Who is going to turn on the ventilators?
Quem vai ligar os ventiladores?

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ABSTRACT

Objective: To analyze the COVID-19 pandemic in Brazil, a continental-sized country, considered as an emerging economy but with several regional nuances, focusing on the availability of human resources, especially for intensive care units. Methods: The database of the National Registry of Health Facilities was accessed. Healthcare professionals in the care of COVID-19 were georeferenced. We correlated the number of professionals with the parameters used by the World Health Organization. According to the Brazilian Intensive Care Medicine Association, we correlated the data for adult intensive care unit beds in each state with the number of professionals for each ten intensive care unit beds. The number of professionals, beds, and cases were then organized by state. Results: The number of physicians per 100 thousand inhabitants followed the World Health Organization recommendations; however, the number of nurses did not. The number of intensivists, registered nurses, nurse technicians specialized in intensive care, and respiratory therapists, necessary for every ten intensive care beds, was not enough for any of these professional categories. A complete team of critical care specialists was available for 10% of intensive care unit beds in Brazil. Conclusion: There is a shortage of professionals for intensive care unit, as we demonstrated for Brazil. Intensive care physical resources to be efficiently used require extremely specialized human resources; therefore, planning human resources is just as crucial as planning physical and structural resources.

Keywords: COVID-19; Coronavirus infections; SARS-CoV-2; Health personnel; Intensive care units

RESUMO

Objetivo: Analisar a pandemia da COVID-19 no Brasil, um país de dimensões continentais, considerado uma economia emergente, mas com inúmeras diferenças regionais, abordando a disponibilidade de recursos humanos, especialmente para unidades de terapia intensiva. Métodos: Foi acessado o banco de dados do Cadastro Nacional de Estabelecimentos de Saúde. Os profissionais de saúde que atuavam nos cuidados para COVID-19 foram georreferenciados. O número de profissionais foi correlacionado com os parâmetros utilizados pela Organização Mundial da Saúde. De acordo com a Associação de Medicina Intensiva Brasileira, correlacionaram-se os dados de leitos de terapia intensiva adulta em cada unidade federativa com o número de profissionais para cada dez leitos de terapia intensiva. Os números de profissionais, leitos e casos foram, então, organizados por unidade federativa. Resultados: O número de médicos por 100 mil habitantes seguiu as recomendações da Organização Mundial da Saúde; mas não o número de enfermeiras. O número de intensivistas, enfermeiros, técnicos de enfermagem especializados em terapia intensiva e fisioterapeutas respiratórios, necessário a cada dez leitos de terapia intensiva, não foi suficiente para nenhuma dessas categorias profissionais. Uma equipe completa desses especialistas esteve disponível para 10% dos leitos de terapia intensiva do Brasil. Conclusão: Há carência de profissionais para unidade de terapia intensiva, como demonstrado no Brasil. Os recursos físicos da terapia intensiva, para serem usados de forma eficiente, precisam de recursos humanos extremamente especializados; portanto, o planejamento de recursos humanos é tão crucial quanto o planejamento de recursos físicos e estruturais.

Descritores: COVID-19; Infecções por coronavírus; SARS-CoV-2; Pessoal de saúde; Unidades de terapia intensiva
INTRODUCTION

The coronavirus disease 2019 (COVID-19) is a viral respiratory disease caused by severe acute respiratory syndrome coronavirus 2 (SARS-Cov-2), which was first detected, in Wuhan, China, in December 2019. Patients may be classified as asymptomatic or symptomatic, and the clinical presentation comprises a broad range of unspecified symptoms, such as fever, dry cough, dyspnoea, headache, sputum production, loss of smell and taste, hemoptysis, myalgia, fatigue, nausea, vomiting, diarrhoea, and abdominal pain. The ongoing epidemic of COVID-19 has spread very quickly, and currently, almost all countries have cases of COVID 19, totalling up 20,391.697 cases, and 743,724 deaths worldwide on December 8, 2020. Of the total cases 13,368.262 (65.6%) already have an outcome: 12,624.538 (94.4%) recovered and were discharged, but 743,724 people died (5.6%).(1)

Infection with SARS-Cov-2 can cause severe illness, and between 12% and 15% of all cases identified as positive for SARS-Cov-2 require admission to the intensive care unit (ICU).(2)

Although the percentage of COVID-19 patients that require ICU is not substantial, when this percentage is analysed as absolute numbers, the number of patients is sufficient to burden ICUs in the different health systems all over the world.(3,4)

Throughout this pandemic, much is said about the need for intensive care beds, mechanical ventilation devices, dialysis devices, and monitors.(3-7) But for these physical resources to be effectively used, there is a need for extremely specialized human resources.

