JIDC | THE JOURNAL OF INFECTION IN DEVELOPING COUNTRIES

Original Article

Retrospective study: China's pediatric hospital infections before and during the COVID-19 pandemic

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Abstract

Introduction: The COVID-19 pandemic probably influenced the incidence of healthcare-associated infections (HAIs) in pediatric hospitals. This study aimed to assess HAIs and the impact of multidrug-resistant organisms in pediatric intensive care units (ICUs) before and during the pandemic.

Methodology: This retrospective study was conducted at the Children's Hospital of Soochow University from January 2017 to December 2022, covering various ICU units. Statistical analyses compared HAI rates, including Ventilator-associated pneumonia (VAP), central line-associated bloodstream infections (CLABSI), and catheter-associated urinary tract infections (CAUTI), and the prevalence of multidrug-resistant pathogens.

Results: Child hospital admissions were analyzed, with 185,116 admissions pre-pandemic and 218,681 during the pandemic. The average length of stay (LOS) increased across ICU units. Overall, the HAI rates declined from 2.7 to 1.79 ($p < 0.01$) with NICU rates decreasing from 2.93 to 2.07 ($p < 0.01$) and SICU rates from 7.17 to 4.56 ($p < 0.01$) except for general ICUs. VAP rates declined in the general ICU and NICU, while the rates in the SICU remained statistically unchanged. The CLABSI and CAUTI rates remained stable across all ICUs. The total count of multidrug-resistant bacteria increased by 41 instances with significant increases in gram-negative bacteria, particularly CRPA (13%) and CRAB (3%), while MRSA decreased by 12%. CRE strains decreased by 10 counts in the NICUs, while CRAB increased by 12 in the general ICUs and by 8 in the SICUs.

Conclusions: This study reveals a significant HAI decline in pediatric hospitals during the pandemic, suggesting implications for pediatric ICU infection control.

Key words: COVID-19; pediatrics; intensive care units; infection control.

J Infect Dev Ctries 2025; 19(5):669-676. doi:10.3855/jidc.20672

(Received 02 August 2024 – Accepted 15 October 2024)

Introduction

Globally, the World Health Organization declared the COVID-19 pandemic in March 2020 [1]. SARS-CoV-2 infections are often mild or asymptomatic, mainly affecting children's upper respiratory tracts [2]. Common symptoms include fever (59.1%) and cough (55.9%) [3,4]. Children show relative resistance to severe SARS-CoV-2 infections, which may be due to melatonin's direct antioxidant properties and its modulation of ACE2 receptors [5,6]. However, Multisystem Inflammatory Syndrome (MIS-C) in Children has been reported. Its clinical manifestations range from mild inflammation to severe shock involving multiple organs, often requiring care in pediatric intensive care units (PICUs) [7,8]. In these PICUs, critical cases, especially SARS-CoV-2 infections in children with underlying conditions like congenital heart disease and malnutrition, may affect HAIs.

HAIs are a major cause of increased mortality and morbidity in PICUs. The most common HAIs are CLABSI at 25-30%, VAP at 20-25%, CAUTI at 15%, and surgical site infections (SSI) at 11% [9]. HAIs in PICUs have been studied in various countries, including Turkey [10], Rome [11], South Korea [12], Italy [4], Switzerland [13], Spain [8], and the United States [14]. Although the impact of COVID-19 on HAIs has been recognized, most existing studies have been short-term, covering less than a year and involving small samples of pediatric patients. The prevalence of antibiotic-resistant bacteria varies among pediatric ICUs in different regions [15]. Thus, our understanding of the pandemic's effects on children's hospitals and the prevalence of antibiotic-resistant bacteria remains

limited.

This study aims to assess the impact of the COVID-19 pandemic on HAIs and changes in drug-resistant bacteria, particularly in PICUs. Notably, more attention has been paid to NICUs and SICUs. We found that HAI rates decreased during the pandemic, especially in NICU and SICU settings. Moreover, there was a significant decline in infection rates related to equipment-associated invasive procedures, such as VAP.

