



Research article

The impact of the COVID-19 pandemic on a surgical PICU in China that did not admit COVID-19 patients

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ARTICLE INFO

Keywords:

Critical care
Surgical pediatric intensive care unit
COVID-19
Children
Admission

ABSTRACT

Background: The unprecedented COVID-19 pandemic has been spreading for a long time. However, it is unclear whether the pandemic influenced admission in a surgical pediatric intensive care unit (PICU) that never received COVID-19 patients during the early outbreak in China.

Methods: A retrospective study was conducted in a surgical PICU in a tertiary hospital in Chengdu, China. We sought to describe the trend in admission numbers from January 2018 to April 2021. We explored the impact of the COVID-19 outbreak on PICU admission characteristics by including all patients younger than 18 years admitted to the PICU between January 23 and April 8 in 2020 and those admitted in the same time periods in pre-pandemic years (2018 and 2019) and in 2021.

Results: The percentage of patients admitted to the PICU from the Chengdu region increased from 34.2 percent in 2019 to 40.4 percent in 2020, whereas that from other provinces decreased from 11.7 percent in 2019 to 5.8 percent in 2020 ($P = 0.012$). The median length of stay (LOS) in the PICU was significantly longer in the 2020 cohort (4.0 days) than in the 2019 cohort (2.0 days) ($P < 0.001$); the median hospital LOS was also significantly longer in the former (12.0 days) than in the latter (8.0 days) ($P < 0.001$). Hospital outcomes ($P = 0.005$) and primary diagnosis distributions ($P = 0.025$) between the 2020 and 2019 cohorts were both statistically significant.

Conclusions: In a surgical PICU that never received COVID-19 patients, the onset of the 2020 major outbreak was accompanied by changes in the composition of the regional sources of patients, longer PICU and hospital stays, increased proportions of unauthorized discharges, and changes in the distribution of primary diseases for admission. These findings have yet to be strengthened by additional studies involving similar healthcare backgrounds.

1. Introduction

Since the report of unexplained viral pneumonia cases in December 2019, the coronavirus disease 2019 (COVID-19) pandemic resulting from person-to-person transmission of severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) has been spreading for a long time [1]. Most intensive care units (ICUs), including pediatric ICUs (PICUs), played a crucial role during the pandemic as the department of care for critically ill patients infected by SARS-CoV-2, regardless of whether they received predominantly medical or surgical patients before the COVID-19 pandemic [2, 3]. However, during the early outbreak in 2020 (from January 23 to April 8, 2020), strict infectious disease control measures

were implemented in China to contain the spread of the pandemic [4], resulting in a relatively less difficult situation in China outside the epicenter [5], where most ICUs never admitted COVID-19 patients while maintaining fairly routine operations for non-COVID-19 patients.

Numerous reports worldwide have emerged about the admission characteristics or clinical management of ICUs or PICUs caring for COVID-19 patients [3, 6, 7, 8, 9]. However, there are only limited data about the admission characteristics of surgical PICUs that were not scheduled to receive COVID-19 patients. Hence, it remains unclear whether the pandemic influenced the admission characteristics of surgical PICUs not receiving COVID-19 patients in the area of China outside the epicenter.

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Received 1 April 2022; Received in revised form 31 May 2022; Accepted 13 December 2022

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2. Materials and methods

2.1. Population and research design

We performed a single-center study of children (under the age of 18 years old) admitted to a surgical PICU in the West China Hospital of Sichuan University, which is a comprehensive tertiary hospital in Chengdu, Sichuan Province with a total of 4300 beds, including 26 PICU beds for children with surgical conditions. Upon admission to the PICU, patients receive vital sign monitoring, respiratory and circulatory support, sedation and analgesia, anti-infection and nutritional support, and other treatments.

The PICU admission data used in this research were accessed from Hospital Information System (HIS) medical records with assistance from the full-time information technology staff (FITS) at the West China Hospital of Sichuan University. The study was approved by the Ethics Committee of the Central Processing Center (West China Hospital of Sichuan University). Patient informed consent was waived because of the retrospective and descriptive nature of the study.

2.2. Time period investigated and data acquisition

We included all patients younger than 18 years old who were admitted to the PICU from January 2018 to April 2021. We explored the overall trend of the number of admissions to the PICU. On this basis, we extracted all PICU admission records during four investigated time periods (2018 cohort, 2019 cohort, 2020 cohort, and 2021 cohort) between January 23 and April 8 of each year from 2018 to 2021. This time period wholly overlapped with the time span when the entire country was implementing stringent lockdown measures during the early major outbreak in 2020, as mentioned above.