Since the beginning of this century, the World Health Organization (WHO) has warned about the increasing deficit of health workers.(8) It is essential to point out that during a pandemic, human resources are highly susceptible to being infected and, therefore, the workplaces in ICUs are opened.(9)

OBJECTIVE

To analyze the COVID-19 pandemic in Brazil, a continental-sized country, considered as an emerging economy but with several regional nuances, focusing on the availability of human resources, especially for intensive care units.

METHODS

This study was conducted at the Escola Paulista de Medicina of Universidade Federal de São Paulo, São Paulo (SP), Brazil, in May and June 2020. To analyse the availability of human resources for ICUs, in the context of the COVID-19 pandemic in Brazil, we gathered data on health professionals from the database of the Cadastro Nacional de Estabelecimentos de Saúde (CNES).(10) Next, we organized the professionals of interest delivering care for COVID-19 patients as follows: physicians, intensive care physicians, registered nurses, intensive care registered nurses, nurse technicians and intensive care nurse technicians, physical therapists, and respiratory therapists. Each of these professionals was then georeferenced, according to the city of their registration.

The number of professionals was initially correlated with the parameters, when available, used by the WHO Global Health Observatory Data Repository to compare different countries.(11,12)

The data for adult ICU beds in each federation unit (physical structure) were obtained from the Ministry of Health. In the sequence, we related them for each state, with the number of professionals for each ten ICU beds, as per the parameters of the Brazilian Intensive Care Medicine Association (AMIB - Associação de Medicina Intensiva Brasileira), which establish one intensivist, two registered nurses, five nurse technicians, and one respiratory therapist.(13)

The number of registered cases and deaths resulting from COVID-19 was also provided by the Ministry of Health and divided by states.

In the end, with the number of professionals, beds, and cases organized by locality, we identified in each state the care conditions for COVID-19, focusing mainly on ICUs.

With the current spread of the infection to the nonmetropolitan areas, we organized a scenario considering the human resources necessary to assist COVID-19 patients, excluding cases and professionals from the metropolitan regions.

RESULTS

There were 3,109,630 (1,477.30 cases per 100 thousand inhabitants) cases of COVID-19 in Brazil, up to August 12, 2020, and the absolute number of deaths was 103,026 (48.90 deaths per 100 thousand inhabitants) (Figures 1A and 1B).

The total number of ICU beds for adults before the pandemic was 32,031 (15.24 beds per 100 thousand inhabitants). At the beginning of the pandemic, there was an expansion of the number of ICU beds. The Ministry of Health provided them along with the Health
Secretariats of the states and cities, and the number of beds increased to 48,875 (23.26 beds per 100 thousand inhabitants) (Figure 2). Thus, there were 28.69 cases of COVID-19 per adult ICU beds in Brazil (Figure 3).

The total number per 100 thousand inhabitants of physicians, registered nurses, nurse technicians, and physical therapists in Brazil is, 196.84, 127.40, 245.10, and 39.71, respectively (Table 1). While the number of physicians was in accordance with the WHO recommendations, the number of nurses was not. Even if we gather registered nurses and nurse technicians (nursing staff), the figure would not be appropriate. When
Figure 3. COVID-19 cases per intensive care unit beds in Brazil and its states

