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Human resources and medical supplies consumption during the COVID-19 pandemic: a single-center study

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Background: In the face of the unexpected coronavirus disease 2019 (COVID-19) pandemic, every country has struggled with insufficient human resources and medical supplies. This study aims to provide the statistical information necessary for discussing how to model stockpiles of medical resources.
Methods: This study was conducted at the Hallym University Kangnam Sacred Heart Hospital, in South Korea. The study duration was 2 weeks, centered on March 16, 2022, when the number of daily confirmed patients with COVID-19 in Korea peaked. The number of human resources was obtained by counting the number of healthcare workers using CCTV. Drug prescriptions and medical device usage were obtained from electronic medical records.
Results: In total, 117 inpatients and 26,485 outpatients were managed at this hospital during the 2-week study period. Daily visits were highest among nurses in all units, followed by doctors and radiology technicians. The mean daily consumption of personal protective equipment (PPE) per bed was 4.3 sets in the intensive care unit (ICU), 1.8 in the semi-ICU, and 1.4 in the ward. Despite the four-fold difference in the number of patients, there was no statistically significant difference between the two wards in the number of daily visits. Drug prescription rates were higher among inpatients than at-home patients.
Conclusions: The higher the COVID-19 severity, the higher the consumption of PPE per patient. Among healthcare workers, nurses had the highest number of inpatient treatment visits for COVID-19. To efficiently utilize, PPE, structures containing more isolation beds in a single negative pressure isolation system would be preferred.

Keywords: COVID-19; Infections; Personal protective equipment

Introduction

In the face of the unexpected coronavirus disease 2019 (COVID-19) pandemic, every country was significantly impacted by insufficient human resources and medical supplies [1-4]. This was also the case in the Republic of Korea, and the need to prepare for a possible recurrence of COVID-19 is largely agreed upon by healthcare workers who were involved in treating patients, particularly during the early period of the chaotic epidemic.

During the COVID-19 pandemic, unprecedented global demand and severe supply chain disruptions affected many health systems that could not provide adequate personal protective equipment (PPE) to front-line healthcare workers [5,6]. Over time, these problems were exacerbated by the lack of data on PPE consumption. Modeling research for the next pandemic should be actively conducted [7-11]. However, available local data for the calculation of neces-

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sary materials are insufficient. Additionally, although the problem of excessive labor of healthcare workers has been identified, it is difficult to find data that accurately describe how much human resources are required in proportion to the patient population.

This study aims to provide the statistical information necessary for discussing stockpile modeling of medical supplies and human resources.

Methods

Ethical statements: This study was approved by the Institutional Review Board (IRB) of Hallym University Kangnam Sacred Heart Hospital (IRB No. 2022-07-010), and the requirement for informed consent was waived.

This study was conducted at Kangnam Sacred Heart Hospital, a 650-bed hospital in Yeongdeungpo-gu, Seoul, South Korea. The hospital was the only university hospital in charge of the treatment of COVID-19 inpatients and outpatients, with an administrative district population of 376,000. We recorded the situation for 2 weeks (March 10–23, 2022), centered on March 16th, when the number of daily confirmed patients with COVID-19 in Korea peaked at 621,000. There were no empty beds daily during the assessment period. As a result, 117 inpatients and 26,485 outpatients were managed at the hospital during the 2-week study period.

1. Types of the isolation rooms

On admission, patients with COVID-19 were classified into three groups according to severity (oxygen demand): ward (room air O_2 nasal 4 L/min), semi-intensive care unit (ICU) (O_2 facial mask 5–10 L/min), and ICU (high flow nasal canular [HFNC]–mechanical ventilator [MV]). The ICU had eight beds and was divided into two negative pressure isolation systems, each with four beds. The semi-ICU had 12 beds, which were all included in one negative pressure isolation system. The ward had 25 beds and was divided into two negative pressure isolation systems: one with five beds and the other with 20 beds. This is shown in Fig. 1.

