Since January 2020 Elsevier has created a COVID-19 resource centre with free information in English and Mandarin on the novel coronavirus COVID-19. The COVID-19 resource centre is hosted on Elsevier Connect, the company's public news and information website.

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Original Article

The impact of the coronavirus disease 2019 epidemic and national public restrictions on Pediatric Intensive Care Units in Taiwan

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KEYWORDS
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Background/purpose: Coronavirus disease 2019 (COVID-19) pandemic challenges pediatric health globally by limited medical accessibility. In response to COVID-19 epidemic in Taiwan, public restrictions were applied and the Level 3 alert was announced from May to July in 2021 for local outbreak. This study aims to analyze patients' clinical features and outcomes in the pediatric intensive care unit (PICU) during the COVID-19 epidemic with the Level 3 alert in Taiwan.

Methods: Medical records were retrospectively collected in patients admitted to the PICU of National Taiwan University Children's Hospital from May to July 2021 (Level 3 alert) and May to July 2019 and 2020 (control periods). Clinical characteristics and outcomes were compared between patients in the period with the Level 3 alert and control periods.

Results: During the study period, PICU monthly admissions significantly decreased in the Level 3 alert period and were negatively correlated with monthly newly confirmed COVID-19 cases. Patients admitted during the Level 3 alert were older, had higher disease severity, lower proportion of cardiovascular disease, and higher proportion of hematology-oncology diseases than those in the control group. After adjusting for the above factors, admission during Level 3 alert was an independent factor for higher mortality rate and prolonged length of stay (>14 days) in the PICU.

Conclusion: During the COVID-19 epidemic with strict public restrictions, critically ill patients admitted to the PICU decreased but had increased disease severity, prolonged length of stay in the PICU, and higher mortality, reflecting the impact of quarantine and limited medical access.

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Introduction

Severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) infection, first reported in China in 2019, caused the coronavirus disease 2019 (COVID-19), which subsequently spread worldwide and led to a pandemic.[1,2] Compared to adults, children have been spared from severe SARS-CoV-2 infection with rare requirements of pediatric intensive care unit (PICU) admission for acute COVID-19 or related complications such as multi-system inflammatory syndrome in children (MIS-C).[3–5] However, the COVID-19 pandemic challenges pediatric health care in different ways, including reduced scheduled congenital heart surgery, different presentations of disease for PICU admission, and the reallocation of PICU to provide critical care for adults with COVID-19.[6–13] A similar situation of reduced visits and different disease presentations (decreased presentations of respiratory infections) has been observed in pediatric emergency services in Taiwan, although the COVID-19 epidemic was not as severe as that in other countries.[14,15]

Since the first case of COVID-19 on January 21, 2020, Taiwan has restricted the domestic outbreak of COVID-19 in 2020 by non-pharmaceutical interventions (NPIs) such as national border restrictions, mandatory use of face masks in public areas, and social distancing.[16–20] However, locally acquired cases of COVID-19 have emerged rapidly in northern Taiwan since May 2021. Therefore, the government raised the COVID-19 alert level to Level 3 from May 19 to July 26 with intensified NPIs, including cessation of gatherings involving more than 5 people indoors or 10 people outdoors, strict mandatory face mask-wearing in public, physical distancing, and limitations of non-essential medical activities.[21–23] After the national Level 3 alert, the confirmed cases of COVID-19 significantly fell from August 2021 to October 2021, and limited medical accessibility was relieved. In response to the different status of the COVID-19 epidemic in Taiwan since 2019, various public restrictions have been applied; however, the impact of these restrictions on patients admitted to the PICU, especially critically ill pediatric patients, remains unclear. We hypothesized that the COVID-19 pandemic also affected PICU epidemiology and congenital heart surgery services, although the pandemic in Taiwan was not as severe as that in most other countries. This study aimed to explore the clinical features and outcomes of patients admitted to the PICU during the COVID-19 epidemic in Taiwan.

Materials and methods

Study design and setting

Location and study period

This retrospective study was performed at a tertiary referral children's hospital (National Taiwan University Children's Hospital, NTUCH), covering a pediatric population of approximately one million in Northern Taiwan. We have a multidisciplinary PICU equipped with 20 single-bed rooms to accommodate critically ill patients. In addition, our hospital is a major referral center for congenital heart surgery in Taiwan. This study was approved by our institutional review board (National Taiwan University Hospital Research Ethics Committee 202112039RINC).