Table 1. Rates of healthcare professionals in Brazil and its states

| State               | Number of physicians per 100,000 inhabitants | Intensive care physicians per 10 ICU beds | Number of intensivists per 100,000 inhabitants | Intensive care nurses per 10 ICU beds | Number of nurse technicians per 100,000 inhabitants | Intensive care nurse technicians per 10 ICU beds | Respiratory physical therapists per 10 ICU beds | Pulmonologists per 10 ICU beds | Infectious disease physicians per 10 ICU beds |
|---------------------|---------------------------------------------|------------------------------------------|-----------------------------------------------|--------------------------------------|---------------------------------------------------|-----------------------------------------------|----------------------------------------|--------------------------------|----------------------------------------|
| Rondônia            | 142.4                                       | 0.546                                    | 108.1                                         | 0.029                                | 252.0                                             | 1.063                                          | 0.057                                  | 0.230                                  | 0.082                                  |
| Acre                | 108.4                                       | 0.089                                    | 118.9                                         | 0.089                                | 249.1                                             | NR                                             | 0.089                                  | 0.268                                  | 1.607                                  |
| Amazonas            | 111.3                                       | 1.045                                    | 102.6                                         | 2.180                                | 249.4                                             | 0.991                                          | 0.018                                  | 0.234                                  | 1.009                                  |
| Roraima             | 136.2                                       | 0.667                                    | 129.1                                         | NR                                   | 381.3                                             | NR                                             | NR                                     | 0.667                                  | 2.222                                  |
| Pará                | 85.3                                        | 0.505                                    | 75.5                                          | 0.488                                | 194.2                                             | 0.334                                          | 0.094                                  | 0.308                                  | 0.625                                  |
| Amapá               | 95.3                                        | 0.337                                    | 109.6                                         | NR                                   | 342.0                                             | 0.112                                          | 0.112                                  | 0.337                                  | 0.787                                  |
| Tocantins           | 145.8                                       | 0.136                                    | 177.6                                         | NR                                   | 381.1                                             | 0.182                                          | 0.045                                  | 0.227                                  | 0.500                                  |
| Maranhão            | 80.9                                        | 0.390                                    | 106.1                                         | 0.554                                | 225.5                                             | 0.543                                          | 0.011                                  | 0.261                                  | 0.239                                  |
| Piauí               | 125.7                                       | 0.475                                    | 112.3                                         | 0.614                                | 215.1                                             | 0.931                                          | 0.178                                  | 0.277                                  | 0.881                                  |
| Ceará               | 125.9                                       | 0.595                                    | 114.6                                         | 0.269                                | 147.2                                             | 0.044                                          | 0.044                                  | 0.294                                  | 0.589                                  |
| Rio Grande do Norte | 151.6                                       | 0.563                                    | 111.6                                         | 0.488                                | 228.9                                             | 0.600                                          | 0.113                                  | 0.238                                  | 0.750                                  |
| Paraíba             | 154.9                                       | 1.194                                    | 149.0                                         | 0.067                                | 216.6                                             | 1.806                                          | 0.060                                  | 0.448                                  | 0.536                                  |
| Pernambuco          | 157.2                                       | 0.675                                    | 117.4                                         | 0.511                                | 241.2                                             | 0.335                                          | 0.293                                  | 0.229                                  | 0.423                                  |
| Sergipe             | 162.3                                       | 0.251                                    | 101.7                                         | 0.084                                | 157.6                                             | 0.111                                          | 0.056                                  | 0.334                                  | 0.891                                  |
| Bahia               | 134.8                                       | 0.863                                    | 124.1                                         | 0.715                                | 218.7                                             | 0.847                                          | 0.016                                  | 0.405                                  | 0.574                                  |
| Minas Gerais        | 221.0                                       | 0.307                                    | 128.1                                         | 0.383                                | 283.4                                             | 0.962                                          | 0.445                                  | 0.307                                  | 0.619                                  |
| Espírito Santo      | 223.5                                       | 0.820                                    | 128.5                                         | 0.179                                | 320.6                                             | 0.955                                          | NR                                    | 0.395                                  | 0.679                                  |
| Rio de Janeiro      | 248.6                                       | 0.918                                    | 139.8                                         | 0.294                                | 265.6                                             | 0.451                                          | 0.059                                  | 0.459                                  | 0.680                                  |
| São Paulo           | 260.0                                       | 0.671                                    | 143.1                                         | 0.183                                | 226.0                                             | 0.632                                          | 0.048                                  | 0.372                                  | 0.947                                  |
| Paraná              | 209.1                                       | 0.329                                    | 128.2                                         | 0.545                                | 228.8                                             | 0.373                                          | 0.044                                  | 0.219                                  | 0.570                                  |
| Santa Catarina      | 221.0                                       | 0.269                                    | 127.9                                         | 0.446                                | 290.1                                             | 0.715                                          | 0.064                                  | 0.361                                  | 0.673                                  |
| Rio Grande do Sul   | 243.6                                       | 0.565                                    | 138.2                                         | 0.552                                | 353.2                                             | 1.064                                          | 0.031                                  | 0.858                                  | 0.702                                  |
| Mato Grosso do Sul  | 195.4                                       | 0.491                                    | 127.8                                         | 0.203                                | 249.3                                             | 0.321                                          | 0.017                                  | 0.203                                  | 0.677                                  |
| Mato Grosso         | 148.3                                       | 0.549                                    | 123.0                                         | 0.294                                | 270.1                                             | 0.447                                          | 0.064                                  | 0.217                                  | 0.600                                  |
| Goiás               | 169.2                                       | 0.348                                    | 101.0                                         | 0.283                                | 230.5                                             | 0.319                                          | 0.015                                  | 0.348                                  | 0.703                                  |
| Distrito Federal    | 338.2                                       | 1.269                                    | 196.2                                         | 0.363                                | 349.4                                             | 0.253                                          | 0.065                                  | 0.408                                  | 0.408                                  |
| Brazil              | 196.8                                       | 0.634                                    | 127.4                                         | 0.368                                | 245.1                                             | 0.621                                          | 0.100                                  | 0.360                                  | 0.711                                  |

ICU: intensive care unit; NR: not reported data.
we correlated the number of specialized professionals, *i.e.*, intensivists, registered nurses and nurse technicians specialized in intensive care, besides respiratory therapists, required for every ten intensive care beds, we found a scenario in which, for any of these professional categories, there are not enough professionals. In Brazil, the health care providers to ten beds ratio were 0.634, 0.368, 0.621 and 0.100 for intensivists, ICU registered nurses, nurse technicians specialized in intensive care, and respiratory therapists, respectively (Table 1). Thus, only 10% of ICU beds in Brazil had a complete team of specialists to care for these patients (Table 2).