The extraction and coding process of the admission records was conducted by FITS. The data conversion and classification were manipulated by trained investigators to ensure the reliability of the data by cross-checking. Available variables extracted from records comprise three significant parts: patient demographics (total admission number, age, sex, ethnicity, and region sources), hospitalization features (admission route, length of stay, hospital outcomes, and total hospitalization expenses), and primary diagnosis distribution. Regional sources referring to residences of admitted patients were classified as Chengdu and non-Chengdu areas in Sichuan Province and other provinces. The primary diagnosis distribution refers to classifying the primary diagnoses of all admitted patients in each investigated time period. Primary diagnosis was recognized and classified using the corresponding code of the same named entry in the records according to the International Classification of Diseases, Tenth Revision, Clinical Modification (ICD-10, CM) (see the supplementary file).

2.3. Statistical analysis

Continuous variables with a nonnormal distribution are described as the median with 25% and 75% quartiles (IQR, interquartile range). All categorical variables are expressed as counts (constituent ratios). Age, length of stay (LOS), and total hospitalization expenses as continuous variables were compared between every two cohorts using the Mann-Whitney U test after rank transformation. The chi-squared test was applied to analyze categorical data between every two cohorts. All statistical analyses were performed using SPSS 26.0 for Windows (SPSS Inc., Chicago, IL, USA). A 2-sided P value < 0.05 was considered to be statistically significant.

3. Results

The general trend of admission number from January 2018 to April 2021 in the investigated PICU is displayed in Figure 1. The range ($R = \text{Max} - \text{Min}$) of admission numbers in 2020 ($R_{2020} = 77$, minimum and

maximum values were 14 cases at T_3 [T_x denotes any time point in Figure 1, and the integer X ranges from 1 to 26] and 91 cases at T_{14} , respectively) were higher than the prepandemic two years examined ($R_{2018} = 30$, $\text{Min}_{2018} = 55$ at T_4 , $\text{Max}_{2018} = 85$ at T_{21} ; $R_{2019} = 37$, $\text{Min}_{2019} = 48$ at T_3 , $\text{Max}_{2019} = 85$ at T_{15}) (Figure 1). The trend line of 2020 from T_2 to T_8 appeared at the beginning to a visible decline to the nadir at T_3 (from January 27 to February 9, 2020) and then followed a gradual increase (Figure 1). Data for 1281 admission records in the four investigated time periods were collected and analyzed (Tables 1 and 2). The change in proportions of primary diagnoses is depicted in Table 2.

The difference in age between the 2020 cohort and 2019 cohort was statistically significant ($P = 0.022$) (Table 1), though there was no difference in age between the 2019 cohort and 2018 cohort ($P = 0.060$) (Table 1). In addition, age between the 2021 cohort and 2020 cohort was statistically significant ($P < 0.001$) (Table 1).

There was no difference in age group between the 2020 cohort and 2019 cohort ($P = 0.113$) or between the 2019 cohort and 2018 cohort ($P = 0.090$) (Table 1). Among the years, 2020 showed the highest percentage of infants (< 1 year old). Patients admitted in 2021 were older, whereby those ≥ 10 years old and younger than 18 years old accounted for 14.9 percent in the 2021 cohort and 8.4 percent in the 2020 cohort; infants accounted for 33.7 percent in the 2021 cohort and 49.3 percent in the 2020 cohort ($P = 0.001$) (Table 1).

There was no difference in sex between the 2020 cohort and 2019 cohort ($P = 0.866$) or between the 2019 cohort and 2018 cohort ($P = 0.551$) (Table 1). However, the percentage of male patients admitted in 2021 decreased compared to that in 2020 ($P = 0.037$) (Table 1). Moreover, there was no difference in ethnic group between every two cohorts (Table 1).

Although there was no difference in regional sources between the 2019 cohort and 2018 cohort ($P = 0.957$) (Table 1), the percentage of patients admitted to the PICU from the Chengdu region increased from 34.2 percent to 40.4 percent, and that from other provinces decreased from 11.7 percent to 5.8 percent between the 2019 and 2020 cohorts, and these differences were significant ($P = 0.012$) (Table 1). When comparing the 2020 and 2021 cohorts, the percentage of patients admitted to the PICU from the Chengdu region decreased from 40.4 percent to 33.7 percent, and that from other provinces increased from 5.8 percent to 13.6 percent, which were also significant differences ($P = 0.009$) (Table 1).