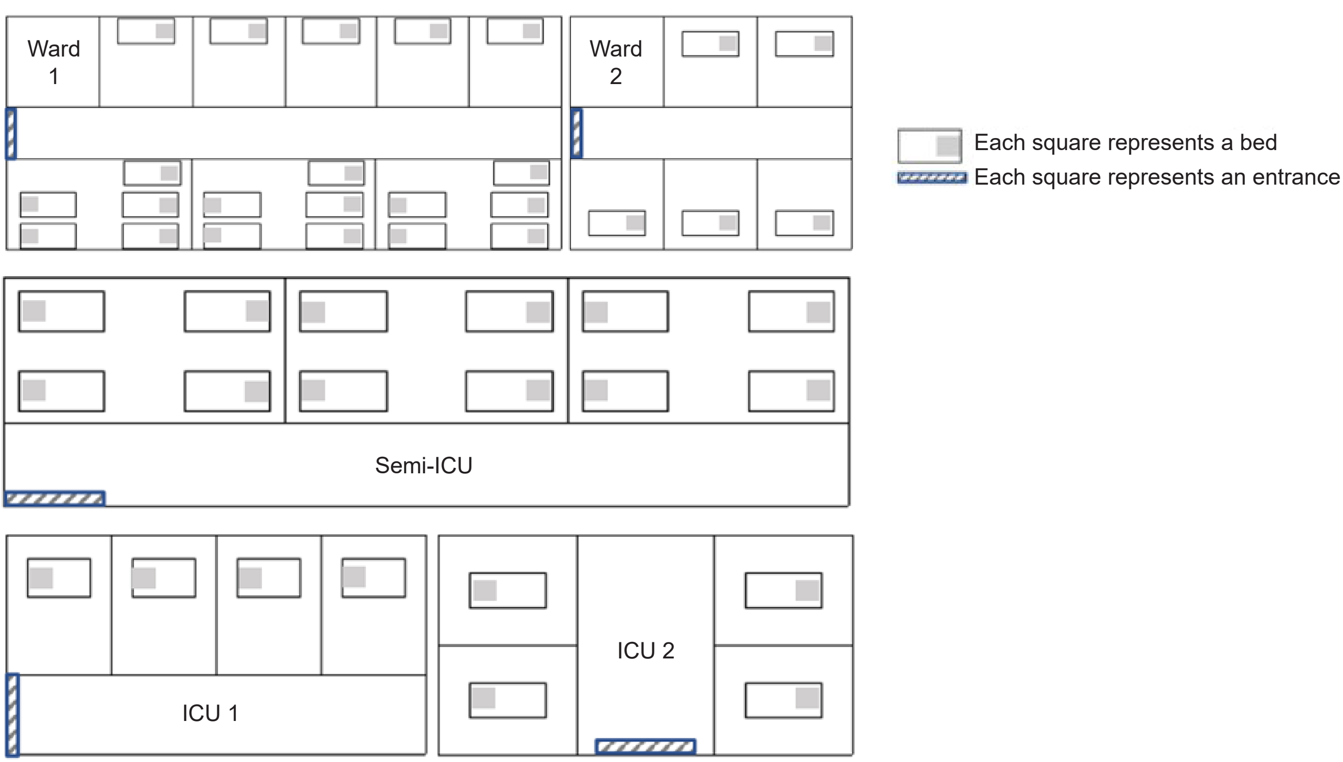

Fig. 1. Various types of isolation units. ICU, intensive care unit.

2. At-home care for outpatients

As the number of COVID-19 patients in Korea surged, at-home care was introduced [12]. In Korea, COVID-19 was designated as a class 1 legal infectious disease, meaning that all confirmed patients must be reported to public health authorities and quarantined for a certain period. Public health center officials interviewed all patients who were positive for COVID-19 to determine whether at-home care or hospitalization was appropriate. Patients who could be treated at home and provided consent to the public health center were registered as at-home care patients at our institution.

A total of 16 nurses monitored at-home care patients. Monitoring was carried out twice a day, and for this, ten and three nurses were assigned, respectively. Four doctors prescribed the necessary medication according to the symptoms of the patients. Doctors were also divided twice a day, with one person assigned to each. Overall, the institution managed up to 2,614 patients daily during the study period.

3. Regular components of the PPE

When entering and exiting a confined space belonging to the same negative pressure isolation system, a healthcare worker wore one set of PPE when entering the space and removed the PPE when leaving the space. In other words, one set of PPE was used per healthcare worker, even when multiple patients were attended to, once they were in the same negative pressure isolation system. Therefore, the number of visits by healthcare workers could be interpreted as equal to the number of PPE sets used. One set of PPE comprised four items following the national PPE wearing guidelines (1: face shield or goggles, 2: N95 mask, 3: a pair of gloves, 4: isolation gown) [3].