This situation got worse when we took into account the spreading of the infection to nonmetropolitan areas. When we excluded the metropolitan regions of the state capital cities, the nonmetropolitan areas of Brazil already had a higher number of cases than the metropolitan areas (52.5%), while during this research, the number of deaths was lower (36.5%) (Figure 4). We had 1,632,812 cases (1,345.88 cases per 100 thousand inhabitants) and 37,608 deaths (30.99 deaths per 100 thousand inhabitants) (Figures 1C and 1D).

Before the pandemic, the nonmetropolitan areas of Brazil had 12,280 ICU beds for adults (10.12 beds for every 100 thousand inhabitants). After the availability of emergency ICU beds, there were 18,743 ICU beds for adults (15.45 beds for every 100 thousand inhabitants) (Figure 5). Thus, until August 12, 2020, we had 87.12 cases of COVID-19 for each ICU bed for adults in the nonmetropolitan areas of Brazil (Figure 6).

**Table 2. Number of complete teams of specialists in Brazil and its states to treat COVID-19 critically-ill patients**

| State               | ICU beds assisted by intensive care physicians | ICU beds assisted by intensive care nurses | ICU beds assisted by intensive care nurse technicians | ICU beds assisted by respiratory therapists | Total number of ICU beds | Total number of complete ICU teams (human resources) | Complete teams per ICU beds (%) |
|---------------------|-----------------------------------------------|------------------------------------------|------------------------------------------------------|--------------------------------------------|--------------------------|-----------------------------------------------------|--------------------------------|
| Rondônia            | 190                                           | 5                                        | 74                                                   | 20                                        | 348                      | 5                                                   | 1                              |
| Acre                | 10                                            | 5                                        | 0                                                    | 10                                        | 112                      | 0                                                   | 0                              |
| Amazonas            | 580                                           | 605                                      | 110                                                  | 10                                        | 555                      | 10                                                  | 2                              |
| Roraima             | 30                                            | 0                                        | 0                                                    | 0                                         | 45                       | 0                                                   | 0                              |
| Pará                | 590                                           | 285                                      | 78                                                   | 110                                       | 1,168                    | 78                                                  | 7                              |
| Amapá               | 30                                            | 0                                        | 2                                                    | 10                                        | 89                       | 0                                                   | 0                              |
| Tocantins           | 30                                            | 0                                        | 8                                                    | 10                                        | 220                      | 0                                                   | 0                              |
| Maranhão            | 340                                           | 255                                      | 100                                                  | 10                                        | 921                      | 10                                                  | 1                              |
| Riauí               | 240                                           | 155                                      | 94                                                   | 90                                        | 505                      | 90                                                  | 18                             |
| Ceará               | 950                                           | 215                                      | 14                                                   | 70                                        | 1,598                    | 14                                                  | 1                              |
| Rio Grande do Norte | 450                                           | 195                                      | 128                                                  | 90                                        | 800                      | 90                                                  | 11                             |
| Paraíba             | 800                                           | 220                                      | 242                                                  | 40                                        | 670                      | 40                                                  | 6                              |
| Pernambuco          | 1,770                                         | 670                                      | 176                                                  | 770                                       | 2,824                    | 176                                                 | 7                              |
| Alagoas             | 180                                           | 75                                       | 98                                                   | 20                                        | 520                      | 20                                                  | 4                              |
| Sergipe             | 90                                            | 15                                       | 8                                                    | 20                                        | 359                      | 8                                                   | 2                              |
| Bahia               | 2,150                                         | 890                                      | 422                                                  | 40                                        | 2,491                    | 40                                                  | 2                              |
| Minas Gerais        | 1,460                                         | 866                                      | 916                                                  | 2,120                                     | 4,763                    | 865                                                 | 18                             |
| Espírito Santo      | 1,100                                         | 120                                      | 256                                                  | 0                                         | 1,341                    | 0                                                   | 0                              |
| Rio de Janeiro      | 5,620                                         | 900                                      | 552                                                  | 360                                       | 6,120                    | 360                                                 | 6                              |
| São Paulo           | 8,670                                         | 1,185                                    | 1,632                                                | 620                                       | 12,917                   | 620                                                 | 5                              |
| Paraná              | 900                                           | 745                                      | 204                                                  | 120                                       | 2,736                    | 120                                                 | 4                              |
| Santa Catarina      | 380                                           | 315                                      | 202                                                  | 90                                        | 1,412                    | 90                                                  | 6                              |
| Rio Grande do Sul   | 1,280                                         | 625                                      | 482                                                  | 70                                        | 2,266                    | 70                                                  | 3                              |
| Mato Grosso do Sul  | 290                                           | 60                                       | 38                                                   | 10                                        | 591                      | 10                                                  | 2                              |
| Mato Grosso         | 430                                           | 115                                      | 70                                                   | 50                                        | 783                      | 50                                                  | 6                              |
| Goiás               | 480                                           | 195                                      | 88                                                   | 20                                        | 1,379                    | 20                                                  | 1                              |
| Distrito Federal    | 1,960                                         | 280                                      | 78                                                   | 100                                       | 1,544                    | 78                                                  | 5                              |
| Brazil              | 31,000                                        | 8,995                                    | 6,072                                                | 4,880                                     | 48,875                   | 4,880                                                | 10                             |