In response to the severity of the COVID-19 outbreak, four epidemic warning levels have been planned in Taiwan. A Level 3 alert is imposed when more than three clustered infection cases in a week or over 10 cases of domestic infection with an unknown source occur within one day.[24] During the study period, the domestic outbreak of COVID-19 emerged in North Taiwan on May 14, 2021, and the Level 3 alert was imposed between May 19 and July 26, 2021, with important societal measures listed as follows: wearing masks outdoors at all times with recommended social distancing; limited indoor gatherings; cessation of school activities, closing major leisure and business venues except for essential services such as police departments, hospitals, and government buildings; avoidance of unnecessary movement, activities, or gatherings; restricted indoor food and beverage distribution.[21–24] In addition, all elective operations were postponed in our hospital to preserve healthcare capacity during the COVID-19 pandemic. The use of steam inhalation was restricted to patients confirmed to be negative for SARS-CoV-2 infection and only stayed in one room.

Data collection and outcomes measurements

The monthly number of domestic patients diagnosed with COVID-19 between January 2020 and December 2021 was obtained from publicly available disease surveillance reports announced by the Centers for Disease Control (CDC) in Taiwan.[25] All confirmed cases of COVID-19 met one or both of the following laboratory criteria: SARS-CoV-2 isolated on viral culture or positive SARS-CoV-2 RNA detected in a clinical specimen. We extracted data regarding the monthly bed occupancy rate of the PICU, monthly number of PICU admissions, and the number of congenital heart disease (CHD) surgeries from our electronic hospital database from January 2019 to December 2021. We defined bed occupancy, PICU admission numbers, and the number of congenital heart surgeries as surrogates of the PICU utility and service.

To evaluate the influence of strict social restrictions (Level 3 alert) on PICUs, we focused on admissions during the Level 3 alert restriction (May—July 2021) and chose admissions during the same months in 2019 and 2020, in non-Level 3 periods, as the control group to compare the epidemiology in the PICU. We collected the following clinical data: age, sex, diagnosis, and severity of illness evaluated using the Pediatric Logistic Organ Dysfunction (PELOD) score,[26,27] assessed within the first 24 h after admission.

Frequently used life support in our PICU included invasive mechanical ventilation, inotropic agents, renal replacement therapy (RRT), and extracorporeal membrane oxygenation (ECMO). In this study, the primary outcome measure was mortality in the PICU, and the secondary outcomes included PICU length of stay (LOS) and the number of patients with prolonged LOS, which was defined as over 14 days. All subjects were followed up for at least three months, and a 90 days survival analysis was performed.

Statistical analysis

Descriptive statistics were expressed as absolute counts with percentages or summarized using the mean with standard deviation (STD) for normally distributed data or median with interquartile range (IQR) for skewed continuous variables. The correlation coefficient was calculated using Spearman's rank-order correlation to analyze the associations between the two factors. Pearson's chi-square test was used to compare differences in proportions for categorical variables. The Mann—Whitney *U* test or Student's t-test was used to compare skewed or normally distributed continuous variables between the two groups. A *p*-value less than 0.05 was considered statistically significant for all analyses. Multiple logistic regression analyses were performed to analyze the associations between clinical factors and clinical outcomes, such as mortality or prolonged LOS in the PICU. For survival analysis, the Kaplan—Meier curves with the log-rank test were applied, and adjusted hazard ratios were calculated by Cox regression with adjustments of all factors related to the period with the Level 3 alert. Both odds and hazard ratios are presented with a 95% confidence interval (CI). Statistical analysis was performed using the Statistical Package for the Social Sciences (SPSS, version 22.0; SPSS, Inc., Chicago, IL, USA).

Results

Trends of PICU utilization and CHD surgery under COVID-19 pandemic

Since the beginning of the COVID-19 pandemic and the first domestic patient with COVID-19 in Taiwan on January 28, 2020,[28] there were a total of 17,118 confirmed cases of SARS-CoV-2 infections, including 14,609 (85.3%) domestic cases and 851 (4.97%) deaths until December 2021. Three domestic COVID-19 outbreaks occurred from January to April 2020, December 2020 to February 2021, and April to December 2021, with peaks in monthly domestic COVID-19 cases of 27, 19, and 8788 in March 2020, January 2021, and May 2021, respectively (Fig. 1). As a result, the PICU bed occupancy rate, as well as new admissions and numbers of congenital heart surgeries, declined subsequently, with the lowest level one month after the peak domestic cases, that is, April 2020, February 2021, and June 2021, as shown in Fig. 1. Furthermore, new admissions to the PICU and the number of congenital heart surgeries representing PICU utilization from May to July in 2019, 2020, and 2021 were significantly negatively correlated with monthly new confirmed COVID-19 cases with Spearman's rank correlation coefficients of −0.822 ($p = 0.007$) and −0.825 ($p = 0.006$), respectively.