4. Investigated medical supplies and human resources

1) Human resources

The quantity of human resources was obtained by counting the number of healthcare workers entering and exiting each negative pressure isolation unit using the CCTV installed in each corridor of the negative pressure isolation units. Healthcare workers were classified as nurses, doctors, radiology technicians, and sanitation workers. Since most patients present with respiratory symptoms, it is important to be careful about the high risk of infection due to aerosol formation. The ward was cleaned by sanitation workers when the previous patient was discharged and was empty before the next patient was admitted. Cleaning the ICU and semi-ICU was performed by nurses, not by sanitation workers.

2) Drugs

Through electronic medical records, drug usage was investigated by counting the number of prescriptions. Drug selection was performed following Korean COVID-19 treatment guidelines [3]. Therefore, remdesivir, dexamethasone, and enoxaparin were administered to inpatients, and nirmatrelvir-ritonavir was administered to at-home care patients. For both inpatients and at-home patients, symptom control-related drugs, including levodropropizine, ambroxol, acetaminophen, and naproxen, were used.

3) Medical devices

The medical devices investigated included HFNC, MV, continuous renal replacement therapy (CRRT), and extracorporeal membrane oxygenation (ECMO). We investigated the number of patients using these devices and the days each medical device was used by patients in isolation ICUs during the study period.

5. Statistical analysis

Continuous variables are presented as mean. Non-categorical variables were tested using the Mann-Whitney *U* test. Statistical significance was set at $p<0.05$. All statistical analyses were performed using SPSS version 27 (IBM Corp.).

Results

1. Number of treatment visits by healthcare workers

A total of 117 inpatients and 26,485 outpatients were managed at this hospital during the 2-week study period. Of the 117 inpatients, 20 were treated in the ICU and 32 in the semi-ICU. Table 1 shows the mean number of visits per day for each isolation unit. The number of daily visits was the highest among nurses in all units, followed by doctors and radiology technicians.

The mean number of total daily ICU visits was 14.9 times for ICU 1 and 19.1 times for ICU 2. That is, a mean of 34 PPEs were consumed per day in the ICUs with a total of eight beds. The mean number of visits to the semi-ICU per

Table 1. Mean number of visits per day for each isolation unit

Isolation unit (bed count)	Nurses	Doctors	Radiology technicians	Total
ICU 1 (4)	11.8	2.1	1.0	14.9
ICU 2 (4)	12.0	5.2	1.9	19.1
Semi-ICU (12)	14.9	4.6	2.0	21.5
Ward 1 (20)	11.7	5.1	1.4	18.2
Ward 2 (5)	12.4	4.1	0.6	17.1

ICU, intensive care unit.

day was 14.9 times for nurses, 4.6 times for doctors, and 2.0 times for radiology technicians, requiring 21.5 sets of PPE.

For ease of comparison, the mean daily consumption of PPE was divided by the number of beds in each unit. The mean daily consumption of PPE per bed was 4.3 sets in ICU, 1.8 sets in the semi-ICU, and 1.4 sets in the ward. Fig. 2 shows the consumption by each healthcare worker classification. For nurses, the mean daily consumption of PPE was 2.97 sets for ICU, 1.24 sets for semi-ICU, and 0.97 sets for the ward. The higher the severity, the greater the consumption of PPE per bed (ICU-semi-ICU $p<0.001$, semi-ICU-ward $p=0.004$, ICU-ward $p<0.001$).

As mentioned earlier, the ward was further divided into two types, wards 1 and 2, with 20 and five beds, respectively. This is shown in Fig. 3. The daily mean number of visits was 18.2 times and 17.1 times in wards 1 and 2, respectively. Compared to the four-fold difference in the number of patients, there was no statistical difference between the two wards in the number of visits per day (18.2 vs. 17.1, $p=0.285$).