ICU: intensive care unit.
Figure 4. Map of Brazil showing the metropolitan region of each state

Figure 5. Adult intensive care unit beds per 100 thousand inhabitants in Brazil and its states, excluding metropolitan regions
There was less availability of physicians, registered nurses, nurse technicians and physical therapists in the nonmetropolitan areas of Brazil, accounting for every 100 thousand inhabitants, 147.1, 111.5, 224.0 and 37.2, respectively (Table 3).

Table 3. Rate of healthcare specialists in Brazil and its states, excluding the metropolitan areas

| State             | Number of physicians per 100,000 inhabitants | Intensive care physicians per ten ICU beds | Number of nurses per 100,000 inhabitants | Intensive care nurses per ten ICU beds | Number of nurse technicians per 100,000 inhabitants | Intensive care nurse technicians per ten ICU beds | Respiratory physical therapists per ten ICU beds | Pulmonologists per ten ICU beds | Infectious disease physicians per ten ICU beds |
|-------------------|--------------------------------------------|------------------------------------------|------------------------------------------|--------------------------------------|-----------------------------------------------|-----------------------------------------------|-----------------------------------------------|---------------------------------|-----------------------------------------------|
| Rondônia          | 108.8                                      | 0.410                                    | 89.7                                     | NR                                  | 179.2                                          | 0.410                                          | 0.164                                          | 0.246                                          | 0.410                                          |
| Acre              | 57.9                                       | NR                                       | 89.8                                     | NR                                  | 208.0                                          | NR                                              | NR                                             | 0.323                                          | 0.968                                          |
| Amazonas          | 48.0                                       | NR                                       | 86.9                                     | NR                                  | 176.8                                          | 2.500                                          | NR                                             | NR                                             | 5.000                                          |
| Roraima           | 56.0                                       | NR                                       | 111.5                                    | NR                                  | 330.7                                          | NR                                              | NR                                             | NR                                             | NR                                             |
| Pará              | 47.3                                       | 0.196                                    | 66.1                                     | 0.342                               | 176.4                                          | 0.489                                          | 0.024                                          | 0.049                                          | 0.440                                          |
| Amapá             | 51.2                                       | NR                                       | 85.8                                     | NR                                  | 307.9                                          | NR                                              | NR                                             | NR                                             | NR                                             |
| Tocantins         | 107.4                                      | 0.086                                    | 136.3                                    | NR                                  | 325.5                                          | 0.354                                          | NR                                             | 0.086                                          | 0.442                                          |
| Maranhão          | 56.4                                       | 0.313                                    | 86.6                                     | 0.521                               | 179.9                                          | 0.391                                          | NR                                             | 0.156                                          | 0.234                                          |
| Piauí             | 73.5                                       | 0.262                                    | 92.9                                     | NR                                  | 148.3                                          | 0.715                                          | NR                                             | 0.070                                          | 0.493                                          |
| Ceará             | 74.3                                       | 0.132                                    | 96.9                                     | 0.066                               | 133.8                                          | 0.017                                          | 0.033                                          | 0.149                                          | 0.182                                          |
| Rio Grande do Norte | 90.7                                      | 0.109                                    | 97.5                                     | 0.290                               | 183.0                                          | 0.254                                          | 0.072                                          | 0.036                                          | 0.072                                          |
| Paraíba           | 113.2                                      | 0.471                                    | 133.0                                    | 0.168                               | 190.3                                          | 0.404                                          | NR                                             | 0.404                                          | 0.539                                          |
| Pernambuco        | 88.5                                       | 0.520                                    | 88.6                                     | 0.669                               | 170.3                                          | 0.588                                          | 0.242                                          | 0.204                                          | 0.297                                          |