Comparisons of PICU utilization and epidemiology between the level 3 restriction and non-level 3 periods since 2020

To evaluate the impact of strict public restrictions (Level 3) during the COVID-19 pandemic on PICU utilization and service, we compared the new PICU admission and the

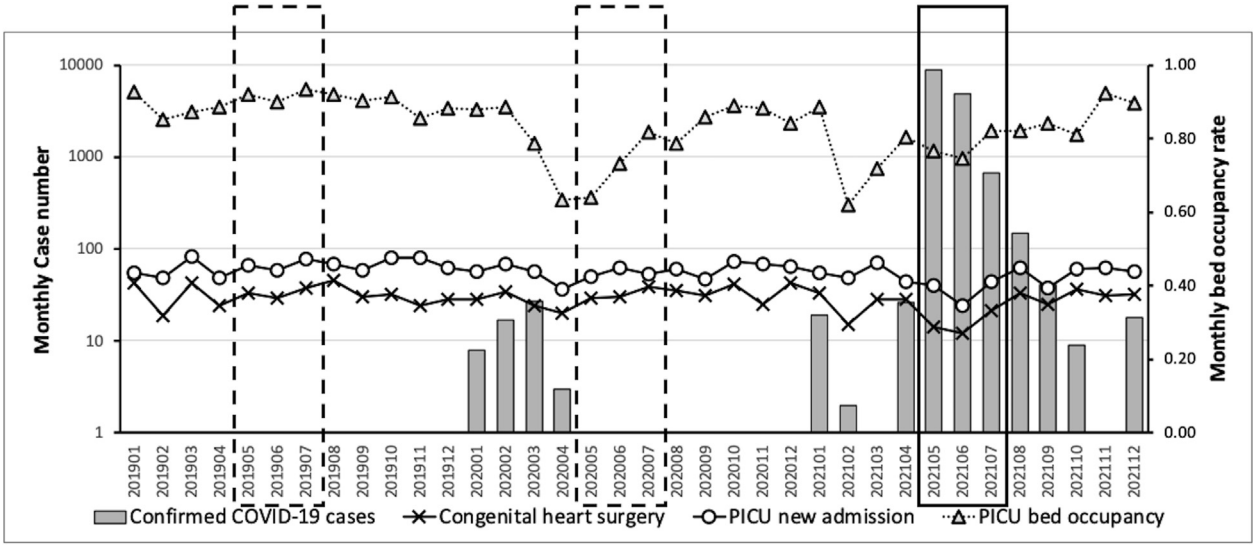

Fig. 1 The monthly numbers of confirmed coronavirus disease 2019 cases, congenital heart surgery, pediatric intensive care unit new admission, and monthly pediatric intensive care unit bed occupancy rate from 2019 to 2021. As confirmed COVID-19 cases surged, the monthly bed occupancy rate of the PICU and monthly cases of PICU admissions, as well as congenital heart surgery, decreased subsequently decreased. The square indicates the Level 3 alert to the COVID-19 epidemic in Taiwan from May to July 2021. The dotted squares indicated the control period from May to July 2019 and 2020. PICU: Pediatric intensive care unit.

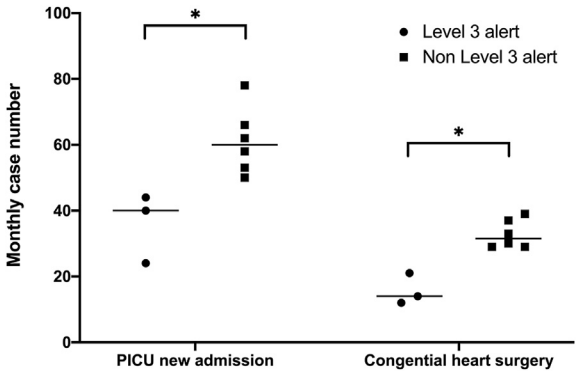

Fig. 2 Comparison of pediatric intensive care unit new admission and congenital heart surgery between the Level 3 alert period and the non-Level 3 alert period (control group). The significant reduction in PICU admissions and congenital heart surgery during the period with the Level 3 alert. *$p < 0.05$. PICU: pediatric intensive care unit.

number of CHD surgeries in the Level 3 restriction period (May–July 2021) and the non-Level 3 period (control group). We found that both services significantly declined under the strict social restriction policy, with *p*-values of 0.024 and 0.024, respectively, as shown in Fig. 2. Furthermore, we described the epidemiology of patients admitted to our PICU in Level 3 and non-Level 3 restrictions. A total of 471 admissions were recruited; their clinical characteristics are shown in Table 1. During the pandemic period, only two confirmed SARS-CoV-2 infected children without desaturation were admitted because of poor appetite with dehydration and mild shortness of breath. Caregivers were quarantined. In the meantime, the PICU accommodated two adults with severe COVID-19. They were desaturated in severe distress, and both were supported with a high-flow nasal cannula in May 2021. The patients recovered without any sequelae.