2. Medical supplies consumption

Table 2 shows medication consumption during the study period. Remdesivir, dexamethasone, and enoxaparin were prescribed to 100%, 75%, and 60% of patients in the ICU, respectively, which showed higher prescription rates than those in the semi-ICU and ward. Remdesivir, dexamethasone, and enoxaparin were prescribed to 96.9%, 65.6%, and 21.9% of patients in the semi-ICU, and 76.9%, 35.4%, and 36.9% of patients in ward, respectively. Drug prescription rates for symptom control, such as levodropropizine, ambroxol, acetaminophen, and naproxen, were 5.6%, 2.5%, 4.2%, and 1.3% in at-home patients, respectively, which showed lower than in inpatients. In the ward, the prescription rates of levodropropizine, ambroxol, acetaminophen, and naproxen were 30.8%, 6.2%, 12.3%, and 4.6%, respectively. The proportion of at-home patients receiving the oral antiviral drug nirmatrelvir-ritonavir was 0.4%. However, since the drugs were not administered throughout the patients' treatment period, Table 2 also shows the mean number of prescriptions per day to facilitate the calculation of drug consumption. The number of times each drug was prescribed over a 2-week period was divided by 14. In the ICU, which consisted of a total of 8 beds, a total of 20 patients were hospitalized over a 2-week period, and remdesivir was prescribed 4.1 times, dexamethasone 6 times, and enoxaparin 5 times on mean per day, respectively. During a 2-week period, a total of 26,485 patients were treated as at-home care, and nirmatrelvir-ritonavir was prescribed a mean of 7.3 times, levodropropizine 105 times, ambroxol 47.7 times, acetaminophen 79.7 times, and naproxen 25 times per day for them, respectively.

During the study period, 20 patients were admitted to the ICU. Table 3 shows the consumption of medical devices. Thirteen of them used the HFNC for a mean of 9.7 days per patient; 10 used the MV for a mean of 13.1 days; seven used the CRRT for a mean of 10.1 days; and one used the ECMO for 16 days.

Discussion

This report provides data for modeling to prepare for future COVID-19 pandemics, by recording the exact number of medical supplies used and the need for human resources. Presenting the COVID-19 PPE stockpiling paper surveyed by a single institution in Australia, the study prospectively audited data from 1 to 30 April 2020 [13]. In the ward-managed group, 40 inpatient days were randomly selected, and in the ICU, 3 consecutive days for a single patient were audited. The mean number of staff-to-patient interactions in a 24-hour period was presented; 11.9 for ward-managed patients, and 30.0 for ICU-managed patients. In compar-