| Alagoas           | 77.0                                       | 0.200                                    | 84.1                                     | 0.100                               | 122.1                                          | 0.200                                          | 0.050                                          | 0.150                                          | 0.200                                          |
| Sergipe           | 58.7                                       | 0.238                                    | 71.0                                     | 0.476                               | 95.8                                           | NR                                              | NR                                             | NR                                             | 0.238                                          |
| Bahia             | 88.2                                       | 0.580                                    | 101.6                                    | 0.328                               | 183.3                                          | 0.732                                          | NR                                             | 0.404                                          | 0.454                                          |
| Minas Gerais      | 172.1                                      | 0.243                                    | 117.8                                    | 0.236                               | 253.0                                          | 0.858                                          | 0.181                                          | 0.291                                          | 0.465                                          |
| Espírito Santo    | 162.4                                      | 0.373                                    | 105.7                                    | 0.000                               | 244.5                                          | 0.132                                          | NR                                             | 0.241                                          | 0.395                                          |
| Rio de Janeiro    | 220.7                                      | 0.511                                    | 125.5                                    | 0.432                               | 283.2                                          | 0.535                                          | 0.031                                          | 0.346                                          | 0.456                                          |
| São Paulo         | 230.9                                      | 0.438                                    | 131.5                                    | 0.230                               | 250.9                                          | 0.609                                          | 0.047                                          | 0.384                                          | 0.922                                          |
| Paraná            | 165.1                                      | 0.136                                    | 129.2                                    | 0.842                               | 215.4                                          | 0.458                                          | 0.068                                          | 0.149                                          | 0.532                                          |
| Santa Catarina    | 200.7                                      | 0.132                                    | 122.0                                    | 0.406                               | 282.0                                          | 0.775                                          | 0.038                                          | 0.340                                          | 0.539                                          |
| Rio Grande do Sul | 195.9                                      | 0.177                                    | 129.1                                    | 0.473                               | 337.4                                          | 0.583                                          | 0.017                                          | 0.465                                          | 0.541                                          |
| Mato Grosso do Sul | 130.2                                      | 0.159                                    | 111.4                                    | 0.319                               | 199.9                                          | 0.757                                          | 0.040                                          | 0.080                                          | 0.558                                          |
| Mato Grosso       | 113.2                                      | 0.218                                    | 107.2                                    | 0.062                               | 246.4                                          | 0.031                                          | 0.156                                          | 0.125                                          | 0.405                                          |
| Goiás             | 119.5                                      | 0.256                                    | 94.0                                     | 0.085                               | 217.7                                          | 0.455                                          | 0.028                                          | 0.199                                          | 0.540                                          |
| Brazil            | 147.1                                      | 0.319                                    | 111.5                                    | 0.327                               | 224.1                                          | 0.579                                          | 0.068                                          | 0.296                                          | 0.585                                          |

ICU: intensive care unit; NR: not reported data.
In nonmetropolitan areas of Brazil, for every ten ICU beds for adults, there was, respectively, 0.319 and 0.327, 0.579, and 0.068, intensivists and ICU registered nurses and nurse technicians specialized in intensive care, and respiratory therapists (Table 3). Only 7% of ICUs in the nonmetropolitan areas of Brazil had a complete ICU staff to care for patients (Table 4).

Table 4. Number of complete team of specialists in Brazil and its states to treat COVID-19 critically-ill patients, excluding the metropolitan areas