One hundred and eight PICU admissions were identified from this cohort during the Level 3 social restriction period (May–July 2021). Compared with 363 patients who were admitted in the non-Level 3 periods (control group), patients admitted during the Level 3 restriction period were older (9.2, IQR 1.3–16.1 vs. 3.8, IQR 0.7–12.2; $p = 0.007$), had a higher PELOD score (5.6 vs. 3.6, $p = 0.017$), fewer had cardiovascular disease (n = 22, 20.4%, vs. n = 142, 39.1%, $p < 0.001$), and had hematology-oncology disease (n = 16, 14.8%, vs. n = 25, 6.9%, $p = 0.01$) (Table 1). However, there were no significant differences in other diagnostic categories such as respiratory and metabolic diagnoses for PICU admissions between the groups (Table 1).

Outcome analysis

Table 1 shows that the median PICU length of stay in the Level 3 restriction period was not longer than that in the non-Level 3 period ($p = 0.424$). However, more patients stayed in the PICU for >14 days (22.2% vs. 12.4%,

Table 1 Clinical characteristics of patients admitted to the pediatric intensive care unit during the Level 3 alert period and the non-Level 3 alert period.

	Total	Level 3 alert	Non-level 3 alert	*p*
Months	9	3	6	
PICU admissions	471	108	363	
Sex, male (%)	268 (56.9%)	59 (54.6%)	209 (57.6%)	0.587
Median Age, years (IQR)[a]	4.7 (0.8–13.8)	9.2 (1.3–16.1)	3.8 (0.7–12.2)	0.007
Infant (%)	138 (29.3%)	25 (23.1%)	113 (31.1%)	0.110
Mean PELOD (STD)[b]	4.0 (6.7)	5.6 (7.7)	3.6 (6.3)	0.017
Primary diagnosis in PICU, N (%)				
Respiratory	98 (20.8%)	25 (23.1%)	73 (20.1%)	0.495
Cardiovascular	164 (34.8%)	22 (20.4%)	142 (39.1%)	<0.001
Hepatobiliary/gastrointestinal	50 (10.6%)	11 (10.2%)	39 (10.7%)	0.869
Neuromuscular	45 (9.6%)	11 (10.2%)	34 (9.4%)	0.799
Metabolic/syndromic	19 (4%)	5 (4.6%)	14 (3.9%)	0.720
Hematology-oncology	41 (8.7%)	16 (14.8%)	25 (6.9%)	0.010
Others	54 (11.5%)	18 (16.7%)	36 (9.9%)	0.053
Invasive ventilation (%)	107 (22.7%)	23 (21.3%)	84 (23.1%)	0.688
Inotropic use (%)	59 (12.5%)	16 (14.8%)	43 (11.8%)	0.413
CRRT (%)	10 (2.1%)	2 (1.9%)	8 (2.2%)	0.824
ECMO (%)	8 (1.7%)	0 (0%)	8 (2.2%)	0.120
Median PICU LOS, days (IQR)[a]	2 (1–7)	3 (1–10.5)	2 (1–6)	0.424
PICU LOS >14 days (%)	69 (14.6%)	24 (22.2%)	45 (12.4%)	0.011
Death (%)	20 (4.2%)	9 (8.3%)	11 (3.0%)	0.016

PICU, pediatric intensive care unit; STD, standard deviation; PELOD, pediatric logistic organ dysfunction; RRT, renal replacement therapy; ECMO, extracorporeal membrane oxygenation; LOS, length of stay.
[a] Presented as median and interquartile range.
[b] Presented as mean and standard deviation.

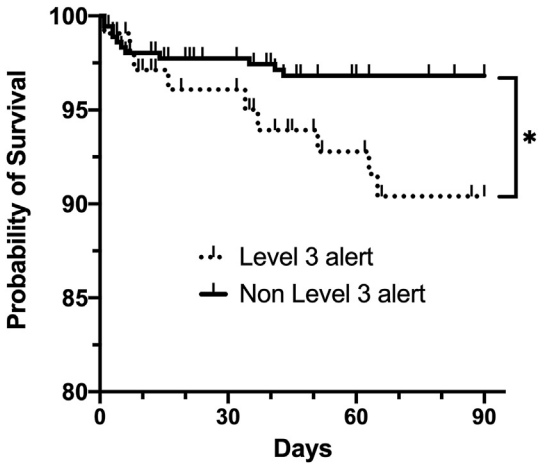

Fig. 3 Survival curve of patients in the periods with the Level 3 alert and without the Level 3 alert (control group). Patients admitted to the pediatric intensive care unit in the Level 3 alert period had a lower probability of survival than those in the non-Level 3 alert period. *$p < 0.05$.