Nevertheless, there was no difference in admission route between the 2020 cohort and 2019 cohort ($P = 0.128$) or between the 2019 cohort and 2018 cohort ($P = 0.265$) (Table 2). However, there was a significant decline in the number of patients originating from both emergency care and outpatient care in 2020 (Table 2). The percentage of outpatient patients admitted to the 2021 cohort increased compared to that of the 2020 cohort ($P = 0.013$) (Table 2).

The PICU LOS between the 2020 cohort and 2019 cohort ($P < 0.001$) and between the 2019 cohort and 2018 cohort ($P = 0.004$) was statistically significant (Table 2). The median PICU LOS was significantly longer in the 2020 cohort (4.0 days) than in the 2019 cohort (2.0 days) ($P < 0.001$), though the difference in median PICU LOS between 2021 and 2020 was not significant ($P = 0.083$) (Table 2). The hospital LOS between the 2020 cohort and 2019 cohort ($P < 0.001$) and between the 2019 cohort and 2018 cohort ($P < 0.001$) was also statistically significant (Table 2). The median hospital LOS was significantly longer in the 2020 cohort (12.0 days) than in the 2019 cohort (8.0 days) ($P < 0.001$), but there was no statistical significance in hospital LOS between the 2021 and 2020 cohorts ($P = 0.154$) (Table 2).

Hospital outcomes between the 2020 cohort and 2019 cohort ($P = 0.005$) were statistically significant (Table 2). The proportion of hospital outcomes with unauthorized discharge was increased in the 2020 cohort compared with the 2019 cohort (Table 2). In addition, hospital outcomes were significantly different between the 2019 cohort and 2018 cohort ($P = 0.002$) and between the 2021 cohort and 2020 cohort ($P = 0.002$).

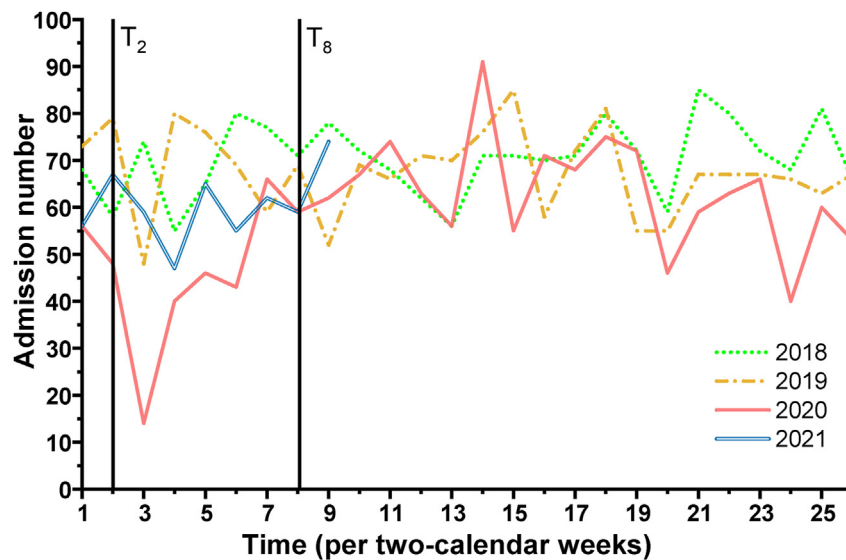


Figure 1. Line chart showing the trend of the number of PICU admissions over time from January 2018 to April 2021. With two calendar weeks as a time point on the X-axis, the 52 calendar weeks in a year were divided into 26 time points. The vertical lines T_2 and T_8 indicate the time points at which the start date (January 23) and end date (April 8) of the investigated time period each year are located, respectively. “ T_x ” denotes any time point in the figure, and the integer X ranges from 1 to 26.

Table 1. All available demographics over the four investigated time periods.