| State              | ICU beds assisted by intensive care physicians | ICU beds assisted by intensive care nurses | ICU beds assisted by intensive care nurse technicians | ICU beds assisted by respiratory therapists | Total number of ICU beds | Total number of complete ICU teams (human resources) | Complete teams per ICU beds (%) |
|--------------------|-----------------------------------------------|-------------------------------------------|-----------------------------------------------------|-------------------------------------------|--------------------------|-----------------------------------------------------|---------------------------------|
| Rondônia           | 50                                            | 0                                         | 10                                                  | 20                                        | 122                      | 0                                                   | 0                               |
| Acre               | 0                                             | 0                                         | 0                                                   | 0                                         | 31                       | 0                                                   | 0                               |
| Amazonas           | 0                                             | 0                                         | 6                                                   | 0                                         | 12                       | 0                                                   | 0                               |
| Roraima            | 0                                             | 0                                         | 0                                                   | 0                                         | 0                        | 0                                                   | 0                               |
| Pará               | 80                                            | 70                                         | 40                                                  | 10                                        | 409                      | 10                                                  | 2                               |
| Amapá              | 0                                             | 0                                         | 0                                                   | 0                                         | 5                        | 0                                                   | 0                               |
| Tocantins          | 10                                            | 0                                         | 8                                                   | 0                                         | 113                      | 0                                                   | 0                               |
| Maranhão           | 120                                           | 100                                        | 30                                                  | 0                                         | 384                      | 0                                                   | 0                               |
| Piauí              | 40                                            | 0                                         | 22                                                  | 0                                         | 142                      | 0                                                   | 0                               |
| Ceará              | 80                                            | 20                                         | 2                                                   | 20                                        | 605                      | 2                                                   | 0                               |
| Rio Grande do Norte| 30                                            | 40                                         | 14                                                  | 20                                        | 276                      | 14                                                  | 5                               |
| Paraíba            | 140                                           | 25                                         | 24                                                  | 0                                         | 297                      | 0                                                   | 0                               |
| Pernambuco         | 280                                           | 180                                        | 60                                                  | 130                                       | 538                      | 60                                                  | 11                              |
| Alagoas            | 40                                            | 10                                         | 8                                                   | 10                                        | 200                      | 8                                                   | 4                               |
| Sergipe            | 10                                            | 10                                         | 0                                                   | 0                                         | 42                       | 0                                                   | 0                               |
| Bahia              | 460                                           | 130                                        | 124                                                 | 0                                         | 793                      | 0                                                   | 0                               |
| Minas Gerais       | 710                                           | 345                                        | 502                                                 | 530                                       | 2,925                    | 345                                                 | 12                              |
| Espírito Santo     | 170                                           | 0                                          | 12                                                  | 0                                         | 456                      | 0                                                   | 0                               |
| Rio de Janeiro     | 660                                           | 275                                        | 136                                                 | 40                                        | 1,272                    | 40                                                  | 3                               |
| São Paulo          | 2,340                                         | 615                                        | 650                                                 | 250                                       | 5,339                    | 250                                                 | 5                               |
| Paraná             | 220                                           | 680                                        | 148                                                 | 110                                       | 1,616                    | 110                                                 | 7                               |
| Santa Catarina     | 140                                           | 215                                        | 164                                                 | 40                                        | 1,058                    | 40                                                  | 4                               |
| Rio Grande do Sul  | 210                                           | 280                                        | 138                                                 | 20                                        | 1,184                    | 20                                                  | 2                               |
| Mato Grosso do Sul | 40                                            | 40                                         | 38                                                  | 10                                        | 251                      | 10                                                  | 4                               |
| Mato Grosso         | 70                                            | 10                                         | 2                                                   | 50                                        | 321                      | 2                                                   | 1                               |
| Goiás              | 90                                            | 15                                         | 32                                                  | 10                                        | 352                      | 10                                                  | 3                               |
| Brazil             | 5,980                                         | 3,060                                      | 2,170                                                | 1,270                                     | 18,743                   | 1,270                                                | 7                               |

ICU: intensive care unit.

II DISCUSSION

Natural catastrophes, like floods and earthquakes, disasters like the bomb explosion in Beirut, or even bigger catastrophes produced by us, such as wars can sharply increase the number of severely-ill patients.\(^{14}\) Fortunately, these are uncommon situations. However, the beginning of a pandemic, such as the one we are facing with COVID-19, caused us to face a situation in which several patients develop respiratory or other organ dysfunction in a short time,\(^{15}\) and the major challenge of providing universal, timely, and affordable access to intensive care has become even more difficult.

Multiple adverse factors have emerged, such as some patients presenting with very severe disease, which we know little about it, and the consequent massive use of physical and human resources. Of especial concern is the work overload on the front line team, and the possibility of worsening this situation due to some team members getting infected and consequent absenteeism.\(^{16}\)
Who is going to turn on the ventilators?

However, most studies published only considered the number of hospital beds and equipment, relegating the availability of trained professionals to provide critical care much needed to critically ill patients with COVID-19 to a secondary level.\(^\text{2,4,6,7,17}\)

Nevertheless, as we could demonstrate with this study, planning human resources is just as crucial as planning physical and structural resources.\(^\text{16}\) The pandemic generated an urgent need for data on the number and qualification of health professionals that perform several tasks, and who have become crucial at this moment, especially to deliver care to severely-ill patients.