$p = 0.011$), and the PICU mortality rate was significantly higher (8.3% vs. 3.0%, $p = 0.016$) in the Level 3 restriction group. In addition, patients admitted during level 3 restriction had inferior 90-day survival rates, as shown in Fig. 3 ($p = 0.014$). After adjustments for age, PELOD score as disease severity, and cardiovascular (CV) as well as oncological disease, admission during the Level 3 restriction period remained a significant independent risk factor for higher mortality, prolonged LOS in the PICU, and 90 days fatality with adjusted odds ratios of 3.12, 2.51, and adjusted hazard ratio of 3.67, respectively (Table 2).

Discussion

The main findings of our single-center retrospective study of the impact of the COVID-19 epidemic and strict social restrictions on the PICU in Taiwan are as follows: accompanying the increase in domestic COVID-19 confirmed cases, there was a significant decrease in the monthly PICU bed occupancy rate and monthly new admissions as well as operations for congenital heart disease. Patients admitted to the PICU during strict public restrictions (Level 3 alert) during the COVID-19 epidemic tended to be older and have higher disease severity, more hematology-oncological disease, and less cardiovascular disease. Their outcome analysis showed prolonged LOS in the PICU, higher mortality, and lower 90-day survival in patients admitted to the PICU during the Level 3 alert period. After adjusting for related factors, PICU admission during strict public restrictions remained a significant independent risk factor for higher mortality, prolonged LOS in the PICU, and lower 90 days survival rate.

Similar to previous studies, our study revealed significantly reduced admissions to the PICU[11,29–31] and increased disease severity[10] in patients admitted to PICUs during the COVID-19 epidemic with strict NPIs. In contrast to previous studies,[9,10,29–32] our study showed no change in the proportion of patients admitted for severe respiratory infections with respiratory failure but significantly decreased PICU admission for cardiovascular disease. As a major referral center for congenital heart disease in Taiwan, our hospital provided critical care and surgery for patients with critical congenital heart disease; however, constraints on transportation as well as restricted non-essential medical activity during the COVID-19 epidemic with strict NPIs significantly reduced the referrals and operations for these patients, which were also reported in other countries.[7,8] During COVID-19 epidemic, cardiac surgeons cancelled simple cardiac surgeries such as repair of ventricular septal defects which may explain the presentation of increased disease severity in PICU during the Level 3 alert. However, surgery deferral may increase the risk of worsening cardiac conditions and poor surgical prognosis. Furthermore, strict NPIs with restricted medical accessibility may have increased the severity and mortality of patients admitted to the PICU during the epidemic, as shown in our study. These findings highlight the disadvantages of strict NPIs in pediatric critical care, including restricted medical accessibility, rather than the advantages of an overall reduction in non-COVID-19-related respiratory infections in Taiwan. The higher proportion of hematology/oncology patients admitted to PICUs during the COVID-19 epidemic may be attributed to hospital policy to defer port-A catheter implantations, which increased PICU admissions for central line insertion for chemotherapy. In addition, patients with cardiovascular and

Table 2 Multivariable analysis for factors associated with mortality and prolonged pediatric intensive care unit stay.

	Mortality		PICU LOS >14 days		90 days fatality	
	aOR (95% CI)	*p*	aOR (95% CI)	*p*	aHR (95% CI)	*p*
Level 3 alert	3.12 (1.09–8.95)	0.034	2.51 (1.28–4.92)	0.007	3.67 (1.60–8.43)	0.002
Age	1.00 (0.94–1.05)	0.863	0.93 (0.89–0.97)	0.001	1.00 (0.95–1.04)	0.805
PELOD score	1.12 (1.07–1.78)	<0.001	1.10 (1.05–1.13)	<0.001	1.10 (1.06–1.13)	<0.001
CV disease	0.29 (0.06–1.33)	0.110	1.87 (1.03–3.43)	0.041	0.64 (0.23–1.78)	0.387
Hematology/Oncology	0.29 (0.03–2.74)	0.278	0	0.997	1.23 (0.35–4.32)	0.746

Multiple logistic regressions and Cox regressions showed that the period with Level 3 alert was an independent risk factor for high mortality and low 90 days survival after adjustments for age, disease severity, and underlying cardiovascular as well as hematological/oncological disease. PICU, pediatric intensive care unit; LOS, length of stay; aOR, adjusted odds ratio; aHR, adjusted hazard ratio; CI, confidence interval; CV, cardiovascular.

hematology/oncology diseases accounted for higher proportions of infants and teenagers, respectively. Thus, a lower frequency of cardiovascular disease and higher frequency of hematology/oncology diseases in the period of the COVID-19 epidemic with the Level 3 alert contributed to a higher median age than those in the control group.

