direction de la Recherche, des Études, des Évaluations et des Statistiques), the French Public Health Insurance (Assurance Maladie) that covers the entire population, Public Health France (Santé Publique France), and the National Institute for Demographic Studies (Institut National d’Études Démographiques). In each data source, the relevant data were collected for the most recent year available as already performed in another study.8

**France and the French population**

France is divided into administrative units, each corresponding to a defined territory. Those administrative units are called departments. There are 95 departments in what is called the metropolitan territory, i.e. excluding overseas departments. Those 95 metropolitan departments were chosen as a unit of analysis because they represent the smallest geographic unit for which the needed data were available. For each department, data regarding the total population, as well as age and gender characteristics, as measured in January 2020 were collected.

**Healthcare supply and care environment**

Data regarding care providers and local healthcare ecosystems were also collected as follows for each of the 95 departments (with the year of availability between brackets): total number of physicians (2017); physician rate per 100,000 people (2017), then divided into general practitioner rate per 100,000 people and specialist rate per 100,000 people (2017); dental surgeon rate per 100,000 (2017); nurse rate per 100,000 (2017); physiotherapist rate per 100,000 (2017); and pharmacist rate per 100,000 (2017). We also retrieved the number of hospital beds per 10,000 people, including surgery beds, medicine beds, obstetrical beds, physical medicine beds, psychiatry beds, and those in long-term care facilities (2017), as per a 2019 report from the French Ministry of Health, and the total number of adult intensive care beds in each department at baseline, i.e. before the outbreak (2020). Finally, the fraction of hospital care activity as measured by hospital days, performed by the for-profit private sector, was collected (2017).

**Health and wealth indicators**

For each department, the following health indicators were retrieved: overall mortality (2019), mortality beyond the age of 65 years (2019), infant mortality (2019), and prevalence of significant chronic condition as defined and fully covered by the national public health insurance (2017). For this latter indicator, prevalence was collected in an aggregated manner and by condition. For the purpose of the present study, only chronic conditions that have been reported in the literature to date to be possible risk factors for COVID–19 fatality were included, namely, diabetes mellitus, cancer, severe hypertension, and chronic obstructive pulmonary disease. We could not retrieve data regarding obesity because they are not recorded as such by the national public health insurance. The complete list of those conditions can be found in Supplemental Material. Because there is a well-established relationship between wealth and health, we also included wealth variables: unemployment rate (last trimester of 2019), median household income (2017), poverty rate (2017), and universal health coverage (2019), which is provided by the French state to people below a certain threshold of total purchasing power.

**Outcome measures**

Aggregated hospital-fatality rate was chosen as the study outcome (i.e. for each day of the study period, the number of hospital deaths divided by the number of admitted patients). We chose not to analyze case fatality rate because it would be unreliable in the French case. Indeed, France has not performed systematic or large SARS-CoV-2 testing, and the number of recorded cases has repeatedly been recognized as being orders of magnitude below the actual frequency. Conversely, all serious cases of suspected COVID-19 were required to be tested for confirmation. Hospitalized cases, whether in regular wards or ICUs, therefore represent a reliable denominator for calculation. For each day of the study period and in each of the 95 French departments, the number of hospitalized patients with COVID–19 and the number of patients with COVID–19 in ICUs were collected. In addition, for each day of the study sample, the cumulative number of COVID–19–related in-hospital deaths over the study period was collected.

**Statistical analysis**

To account for gaps in the outbreak start between areas, the time origin for each department was set to the first day wherein at least 10 deaths due to COVID–19 had been recorded in total. To investigate the relationship between our covariates and the selected outcome, a mixed-effects Poisson generalized linear regression was used. Models were adjusted for two fixed effects: the number of people living in the department, and the corrected day since the beginning which was coded as a third-order polynomial. To account for the hierarchical structure of our data, the department (grouping variable) was used as a random effect. Both a random intercept and random slope (for the corrected days since the beginning) were used. Any variable achieving a P-value <0.2 in the univariable analysis was proposed in the multivariable model. In this model, a backward selection based on P-values was used with a threshold of 0.2. Poisson’s model results are given as the exponent coefficient and thus indicate the multiplicative effect of
the variable on the death count (e.g. a value of two indicates that the variable doubles the death count). All tests were bilateral, and a \( P \)-value of 0.05 was retained for statistical significance. Issues such as aberrant or missing points were handled by linear interpolation. Analyses were performed using R 3.6.2 software and the lme4 package.