To the best of our knowledge, this is the first study that assesses the availability of human resources for the treatment of critically-ill COVID-19 patients. We analysed data from Brazil, a continental-sized country, with significant regional differences and a large population affected by COVID-19. However, we believe that this is not a problem inherent only to Brazil, but to most countries affected by the pandemic.\(^\text{18}\)

The WHO has warned in recent years about the \textit{deficit} of healthcare workers, and this may be a limiting factor to achieve the health-related 2030 Sustainable Development Goals.\(^\text{8,19}\) The WHO was unable to predict this epidemiological situation occurring ten years before the evaluation of the sustainable development goals.\(^\text{19}\)

When considering the number of healthcare professionals, we demonstrated that the number of physicians and nursing professionals is in line with the WHO parameters. If we consider only registered nurses, we find that there are fewer of these professionals per 100 thousand inhabitants than the parameter suggested by the WHO. Nonetheless, when we evaluate the number of professionals outside the metropolitan areas, we find that the vast majority (13 out of 16) of states in the North and Northeast regions of Brazil, have fewer physicians than recommended by WHO. Concerning the nursing team, 18 out of 27 states do not have enough professionals. If we analyse only nurses, no state has enough number of these professionals.

The analysis considering professionals specialized in intensive care shows a very adverse situation. No state has enough professionals, of any category, whether in the metropolitan or nonmetropolitan areas. This finding was true to the number of beds that existed or, even worse, to the number of beds that were provided to meet the demand generated by the pandemic. According to our study, with the current number of professionals with declared qualifications, in the databases consulted, to work in ICUs, only 10\% of total ICU beds would have a complete team. Thus, providing the appropriate number of professionals with proper training, especially for the vast nonmetropolitan areas of Brazil, is a great challenge. It is important to note that we use the parameter of the ratio of professionals per ten ICU beds provided by AMIB.\(^\text{13}\) However, ratio or even the level of care to be provided per patient, varies widely among different countries, because either there is staff shortage, or the policymakers do not agree there is an established need for professionals per bed.\(^\text{20}\)

The quantity and specialization of the team are essential. As stated by Knaus et al., in the last century, in environments such as ICUs, the team’s specialization and the ability of these professionals to work in unison in the care of patients has direct impact on the outcome of patients.\(^\text{21}\) Although the use of invasive technologies, such as mechanical ventilation, renal replacement therapy, or even extracorporeal membrane oxygenation (ECMO) is crucial, they alone are not enough to provide the best care to critically-ill patients.\(^\text{20,21}\)

Undoubtedly, the lack of ICU beds claimed many lives during this pandemic.\(^\text{5}\) The lack of access to the ICU beds puts patients at risk for delaying admission to the ICU and implementation of essential therapeutic measures, in addition to causing premature discharge and cancellation of invasive procedures.\(^\text{6}\) However, the availability of ICU beds without sufficient and adequately trained personnel also puts patients at risk.\(^\text{2}\)

Among the limitations of this study, we must mention the data sources. There may be inaccuracies regarding the number of professionals specialized in intensive care, since it is almost certain that many of the physicians identified in the database as providers of intensive care are not intensivists, but rather hospitalists. On the other hand, the data used represent the professionals who are effectively working at the ICUs. Moreover, we did not assess the training of this workforce. There is also an inaccuracy (underreporting) in the number of cases and deaths by COVID-19, in Brazil.\(^\text{22}\)

One should also note the calculations were carried out not taking into account the working and rest hours these specialized professionals must have, or already have, as provided by the law. Another factor that we did not consider was the number of ICU workers who were infected by SARS-COV2, and removed from duty shifts. Hence, the \textit{deficit} of professionals for ICUs may be greater than we have demonstrated.
CONCLUSION

There is a shortage of professionals for intensive care units, as we have shown in relation to Brazil. However, the expansion of intensive care is probably necessary to deal with some underlying problems of the various health systems, such as improper primary care, an aging population, and more complex and high-risk medical therapies, in addition to possible natural catastrophes, disasters, armed conflicts and outbreaks of infectious diseases. Therefore, governments and public policymakers, as well as hospital administrators, must be aware and organized to increase availability of intensive care unit beds. At the same time, they must pay attention not only to infrastructure and supplies, but also to intensive care unit professionals, in their training and the management of this essential resource. Otherwise, who will turn on the ventilators?

AUTHORS’ CONTRIBUTION

Marcelo Cunio Machado Fonseca: was responsible for study conception and design, acquisition of data, interpretation of data and critical revision. Gabriela Tannus Branco de Araújo, Fulvio Alexandre Scorza and Paulo Sérgio Lucas da Silva: were responsible for study conception and design, interpretation of data and critical revision. Teresa Raquel de Moraes Andrade and Daniela Farah: were responsible for study conception and design, acquisition of data, analysis and interpretation of data and drafting of the manuscript. Dayan Sansone: was responsible for study conception and design, acquisition of data, analysis and interpretation of data and drafting of the manuscript.

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