Letter to the Editor

COVID-19 mortality in ICUs associated with critical care staffing

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To the Editor

Coronavirus disease 2019 (COVID-19) has been around for over a year since December 2019, and the global outlook is not optimistic. Because of its high transmissibility and high mortality, management of the COVID-19 pandemic has become a major challenge for health systems globally, especially for critical care.

However, the level of demand for physicians and nurses in intensive care units (ICUs) to manage critical patients with highly infectious diseases (such as COVID-19) is still unclear [1, 2]. Care for critically ill patients with highly communicable diseases may require more intensive care personnel than for non-communicable diseases. Therefore, we investigated ICU staffing in this cross-sectional survey from January 18 to March 14, 2020. A total of 58 ICUs were invited to participate, including 41 ICUs from Hubei Province and 17 ICUs from the other 11 provinces or municipalities in China. All ICUs included were only applicable for COVID-19 adult patients. In addition, a descriptive analysis of the reinforcements for care of critically ill patients was carried out and the epidemiological data on COVID-19 in Hubei Province was overlaid with this survey. No personal data was analyzed in this study. The data used in this study are considered a part of the public health outbreak investigation. Informed consent and approval was waived by the Institutional Review Board.

A total of 2635 COVID-19 patients were admitted to 58 ICUs with 1340 ICU beds. The number of physicians per bed and nurses per bed in these ICUs were 1.1 (0.7, 1.8) and 3.5 (2.3, 4.2), respectively. The average age of patients was 62.0 years (56.7 years, 65.0 years), and the proportion of male patients was 24.0% (12.0%, 43.0%). The overall mortality and 95% confidence interval (CI) was 23.6% (22.0%, 25.3%). Mortality in these ICUs ranged from 0.0% to 67.3%. This was divided into low mortality group (n = 19, mortality < 7.7%), medium mortality group (n = 20, mortality 7.7–21.2%) and high mortality group (n = 19, mortality > 21.2%). The differences in patient characteristics in the three groups were analysed (Table 1). The average age of the middle mortality and high mortality groups was significantly higher than that of the low mortality group (p = 0.04). The proportion of male patients, patients receiving mechanical ventilation (MV), or continuous renal replacement therapy (CRRT), and use of vasopressors also showed significant differences among the three groups. The ICU staffing is shown...
in Table 1. The higher mortality group showed more ICU beds (p = 0.022) and more ICU admissions (p < 0.001) than the low mortality group. The proportion of nurses per bed in the high mortality group was significantly lower than that in the low and middle mortality groups (p = 0.017).

To explore the relationship between the mortality of COVID-19 patients and ICU staffing, two probit regression models were established. Potential confounding factors such as mean age, proportion of males, use of MVs or CRRT as non-invasive ventilation, IMV invasive mechanical ventilation, ECMO extracorporeal membrane oxygenation, CRRT continuous renal replacement therapy, ICU intensive care unit in Table 1. The higher mortality group showed more ICU beds (p = 0.022) and more ICU admissions (p < 0.001) than the low mortality group. The proportion of nurses per bed in the high mortality group was significantly lower than that in the low and middle mortality groups (p = 0.017).

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Table 2. Factors associated with risk-adjusted ICU mortality in the probit regression models

| Model/Variables                        | Estimate | 95% CI            | Z value | P value |
|----------------------------------------|----------|-------------------|---------|---------|
| Physicians per bed model               |          |                   |         |         |
| Physicians per bed                     | -0.188   | (-0.307, -0.069)  | -3.093  | 0.002   |
| Average age (y)                        | 0.017    | (0.005, 0.030)    | 2.715   | 0.007   |
| Proportion of males (%)                | 0.003    | (0, 0.006)        | 2.042   | 0.041   |
| MV proportion (%)                      | 0.017    | (0.012, 0.021)    | 7.382   | <0.001  |
| Receiving CRRT (%)                     | -0.004   | (-0.010, 0.001)   | -1.305  | 0.132   |
| Use of vasopressors (%)                | 0.003    | (-0.001, 0.006)   | 1.501   | 0.133   |
| Inpatients per bed per month           | 0.202    | (0.088, 0.315)    | 3.474   | 0.001   |
| Nurses per bed model                   |          |                   |         |         |
| Nurses per bed                         | -0.069   | (-0.110, -0.027)  | -3.232  | 0.001   |
| Average age (y)                        | 0.015    | (0.002, 0.028)    | 2.282   | 0.022   |
| Proportion of males (%)                | 0.004    | (0.001, 0.007)    | 2.746   | 0.006   |
| MV proportion (%)                      | 0.017    | (0.013, 0.022)    | 7.554   | <0.001  |
| Receiving CRRT (%)                     | -0.003   | (-0.009, 0.002)   | -1.128  | 0.259   |
| Use of vasopressors (%)                | 0.003    | (0, 0.006)        | 1.728   | 0.084   |
| Inpatients per bed per month           | 0.159    | (0.062, 0.256)    | 3.199   | 0.001   |