Results

Healthcare supply and social indicators in France

There were a total number of 3046 healthcare facilities (including public hospitals, not-for-profit private hospitals, and for-profit private hospitals) gathering 399,865 beds. The for-profit private sector represented 96,988 beds (24.3%), and after excluding psychiatry, physical and rehabilitation facilities, and long-term care facilities, it gathered 16,543,811 hospital days of activity from the for-profit private sector, and for-profit private hospitals, and for-profit private sector (estimate \( = 0.99; P < 0.001 \)) and the ratio of people older than 75 years (estimate \( = 0.91; P = 0.0023 \)). No health indicator was associated with our outcome in the multivariable analysis.

Discussion

The course of the outbreak in terms of hospitalizations, whether in regular wards or the ICU, as well as mortality, also varied among the departments. Four selected examples are presented in Fig. 3.

Univariate and multivariable analysis

The details of univariate and multivariable analyses are given in Table 1. After univariate analysis, eleven factors were included in the multivariable analysis. Apart from the population, four factors were independently associated with a significantly higher aggregated hospital fatality rate from COVID-19: a higher ICU capacity at baseline (estimate \( = 1.47; P = 0.00791 \)), a lower density of general practitioners (estimate \( = 0.95; P = 0.0205 \)), a lower fraction of activity from the for-profit private sector (estimate \( = 0.99; P < 0.001 \)), and the ratio of people older than 75 years (estimate \( = 0.91; P = 0.0023 \)). No health indicator was associated with our outcome in the multivariable analysis.

COVID-19 epidemic

The study included data from January 24, 2020 (first French case), to April 11, 2020. There were 15 missing data of 3467 data points in total (0.4%). On April 11, 2020, a total number of 30,960 COVID-19 epidemic patients were hospitalized, including 6832 in the ICU. A total of 8581 hospital deaths due to COVID-19 had been reported, with a median value of 28 deaths per department (0.4%). On April 11, 2020, a total number of 30,960 COVID-19 epidemic deaths in the current model.

Our study has several strengths. First, it is a nationwide analysis gathering exhaustive data from reliable sources. For most of the covariates, the year of availability was very recent, thereby limiting timeliness issues. In addition, the variables of interest are unlikely to significantly change across a relatively short period of time. Second, we collected a very diverse set of data with regard to demographics, populational health, wealth, and also characteristics of

Table 1

Univariate and multivariable analysis of factors associated with aggregated hospital fatality rate due to COVID-19 among the 95 departments in France until April 11, 2020.