Variables	2018	2019	2020	2021	P value		
					2019 vs. 2018	2020 vs. 2019	2021 vs. 2020
Total admission	379	368	225	309			
Age, yr, median (IQR)	1.0 (0, 4.0)	1.0 (0, 4.0)	1.0 (0, 3.0)	2.0 (0, 6.0)	0.060	0.022	<0.001
Age group, yr, n (%)					0.090	0.113	0.001
<1	179 (47.2)	145 (39.4)	111 (49.3)	104 (33.7)			
1–<5	108 (28.5)	132 (35.9)	65 (29.0)	100 (32.4)			
5–<10	47 (12.4)	52 (14.1)	30 (13.3)	59 (19.1)			
10–<18	45 (11.9)	39 (10.6)	19 (8.4)	46 (14.9)			
Sex, n (%)					0.551	0.866	0.037
Female	173 (45.6)	176 (47.8)	106 (47.1)	175 (56.6)			
Male	206 (54.4)	192 (52.2)	119 (52.9)	134 (43.4)			
Ethnic group, n (%)					0.137	0.105	0.297
Han	324 (85.5)	319 (86.7)	191 (84.9)	256 (82.8)			
Tibetan	26 (6.9)	28 (7.6)	14 (6.2)	28 (9.1)			
Yi	29 (7.7)	18 (4.9)	12 (5.3)	20 (6.5)			
Other*	0	3 (0.8)	8 (3.6)	5 (1.6)			
Region sources, n (%)					0.957	0.012	0.009
Chengdu	125 (33.0)	126 (34.2)	91 (40.4)	104 (33.7)			
Non-Chengdu in Sichuan ⁺	199 (52.5)	192 (52.2)	121 (53.8)	163 (52.8)			
Other provinces [#]	46 (12.1)	43 (11.7)	13 (5.8)	42 (13.6)			
Unknown [§]	9 (2.4)	7 (1.9)	0	0			

Abbreviations: IQR, interquartile range.

* including Hui, Qiang, Mongolian, Buyi, Zhuang, Tujia, Miao ethnic groups in China.

⁺ including Zigong, Panzhihua, Luzhou, Deyang, Mianyang, Guangyuan, Suining, Neijiang, Leshan, Nanchong, Meishan, Yibin, Dazhou, Ya'an, Bazhong, Ziyang, Aba, Ganzi, and Liangshan.

[#] including Chongqing, Yunnan, Guizhou, Gansu, Ningxia, Tibet, Qinghai, Fujian, Guangdong, Hunan, Xinjiang, Hubei, Zhejiang.

[§] indicates missing data

Furthermore, primary diagnosis distributions were significantly different considering 2020 versus 2019 ($P = 0.025$) and 2019 versus 2018 ($P = 0.013$) (Table 2). Conversely, the primary diagnosis distribution between the 2021 cohort and 2020 cohort was not significantly different (Table 2).

There was no significant difference in median total hospitalization expenses between the 2020 cohort (10,535.5 yuan) and the 2019 cohort (10,234.5 yuan) ($P = 0.587$) or between the 2019 cohort and the 2018

cohort (11,873.0 yuan) ($P = 0.227$) (Table 2). Nevertheless, median total hospitalization expenses were greater in the 2021 cohort than in the 2020 cohort ($P < 0.001$) (Table 2).

4. Discussion

The investigated PICU was not set up to receive confirmed COVID-19 cases during the entire COVID-19 outbreak in 2020. Based on the

Table 2. All available hospitalization features and diagnosis distributions over the four investigated time periods.

Variables	2018	2019	2020	2021	P value		
					2019 vs. 2018	2020 vs. 2019	2021 vs. 2020
Admission route, n (%)					0.265	0.128	0.013
Emergency ^a	133 (35.1)	115 (31.3)	84 (37.3)	83 (26.9)			
Outpatient ^b	246 (64.9)	253 (68.8)	141 (62.7)	226 (73.1)			
LOS, day, median (IQR)							
PICU	3.0 (1.0, 5.0)	2.0 (1.0, 4.0)	4.0 (2.0, 7.0)	4.0 (2.0, 7.0)	0.004	<0.001	0.083
Hospital	12.0 (9.0, 18.0)	8.0 (6.0, 12.0)	12.0 (8.0, 17.0)	11.0 (7.0, 15.0)	<0.001	<0.001	0.154
Hospital outcomes, n (%)					0.002	0.005	0.002
Authorized discharge	324 (85.5)	338 (91.8)	189 (84.0)	238 (77.0)			
Authorized transfer	33 (8.7)	8 (2.2)	7 (3.1)	39 (12.6)			
Unauthorized discharge	13 (3.4)	14 (3.8)	25 (11.1)	28 (9.1)			
Death	8 (2.1)	5 (1.4)	4 (1.8)	4 (1.3)			
Unknown ^s	1 (0.3)	3 (0.8)	0	0			
Primary diagnosis**, n (%)					0.013	0.025	0.221
Malignant neoplasms	13 (3.4)	24 (6.5)	27 (12.0)	30 (9.7)			
Benign neoplasms	6 (1.6)	5 (1.4)	6 (2.7)	12 (3.9)			
Neoplasms of uncertain behavior	14 (3.7)	14 (3.8)	12 (5.3)	8 (2.6)			
Nervous system	23 (6.1)	4 (1.1)	9 (4.0)	7 (2.3)			
Circulatory/respiratory system	15 (4.0)	14 (3.8)	7 (3.1)	13 (4.2)			
Digestive system	38 (10.0)	39 (10.6)	20 (8.9)	39 (12.6)			
Certain conditions originating in the perinatal period	9 (2.4)	12 (3.3)	3 (1.3)	1 (0.3)			
Congenital malformations	217 (57.3)	219 (59.5)	111 (49.3)	149 (48.2)			
Injury	14 (3.7)	19 (5.2)	14 (6.2)	15 (4.9)			
Other	30 (7.9)	18 (4.9)	16 (7.1)	35 (11.3)			
Total hospitalization expenses, yuan, median (IQR)	11873.0 (5085.8, 32140.9)	10234.5 (3505.8, 32278.1)	10535.5 (4692.9, 27320.4)	42091.7 (31168.3, 63765.6)	0.227	0.587	<0.001