Our study further demonstrated that the Level 3 alert period was an independent risk factor for increased mortality in the PICU even after adjustments for age, disease severity, and primary diagnosis, which was also reported in a recent study.[10] This result may be attributed to the quarantine policy during the COVID-19 epidemic, in which medical staff were requested to wear adequate personal protective equipment (PPE) and conform to international guidelines when performing medical treatments or invasive procedures for patients with confirmed or suspected COVID-19 in the PICU.[33] Previous studies have shown that personal protective equipment increases rescuer fatigue in cardiopulmonary resuscitation and poor performance of life-saving interventions, such as CPR, endotracheal intubation, and intravenous cannulation in simulations.[34,35] Further studies are needed to investigate the quality of medical performance under PPE during the COVID-19 pandemic and their possible effects on mortality in the PICU.

Patients admitted during the COVID-19 epidemic with strict public restrictions tended to have prolonged LOS in our PICU, and the following two reasons may account for this phenomenon. First, restricted steam inhalation for airway hygiene in all patients under initial quarantine before testing results of SARS-CoV-2 screening may prolong ventilator usage and LOS in the PICU. Second, limited hospital visits led to delayed education and family-centered care preparations, which was also a challenge encountered by other countries during the COVID-19 pandemic.[36]

Since the spread of SARS-CoV-2 infection in 2019, Taiwan reported that few pediatric patients with COVID-19 required PICU admission. Only two pediatric patients with mild COVID-19 were admitted to our PICU, which is consistent with the findings of previous studies.[37] However, the outbreak of COVID-19 in May 2021, with surges of adult patients with severe COVID-19, led to unprecedented demand for adult critical care services, and insufficient capacity of the adult intensive care units (ICUs) forced our PICU to receive two adults with severe COVID-19 for medical therapy and respiratory support with a high-flow nasal cannula. Similar to other countries, we adopted hybrid pediatric and adult critical care models and combined care with adult pulmonologists for adult COVID-19 patients.[12,13] Based on our previous experience with adult critical care for congenital heart and neuromuscular diseases and full support by adult pulmonologists, these patients recovered smoothly and were discharged from our PICU without sequelae. This successful flexible hybrid modeling means our professional skills to care for adult patients can provide a valuable resource for future surges with unpredictable demands of adults with COVID-19.

Compared to countries with high cumulative rates of COVID-19, such as the United States, Brazil, and the United Kingdom (as of February 27, 2022, 23,580.13, 13,400.91, and 27,653.96 per 100,000 people, respectively),[15] Taiwan controlled COVID-19 smoothly, with an extremely low cumulative rate of SARS-CoV2 infections (73.23 per 100,000 people).[25] Despite the low prevalence of COVID-19, our study provides insights into the indirect impacts of the COVID-19 epidemic on PICUs and pediatric health systems, including higher disease severity and mortality, which may result from delayed presentations and deferral of operation for congenital heart disease. As strict NPIs continue, these problems may worsen. Thus, we need to balance the pros and cons of strict NPIs during the COVID-19 epidemic regarding children's health. However, a new surge of COVID-19 epidemic caused by Omicron variants of SARS-CoV2 struck Taiwan since April in 2022 and some infected children developed encephalopathy required PICU care. Taiwanese government proposed the "New Taiwan Model" to allow people to resume normally lives as possible with active epidemic prevention measures remain in place. In these complex situations, further research is needed to access the impacts of infections with different strains of SARS-CoV-2 and different national policy of NPIs for the COVID-19 epidemic on children health.

Our study had some limitations. First, this single tertiary medical center hospital study may have led to selection bias, and the results may not apply to other regions or countries. Second, the small sample size and short study period may have rendered some differences or trends that were not statistically significant. Finally, the retrospective design may have caused bias regarding the 90 days survival in some patients due to patients lost to follow-up after discharge from our PICU.

In conclusion, in the era of the COVID-19 pandemic, new surges of COVID-19 outbreaks with strict public restrictions have strongly affected PICUs by reducing admission, deferring congenital heart surgery, prolonging the length of stay in the PICU, and increasing disease severity and mortality. The COVID-19 epidemic with strict NPIs is an independent risk factor for increased mortality and prolonged LOS in the PICU after adjustments for age, disease severity, and diagnoses, which may result from restricted medical performance under the quarantine policy. These findings highlight the possible adverse effects of COVID-19 restrictions, which reduces medical accessibility for patients requiring critical care in PICUs.

Conflict of Interest

The authors declare no conflicts of interest related to the subject matter or materials discussed in this article.