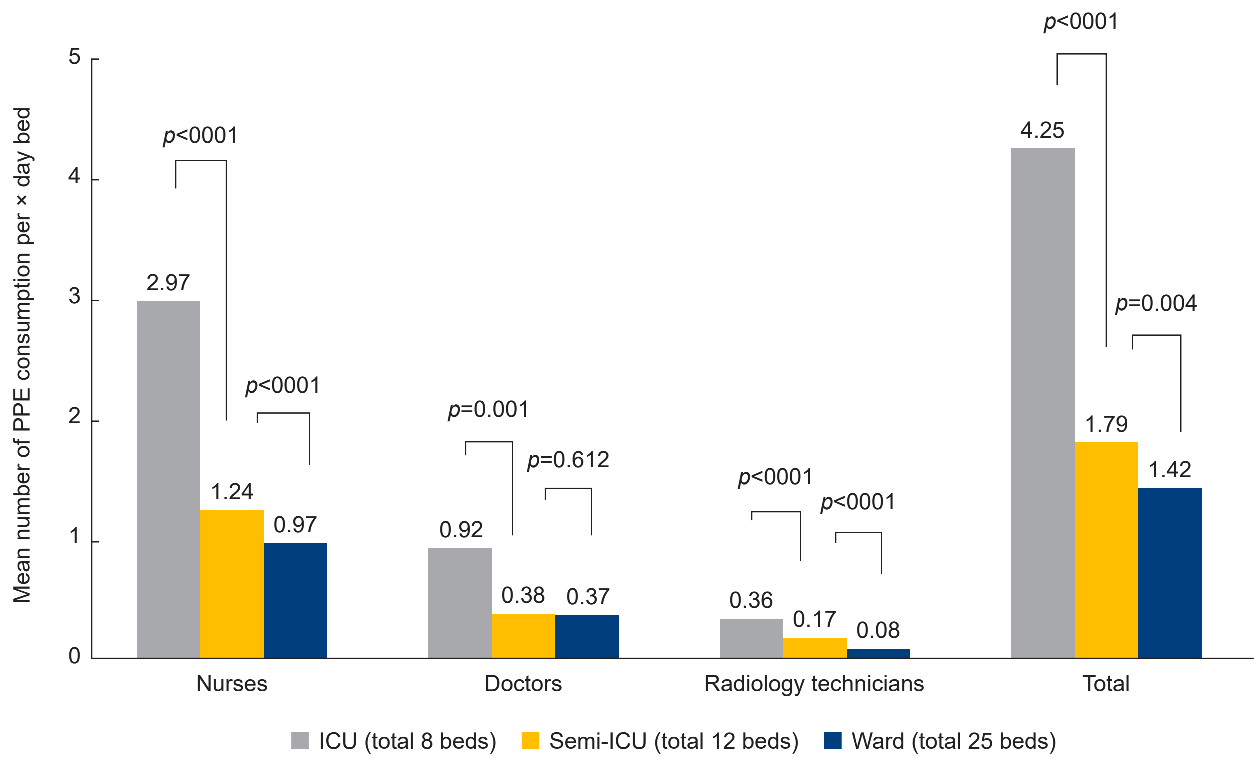

Fig. 2. Mean personal protective equipment (PPE) consumption per day by bed. Mean number of visits per day 2 weeks divided by the number of beds in each unit. Except for the number of visits by doctors between the semi-ICU and ward, as the severity of patients increases, the number of visits by healthcare workers per patient increases with a $p<0.05$, which is statistically significant. ICU, intensive care unit.

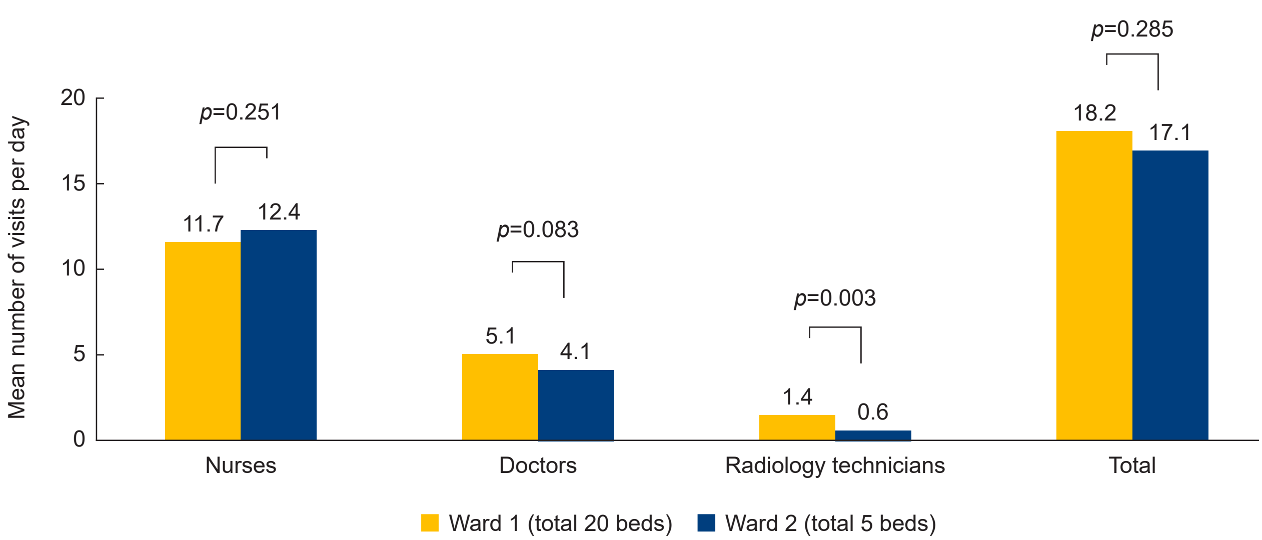

Fig. 3. Mean number of visits per day for each unit of ward. Ward 1 has 20 beds, while ward 2 has five beds. Since the p-value for the number of visits by doctors and nurses between wards is greater than 0.05, there is no statistically significant difference in the mean number of visits between wards 1 and 2. This indicates that they were the same despite the differences in the number of patients.