Abbreviations: IQR, interquartile range; LOS, length of stay.

^a refers to patients come from the emergency department.

^b refers to patients come from surgery ward.

^s indicates missing data.

** see the supplementary file, which describes the detailed items under each category.

preliminary results of this study, specific changes in the demographics and hospitalization features of patients admitted to the PICU during the early outbreak were found in 2020 compared with 2019, including decreased admission numbers from both the emergency department (ED) and outpatient department, increased proportions of infants, increased proportions of patients from Chengdu compared with other provinces, increased PICU and hospital LOS, and more unauthorized discharges.

The most notable variation was that the PICU admission numbers showed a clear decline compared to those in prepandemic years. A similar phenomenon was observed in a study in northern Italy, where unplanned and medical PICU admissions markedly decreased during the COVID-19 outbreak [10]. We also found that the number of PICU admissions due to emergency and outpatient visits synchronously declined in 2020. The total number of ED visits during the early pandemic period in the U.S. was 42% lower than that during the same period in 2019 [11]. This implies a relationship between the decline in PICU admissions due to emergencies and the reduction in ED visits during the COVID-19 outbreak in 2020.

We found that patients in the 2020 cohort were younger and had the most significant proportion of infants (<1 year old) compared to other years. One possible explanation for this finding is that younger children, especially infants, are generally physiologically more vulnerable than older children. At the same time, parents might focus more on younger than on older children. Therefore, parents might be more eager to take their young infants to the doctor once they have abnormal signs or symptoms, contributing partly to the relatively large proportion of infants in the 2020 cohort.

Furthermore, the percentage of admissions from Chengdu increased in 2020 versus 2019, yet the percentage of admissions from other

provinces decreased in 2020 versus 2019 but increased in 2021 versus 2020. Numerous factors can explain these findings. One reason assumes that at the beginning of the early outbreak in 2020, the fear of being infected by SARS-CoV-2 was at an all-time high. People tended to seek medical attention only in cases of emergency while subjectively postponing care-seeking for nonemergencies. The fact that fear of epidemics significantly influences people's health care-seeking behavior was illustrated during the SARS epidemic in 2003 [12]. Similarly, it has been reported that access to or provision of care was delayed in Italy, possibly due to fear of COVID-19, in 2020 [13]. During the early major outbreak in mainland China in 2020, there was no obvious short-term shortage of medical resources outside the central epidemic area. However, widespread implementation of forced controls impacted people's health care-seeking behavior. This may have influence, either through direct restrictions or through the indirect effect of reducing out-of-home activities, on patient demographic characteristics in the PICU during the same period. Strict traffic controls across the country restricted epidemic residents from seeking medical care off-site, resulting in a relatively higher proportion of local patients in the Chengdu region. It is therefore possible that intervention measures such as social distancing or home quarantine rather than the spread of COVID-19 itself influenced the public's healthcare service choices.