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References

1. Wu Z, McGoogan JM. Characteristics of and important lessons from the coronavirus disease 2019 (COVID-19) outbreak in China: summary of a report of 72314 cases from the Chinese

center for disease control and prevention. *JAMA* 2020;**323**:1239–42.
2. World Health Organization. *Director-General's remarks at the media briefing on 2019-nCoV on March 2020*. Available at: https://www.euro.who.int/en/health-topics/health-emergencies/coronavirus-covid-19/news/news/2020/3/who-announces-covid-19-outbreak-a-pandemic.
3. Shekerdemian LS, Mahmood NR, Wolfe KK, Riggs BJ, Ross CE, McKiernan CA, et al. Characteristics and outcomes of children with coronavirus disease 2019 (COVID-19) infection admitted to US and Canadian pediatric intensive care units. *JAMA Pediatr* 2020;**174**:868–73.
4. Swann OV, Holden KA, Turtle L, Pollock L, Fairfield CJ, Drake TM, et al. Clinical characteristics of children and young people admitted to hospital with covid-19 in United Kingdom: prospective multicentre observational cohort study. *BMJ* 2020;**370**:m3249.
5. Kanthimathinathan HK, Buckley H, Lamming C, Davis P, Ramnarayan P, Feltbower R, et al. Characteristics of severe acute respiratory syndrome coronavirus-2 infection and comparison with influenza in children admitted to U.K. PICUs. *Crit Care Explor* 2021;**3**:e0362.
6. Kanthimathinathan HK, Pollak U, Shekerdemian L. Paediatric intensive care challenges caused by indirect effects of the COVID-19 pandemic. *Intensive Care Med* 2021;**47**:698–700.
7. Protopapas EM, Rito ML, Vida VL, Sarris GE, Tchervenkov CI, Maruszewski BJ, et al. Early impact of the COVID-19 pandemic on congenital heart surgery programs across the world: assessment by a global multi-societal consortium. *World J Pediatr Congenit Heart Surg* 2020;**11**:689–96.
8. Shi G, Huang J, Pi M, Chen X, Li X, Ding Y, et al. Impact of early Coronavirus Disease 2019 pandemic on pediatric cardiac surgery in China. *J Thorac Cardiovasc Surg* 2021;**161**:1605–16014 e4.
9. Vasquez-Hoyos P, Diaz-Rubio F, Monteverde-Fernandez N, Jaramillo-Bustamante JC, Carvajal C, Serra A, et al. Reduced PICU respiratory admissions during COVID-19. *Arch Dis Child* 2021;**106**:808–11.
10. Zee-Cheng JE, McCluskey CK, Klein MJ, Scanlon MC, Rotta AT, Shein SL, et al. Changes in pediatric ICU utilization and clinical trends during the coronavirus pandemic. *Chest* 2021;**160**:529–37.
11. Kanthimathinathan HK, Buckley H, Davis PJ, Feltbower RG, Lamming C, Norman L, et al. In the eye of the storm: impact of COVID-19 pandemic on admission patterns to paediatric intensive care units in the UK and Eire. *Crit Care* 2021;**25**:399.
12. Deep A, Knight P, Kernie SG, D'Silva P, Sobin B, Best T, et al. A hybrid model of pediatric and adult critical care during the coronavirus disease 2019 surge: the experience of two tertiary hospitals in london and New York. *Pediatr Crit Care Med* 2021;**22**:e125–34.
13. Sinha R, Aramburo A, Deep A, Bould EJ, Buckley HL, Draper ES, et al. Caring for critically ill adults in paediatric intensive care units in England during the COVID-19 pandemic: planning, implementation and lessons for the future. *Arch Dis Child* 2021;**106**:548–57.
14. Lin CF, Huang YH, Cheng CY, Wu KH, Tang KS, Chiu IM. Public health interventions for the COVID-19 pandemic reduce respiratory tract infection-related visits at pediatric emergency departments in taiwan. *Front Public Health* 2020;**8**:604089.
15. World Health Organization. *WHO coronavirus (COVID-19) dashboard*. Available at: https://covid19.who.int/table.
16. Cheng SC, Chang YC, Fan Chiang YL, Chien YC, Cheng M, Yang CH, et al. First case of coronavirus disease 2019 (COVID-19) pneumonia in taiwan. *J Formos Med Assoc* 2020;**119**:747–51.
17. Cheng HY, Li SY, Yang CH. Initial rapid and proactive response for the COVID-19 outbreak - taiwan's experience. *J Formos Med Assoc* 2020;**119**:771–3.