Table 2. Number of medications prescribed per day

	Total number of patients over 2 wk	Remdesivir	Dexamethasone	Enoxaparin	Nirmatrelvir-ritonavir	Levodro-propizine	Ambroxol	Acetaminophen	Naproxen
ICU	20	4.1 (100)	6 (75.0)	5 (60.0)	-	0.5 (15.0)	0.4 (5.0)	-	-
Semi-ICU	32	7.8 (96.9)	7.5 (65.6)	2 (21.9)	-	0.8 (12.5)	0.8 (6.3)	0.5 (3.1)	0.2 (6.3)
Ward	65	12.4 (76.9)	4.5 (35.4)	6.4 (36.9)	-	3.6 (30.8)	1.2 (6.2)	1.1 (12.3)	0.9 (4.6)
Outpatient	26,485	-	-	-	7.3 (0.4)	105 (5.6)	47.7 (2.5)	79.7 (4.2)	25.0 (1.3)

Values are presented as the mean number of prescriptions per day (prescription ratio relative to the total number of patients).
ICU, intensive care unit

Table 3. Number of patients and days of using medical devices among the 20 patients in the intensive care unit

	HFNC	MV	CRRT	ECMO
Mean number of days per patient	9.8	13.1	10.1	16
Number of patients	13	10	7	1

HFNC, high-flow nasal cannula; MV, mechanical ventilator; CRRT, continuous renal replacement therapy; ECMO, extracorporeal membrane oxygenation.

ison, our study not only included a larger total number of patients, but also presented human resource data broken down by job type.

In our study, the total number of visits per day was the highest among nurses, followed by doctors and radiology technicians. The number of visits increased as COVID-19 severity increased. As the 20-bed ward had more departments involved than the 5-bed ward, the number of doctor visits was higher in the 20-bed ward. However, compared to the four-fold difference in the number of patients, there was no statically significant difference in the mean number of visits between wards 1 and 2. Therefore, isolating a large number of patients in one unit in a COVID-19 isolation system can increase the efficiency of healthcare workers and reduce the use of PPE.

This report also provides data on the consumption of medications and medical devices during the COVID-19 pandemic and the proportion of patients using each medical supply, broken down by unit. Few people wanted nirmatrelvir-ritonavir. We believe this may have been due to limitations such as fear of side effects and contraindications with concomitant medications.

This study had some limitations. First, this data was estimated from one single center. Additionally, we only monitored contact with patients whose diagnoses were confirmed, and data from potentially infected patients were excluded. However, the hospital collected data on 117 inpatients and 26,485 at-home patients during the 2-week study period by performing its role as a government-designated COVID-19 hospital. Additionally, these data are for the period with the highest number of COVID-19 confirmed cases in the Republic of Korea.

Second, since the ICU was divided into two negative pressure systems, it is possible that the calculated number of visits and use of PPE were more than when they were configured in a single negative pressure system. For an accurate comparison according to severity, it is necessary to compare units with the same number of beds in a single negative pressure system.

Third, we did not review the utilization of clinical medical equipment such as syringes, catheters, dressing materials, bedding, and waste management supplies. However, we ensured the accuracy of the data in our research and included the use of drugs and medical devices essential for the treatment of COVID-19 patients.

From an economic point of view, it may be preferable to have many beds in one negative pressure isolation system to minimize the use of PPE, but further additional research may be required for discussing stockpile modeling. Other possibilities that may affect the patients' prognosis, such as the spread of secondary infection between patients, and data that can show differences according to individual patients' comorbidities should be studied.

In conclusion, our findings revealed that the higher the COVID-19 severity, the higher the consumption of PPE per patient. Among healthcare workers, nurses had the highest number of inpatient treatment visits for COVID-19. For the efficient utilization of PPE, a structure that includes more isolation beds in one negative pressure isolation system would be preferred.

Article information

Conflicts of interest
No potential conflict of interest relevant to this article was reported.

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Conceptualization: JJP. Data curation: HJP. Formal analysis: YBS, JJP, SHN, JL. Investigation: HJP. Methodology: HJP, JJP. Project administration: HJP, YBS. Resources: HJP. Software: HJP. Supervision: YBS, JJP. Visualization: HJP. Writing - original draft: HJP. Writing - review & editing: YBS, JJP. Approval of final manuscript: all authors.

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