We found that the median LOS in the PICU and the median LOS in the hospital were longer in 2020 than in 2019. At the same time, the proportion of hospital outcomes with unauthorized discharge was greatest in 2020 compared with that in the other three years. Unauthorized discharge means that, after adequate communication with medical staff, family

members understood that they were to abandon treatment voluntarily, even though discontinuing aggressive medical interventions could accelerate a patient's deterioration. Clinically, unauthorized discharges are often initiated by patient family members when they subjectively recognize that the patient is more likely to have a poor outcome. Therefore, the increase in the proportion of unauthorized discharges may be explained by patients admitted to the PICU in 2020 being more severely ill and requiring longer intensive care treatment. Such factors would result in an increase in unauthorized discharges due to the family's lack of confidence in the patient's recovery. Therefore, the actual mortality rate may be higher than the in-hospital mortality rate because the prognosis of patients who were discharged unauthorizedly is usually poor.

With regard to the distribution of primary diagnoses, the proportion of PICU admissions with a primary diagnosis of malignancy or neoplasms of uncertain behavior was highest in 2020 compared to the other three years. In fact, parents generally are not able to identify malignant tumors and might seek medical care on their own initiative. Therefore, the reasons for the highest proportion of patients with malignancy or neoplasms are more likely to be medically related. For instance, there might be an increase in referrals to tertiary hospitals for further treatment after diagnosis at local hospitals. In addition, pediatric surgeons of the tertiary hospital prioritized admission of patients requiring early treatment during the outbreak and postponed that of patients with slowly progressing diseases, leading to an increase in the proportion of malignant tumor cases. We also found that the proportions of PICU admissions with a primary diagnosis of nervous system diseases and injury were both higher in 2020 than in 2019, indicating that the change in the distribution of primary diagnoses in 2020 may have been influenced by elevations in the proportions of patients admitted for relatively more urgent medical care.

To date, local outbreaks of COVID-19 are still occurring occasionally in some areas of China. This pandemic has impacted many aspects of society, including healthcare systems. Our study appears to show that the COVID-19 pandemic is still affecting daily work in the PICU. Although it is difficult to specify the endpoint of this unprecedented pandemic, the formation of an immune barrier with increased herd immunity rates could theoretically help to address the need for masking sooner [14, 15]. In interpreting these results, some limitations should be taken into account. This was a single-center study using data extracted from the Hospital Information System (HIS) of the West China Hospital of Sichuan University, with no data from other PICUs in Chengdu. Given the limitations of single-center research, some results of our study may not be applicable to different geographic regions. When interpreting LOS and mortality, it should be noted that they represent the entirety of each cohort and are not specifically linked to a particular pathology and treatment or to whether treatment was withdrawn. Additionally, the overall mortality statistics are affected by the fact that some cases of severe disease involved unauthorized discharge, and the outcome of these patients was not followed up. We also investigated only the number of patients admitted without correlating it to pathology, and there are limited data on emergency presentations and treatment details. In addition, we did not include the scoring systems used for critically ill children due to the unavailability of some of the data covered by them. Nevertheless, our study focuses on a surgical PICU that did not admit COVID-19 patients during the 2020 major outbreak outside the epicenter in China, a topic that has received little attention in previous studies.

5. Conclusion

Our study revealed no significant difference in admitted patient demographics between prepandemic years, though the onset of the COVID-19 outbreak was accompanied by changes in the compositions of patients' regional sources in a surgical PICU. Compared to 2019, both the LOS of the PICU and hospital were longer, the proportion of unauthorized discharge increased, and the distribution of primary diseases for

admission changed in this surgical PICU that never received COVID-19 patients during the 2020 major outbreak. These findings have yet to be strengthened by more studies with similar healthcare backgrounds.

Declarations

Author contribution statement

Geng Zhang: Conceived and designed the experiments; Performed the experiments; Analyzed and interpreted the data; Wrote the paper.

Xuepeng Zhang: Analyzed and interpreted the data.

Hua Yao; Yue Zhou: Contributed reagents, materials, analysis tools or data.

Jianlei Fu: Performed the experiments.

Siyuan Chen, M.D., Ph.D.: Conceived and designed the experiments.

Funding statement

Dr. Siyuan Chen was supported by Key Project in the Science & Technology Program of Sichuan Province [2022YFS0225], 1-3-5 Project for Disciplines of Excellence Clinical Research Incubation Project, West China Hospital of Sichuan University [2020HXFH048].

Data availability statement

Data included in article/supp. material/referenced in article.

Declaration of interest's statement

The authors declare no competing interests.

Additional information

Supplementary content related to this article has been published online at <https://doi.org/10.1016/j.heliyon.2022.e12517>.

Acknowledgements

We would like to thank the full-time information technology staff from the Information Center of the West China Hospital of Sichuan University for assistance with the collection of data.

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