18. Wang CJ, Ng CY, Brook RH. Response to COVID-19 in taiwan: big data analytics, new technology, and proactive testing. *JAMA* 2020;**323**:1341–2.
19. Chen CL, Lai CC, Luh DL, Chuang SY, Yang KC, Yeh YP, et al. Review of epidemic, containment strategies, clinical management, and economic evaluation of COVID-19 pandemic. *J Formos Med Assoc* 2021;**120**(Suppl 1):S6–18.
20. Chen C-C, Tseng C-Y, Choi W-M, Lee Y-C, Su T-H, Hsieh C-Y, et al. Taiwan government-guided strategies contributed to combating and controlling COVID-19 Pandemic. *Front Public Health* 2020:653.
21. Lee WC, Su SY. Epidemic trend of COVID-19 in taiwan, may to June 2021. *J Formos Med Assoc* 2021;**121**:580–1.
22. Taiwan Centers for Disease Control. *CECC raises epidemic warning to Level 3 nationwide from May 19 to May 28; strengthened measures and restrictions introduced across Taiwan to reduce community transmission*. Available at: https://www.cdc.gov.tw/En/Bulletin/Detail/VN_6yeoBTKhRKoSy2d0hJQ?typeid=158.
23. Taiwan Centers for Disease Control. *CECC extends nationwide Level 3 epidemic alert until July 26 to safeguard disease prevention efforts in the community*. Available at: https://www.cdc.gov.tw/En/Bulletin/Detail/vlmAORqyqEntz1Tr_Ls7DQ?typeid=158.
24. Wu C, Wu E, Wu C, Wu KC. How taiwan succeeded in containing its 2021 COVID-19 outbreak. *Asian Soc Sci* 2022;**18**:1.
25. Taiwan Centers for Disease Control. *National notifiable disease surveillance report—monthly report*. Available at: https://www.cdc.gov.tw/En/Report/MonthList/14567.
26. Leteurtre S, Martinot A, Duhamel A, Proulx F, Grandbastien B, Cotting J, et al. Validation of the paediatric logistic organ dysfunction (PELOD) score: prospective, observational, multicentre study. *Lancet* 2003;**362**:192–7.
27. Leteurtre S, Duhamel A, Grandbastien B, Lacroix J, Leclerc F. Paediatric logistic organ dysfunction (PELOD) score. *Lancet* 2006;**367**:897. author reply 900-2.
28. Liu YC, Liao CH, Chang CF, Chou CC, Lin YR. A locally transmitted case of SARS-CoV-2 infection in taiwan. *N Engl J Med* 2020;**382**:1070–2.
29. Araujo OR, Almeida CG, Lima-Setta F, Prata-Barbosa A, Colleti Junior J. Brazilian research network in pediatric intensive C. The impact of the novel coronavirus on Brazilian PICUs. *Pediatr Crit Care Med* 2020;**21**:1059–63.
30. Sperotto F, Wolfler A, Biban P, Montagnini L, Ocagli H, Comoretto R, et al. Unplanned and medical admissions to pediatric intensive care units significantly decreased during COVID-19 outbreak in Northern Italy. *Eur J Pediatr* 2021;**180**:643–8.
31. Maddux AB, Campbell K, Woodruff AG, LaVelle J, Lutmer J, Kennedy CE, et al. The impact of strict public health restrictions on pediatric critical illness. *Crit Care Med* 2021;**49**:2033–41.
32. Williams TC, MacRae C, Swann OV, Haseeb H, Cunningham S, Davies P, et al. Indirect effects of the COVID-19 pandemic on paediatric healthcare use and severe disease: a retrospective national cohort study. *Arch Dis Child* 2021;**106**:911–7.
33. Rimensberger PC, Kneyber MCJ, Deep A, Bansal M, Hoskote A, Javouhey E, et al. Caring for critically ill children with suspected or proven coronavirus disease 2019 infection: recommendations by the scientific sections' collaborative of the European society of pediatric and neonatal intensive care. *Pediatr Crit Care Med* 2021;**22**:56–67.
34. Serin S, Caglar B. The effect of different personal protective equipment masks on health care workers' cardiopulmonary

resuscitation performance during the covid-19 pandemic. *J Emerg Med* 2021;**60**:292—8.

35. Kim TH, Kim CH, Shin SD, Haam S. Influence of personal protective equipment on the performance of life-saving interventions by emergency medical service personnel. *Simul-T Soc Mod Sim*. 2016;**92**:893—8.
36. Andrist E, Clarke RG, Harding M. Paved with good intentions: hospital visitation restrictions in the age of coronavirus disease 2019. *Pediatr Crit Care Med* 2020;**21**:e924—6.
37. Cruz AT, Zeichner SL. COVID-19 in children: initial characterization of the pediatric disease. *Pediatrics* 2020;**145**: e20200834.