CI confidence interval, MV mechanical ventilation, CRRT continuous renal replacement therapy

Figure 1. Estimation of the requirement (95% CI) for critical care staffing for the given probability of mortality. The requirements for physician and nurse staffing for different probability of mortality in the participating ICUs were estimated using probit regression models. Horizontal axis: probability of mortality. Vertical axis: estimated number of physicians per bed (a), and nurses per bed (b), and 95% CI. Data are presented as median (interquartile range). CI confidence interval

(Trial) issued by the Ministry of Health of China in 2009 requires that the ratio of ICU beds to hospital beds should be 2–8% [6]. However, intensive care comprised 8% of total bed numbers in the United States in 1991 [7]; compared with 1–2% in the United Kingdom [8]. A review showed that the mean ratio of ICU beds to hospital beds was 1.5% from 15 low-income countries [9]. In fact, the problem in Wuhan is that there are not enough physicians and nurses, and the number of ICU beds is estimated to be insufficient.

Importantly, our findings further demonstrated that the trend in daily death rate decreased when reinforcement teams were introduced into designated hospitals in Hubei Province (Figure 2); while the number of patients and the proportion of professional ICU staffing were comparable, and mortality was negatively correlated with the ratio of physicians or nurses per bed in 58 ICUs, especially nationwide (Table 2). These findings confirmed that ICU staffing was one of the important determinants for mortality in ICUs during the epidemic of a highly infectious disease.

Our aim was to estimate the number of ICU staff needed to reduce mortality in ICUs of hospitals designated for COVID-19. Based on the increasing data, the ICU design and management guidelines recommend that each bed be equipped with 0.8–1 physicians and 2.5–3 nurses [3, 10]. Meanwhile, there was limited evidence on the requirements of ICU staffing for a highly infectious disease. Management of COVID-19 patients may require more ICU staffing than management of ordinary critically ill patients. Based on probit regression models, the estimated values of physicians (nurses) per bed were 5.7 (15.8), 3.8 (10.6), 2.5 (7.0), and 1.5 (4.2), respectively, while ICU mortality rates were 5%, 10%, 15%, and 20%, respectively (Figure 2).

In conclusion, our results showed a significant correlation between critical care staffing and the mortality of critically ill
patients during the early COVID-19 epidemic in China. The COVID-19-specific ICUs required a higher number of intensive care personnel to reduce mortality. Finally, increasing the number of ICU beds is required in the development of ICUs in Hubei Province.

Abbreviations
CI: confidence interval; CRRT: continuous renal replacement therapy; ECMO: extracorporeal membrane oxygenation; HFNC: high-flow nasal cannula oxygen therapy; ICU: intensive care unit; IMV: invasive mechanical ventilation; MV: mechanical ventilation; NIV: noninvasive ventilation

Funding
None.

Authors’ contributions
JX, LZ and SL drafted the manuscript and conducted the analyses. PM and LZ created the idea of the study. PM critically reviewed the manuscript and agreed with the final version and findings. All the authors read and approved this manuscript.

Conflicts of interest
None declared.

Ethics approval and consent to participate
No personal data was analyzed in this study. The data used in this study are considered a part of the public health outbreak investigation. Informed consent and approval was waived by the Institutional Review Board of Peking University Third Hospital.

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Figure 2. Reinforcements of critical care staffing versus critically ill patient deaths during the outbreak of COVID-19 in Hubei Province. Data represents the number of critically ill cases with COVID-19 who remained in designated hospitals (green line) reported on the websites of the National Health Commission of the People’s Republic of China (http://www.nhc.gov.cn) and the Health Commission of Hubei Province (HCHP, http://wjw.hubei.gov.cn) from January 18 to March 14, 2020. Each spot represents the reported data by 0:00 o’clock every day. The brown line shows the new deaths per day; and the blue line shows the daily death rate (%). The red columns represent four reinforcements of critical care staffing labeled with the numbers of ICU physicians and nurses. ICU intensive care unit, P physicians, N nurses