| Variable                                | Observed value in France | Univariate analysis | Multivariable analysis |
|-----------------------------------------|--------------------------|---------------------|------------------------|
|                                         |                          | Estimate \( ^{a} \) | 95% CI                  | \( P \) | Estimate \( ^{a} \) | 95% CI | \( P \) |
| **Healthcare supply**                   |                          |                     |                        |       |                     |       |       |
| ICU beds for 10,000 persons             | 0.6 ± 0.3                | 1.34                | 0.99–1.83              | 0.061 | 1.47                | 1.11–1.96 | 0.0079 |
| Ward beds for 10,000 persons            | 10.9 ± 2.7               | 0.99                | 0.95–1.03              | 0.72  |                     |       |       |
| Doctors for 10,000 persons              | 30.5 ± 8.7               | 1.00                | 0.98–1.01              | 0.70  |                     |       |       |
| GP for 10,000 persons                   | 15.0 ± 2.7               | 0.95                | 0.91–1.00              | 0.033 | 0.95                | 0.91–0.99 | 0.0205 |
| Specialists for 10,000 persons          | 15.4 ± 6.7               | 1.00                | 0.98–1.02              | 0.71  |                     |       |       |
| Private sector (%)                      | 21.9 ± 11.4              | 0.98                | 0.97–0.99              | <0.001 | 0.99                | 0.98–0.99 | <0.001 |
| **Social variables**                    |                          |                     |                        |       |                     |       |       |
| Annual median income (k€)              | 20.4 ± 2.0               | 1.70                | 0.90–3.19              | 0.10  |                     |       |       |
| Poverty rate (%)                       | 14.4 ± 3.0               | 1.01                | 0.98–1.04              | 0.57  |                     |       |       |
| Unemployment rate (%)                  | 7.9 ± 1.6                | 0.99                | 0.93–1.06              | 0.76  |                     |       |       |
| Universal medical insurance (%)        | 1.52 ± 0.75              | 1.00                | 1.00–1.00              | 0.96  |                     |       |       |
| Population (thousands of inhabitants)  | 520.6 (265.5–1079.4)     | 1.34                | 1.09–1.64              | 0.035 | 1.02                | 1.00–1.05 | 0.0035 |
| Population older than 75 years (%)     | 10.8 ± 2.2               | 0.87                | 0.82–0.92              | <0.001 | 0.91                | 0.86–0.97 | 0.0023 |
| Percentage of population aged between 60 and 74 years | 18.8 ± 2.8 | 0.92 | 0.87–0.97 | 0.0012 | NS |
| Population density (inhb/km²)          | 565.8 ± 2425.1           | 1.00                | 1.00–1.00              | 0.0256 | NS |
| **Health variables**                    |                          |                     |                        |       |                     |       |       |
| Departmental mortality rate (%)        | 10.4 ± 2.3               | 0.91                | 0.85–0.97              | 0.0023 | NS |
| Infant mortality rate                  | 3.4 ± 0.8                | 1.22                | 1.07–1.39              | 0.0031 | NS |
| Mortality rate beyond the age of 65 years (%) | 37.3 ± 2.9 | 1.02 | 0.99–1.06 | 0.23 | NS |
| Diabetes mellitus (%)                  | 1.2 ± 0.9                | 1.24                | 1.01–1.51              | 0.036 | NS |
| Severe hypertension (%)                | 0.2 ± 0.2                | 1.49                | 0.64–3.51              | 0.36  | NS |
| Chronic obstructive pulmonary disease (%) | 0.2 ± 0.2 | 1.63 | 0.38–6.99 | 0.51 | NS |
| Oncologic disease (%)                  | 1.0 ± 0.8                | 1.16                | 0.89–1.51              | 0.28  | NS |

ICU, intensive care unit; CI, confidence interval; GP, general practitioner; COVID-19, coronavirus disease 2019; NS, non-significant.

\( ^{a} \) Estimates are exponent Poisson’s model coefficients and thus indicate the multiplicative effect on death counts.
care supply and local healthcare ecosystems. Populational health data were in particular critical to incorporate in the model because they are factors likely to influence the disease outcome. We had very fine health data beyond age, namely, prevalence of chronic conditions that have already been recognized as risk factors for the COVID-19 outcome.\textsuperscript{3,11,12} Third, we used a robust statistical model to analyze the data, namely, a Poisson linear model, as the variables were daily counts, and a mixed model, as the observed data were not independent (repeated measures within a department), which allows separate intercept and slopes for each department. In addition, time adjustment was made so as to align all departments on a similar basis and take into account timeliness issues.

Fig. 1. Daily mortality rate per 100,000 habitants due to COVID-19 among the 95 studied departments. (The blue line represents the overall mean, with confidence interval in gray coded as a third-order polynomial, and the four red lines represent the selected departments in Fig. 3.) COVID-19, coronavirus disease 2019. (For interpretation of the references to colour in this figure legend, the reader is referred to the Web version of this article.)

Fig. 2. Map of the cumulative number of deaths from COVID-19 in each French department based on the (A) total number of habitants and (B) number of patient days of hospitalization. COVID-19, coronavirus disease 2019.

Our findings have implications. Critical care capacity has been a matter of concern with regard to the COVID-19 outbreak. It has been predicted that France did not have enough ICU beds to absorb all of the patients in need along several days or weeks. Yet we found no evidence that less ICU beds at baseline in a given area were associated with a worst outcome. Conversely, we found that areas with an initial higher density of ICU beds were associated with a higher aggregated hospital fatality rate. It may be that critically ill patients were more often transferred from rural areas or smaller facilities to more comprehensive facilities. It also should be underlined that hospitals have anticipated the outbreak.
progression by resetting their organization and creating new ICU capacity in other wards. We could not measure actual ICU beds at a given time because those data were not consistently reported. This will need further investigation. We also found that areas in which the density of general practitioners was higher were associated with a better outcome. Although this should be interpreted with caution, one may hypothesize that general practitioners played a critical role in the epidemic, through adequate orientation of patients with COVID-19 to hospitals while maintaining others at home. Finally, it is remarkable that social and wealth factors were not associated with the chosen outcome. The relationship between wealth and health has been consistently documented by a huge body of literature. Again, we cannot certainly explain why herein departments with more deprivation were not associated with a higher aggregated hospital fatality rate, yet it should be recalled that France has a very protective social system with a great safety net. Perhaps, it helped to attenuate the social risk in the case of the epidemic.

This study has limitations. First, as an observational study, it cannot establish definitive causality. We cannot exclude the possibility that our results might be confounded by factors that were not measured. In particular, we cannot rule out that criteria for admitting patients were different among areas and that some hospitals had more deprivation were not associated with a higher aggregated hospital fatality rate, yet it should be recalled that France has a very protective social system with a great safety net. Perhaps, it helped to attenuate the social risk in the case of the epidemic.

In conclusion, we found significant differences in the aggregated hospital fatality rate across French areas over the early period of the COVID-19 outbreak. Several factors pertaining to local healthcare supply were associated with a worst outcome, such as a higher ICU capacity at baseline and a lower involvement from the private sector as well as a lower density of general practitioners. These findings clearly deserve further investigation with hospital- or patient-level data and over a longer follow-up.

**Author statements**

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Ethical approval

This study used administrative and anonymized data that do not permit any reidentification. Use of such anonymized data complies with the European General Data Protection Regulation and does not require any approval from an ethics committee as per the French law.

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None.

Competing interests

All authors have completed and submitted the ICMJE Form for Disclosure of Potential Conflicts of Interest. No conflict of interest related to the current work was reported. Outside the submitted work, J.-D.Z. reports being an advisor for several consulting firms in link with pharmaceutical industry (Oliver Wyman and Roland Berger). He also reports speaking fees from a manufacturer’s professional association, consulting fees from IQVIA, Ferring, Pierre Fabre, AbbVie, AstraZeneca, Biogen, Boehringer Ingelheim, Takeda, and Johnson & Johnson. He is a personal investor in approximately 20 digital companies, medical device companies, or biotech companies and as a limited partner in an investment fund. He reports being a founding partner of Inato, a company involved in clinical research and whose customers are pharmaceutical companies. J.H.L. reports fees from Ethicon, Takeda, and MD Start, invitation to a medical congress by Biom’up. He is a consultant for SafeHeal.

Author contributions

J.-D.Z. had full access to all of the data in the study and takes responsibility for the integrity of the data and the accuracy of the data analysis. J.-D.Z. contributed to concept, design and acquisition. M.F. and J.H.L. contributed to statistical analysis. J.-D.Z., M.F., and J.H.L. contributed to analysis and interpretation of data. J.-D.Z. contributed to drafting of the manuscript. J.-D.Z., M.F. and J.H.L. contributed to critical revision of the manuscript for important intellectual content. J.-D.Z. contributed to administrative, technical, or material support.

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