Methodology

Study design

The research was carried out at a specialized children's medical center in Suzhou, China, which is affiliated with Soochow University. This hospital, boasting a capacity of 1,500 beds, is renowned for its integration of medicine, education, research, and prevention. Ethical approval was obtained from the local committee affiliated with the Children's Hospital of Soochow University (2023CS203). The study compared two periods: the pre-pandemic period (from January 2017 to December 2019) and the pandemic period (from January 2020 to December 2022). Data on healthcare-associated infection rates were derived from the infection surveillance system. These data covered the entire hospital, as well as the NICUs, general Intensive Care Units (ICUs), and SICUs.

Data collection

This retrospective, single-center study analyzed the inpatient laboratory data collected over a six-year period. Pediatric patients admitted to the ICUs who met specific inclusion criteria were included in the study. Patients with hospital stays of less than 48 hours or those with infections documented within 48 hours prior to admission were excluded. The diagnostic criteria for hospital-associated infections were based on the guidelines of the Ministry of Health of the People's Republic of China, which were adapted from the recommendations of the U.S. Centers for Disease Control and Prevention [16].

Data were retrieved from the hospital's real-time infection surveillance system and laboratory information system. In this study, we analyzed the incidence rates of VAP, CLABSI, and CAUTI both before and during the COVID-19 pandemic. Additionally, we examined the occurrence of multidrug-resistant (MDR) pathogens. HAI rates were calculated using the following formula: episodes detected/number of admissions × 100. Rates of VAP, CAUTI, and CLABSI were calculated per 1,000 device-days. The incidence rate of MDROs was calculated with the formula: MDRO counts/number of antimicrobial susceptibility tests × 100.

Statistical Analysis

Count data are reported as numbers, rates, or percentages. Descriptive statistics for continuous variables encompass the mean ± standard deviation (SD) and median (range). For the comparison of continuous variables, an independent-sample t-test or Mann-Whitney U-test was employed. Categorical variables were analyzed using the Chi-square test or Fisher's exact test. A p value of less than 0.05 was regarded as statistically significant. All statistical analyses were conducted using IBM SPSS Statistics® version 26.0. To compare incidence rates, incidence rate ratios (IRR) for the Poisson distribution were utilized. These IRRs were calculated by dividing the number of incidents by either "device days" or "patient days." The statistical significance of the differences in

Table 1. Episodes of HAIs and HAIs rates for the different pediatric units pre- and during the COVID-19 pandemic.

		2017-2019	2020-2023	χ^2	p
Global	**LOS (mean days, SD)**	**6.45 ± 0.28**	**5.97 ± 0.11**	**1.773**	**0.048[b]**
	Episodes of HAIs	4999	3912		
	total admissions	185,116	218,681		
	†HAIs rate	**2.70**	**1.79**	**386.004**	**0.000[a]**
NICU	LOS (mean days, SD)	18.33 ± 1.49	21.13 ± 1.52	0.033	0.084[b]
	Episodes of HAIs	412	224		
	Admissions	14,060	10,839		
	†HAIs rate	**2.93**	**2.07**	**18.343**	**0.000[a]**
ICU	LOS (mean days, SD)	4.97 ± 0.58	5.87 ± 0.83	0.269	0.195[b]
	Episodes of HAIs	212	159		
	Admissions	4,008	3,325		
	†HAIs rate	5.29	4.78	0.974	0.324[a]
SICU	LOS (mean days, SD)	5.12 ± 0.30	5.38 ± 0.44	1.123	0.451[b]
	Episodes of HAIs	120	69		
	Admissions	1,674	1,512		
	†HAIs rate	**7.17**	**4.56**	**9.661**	**0.002[a]**

LOS: length of stay; HAIs: hospital-acquired infections; NICU: neonatal intensive care units; ICU: general intensive care units; SICU: surgical intensive care units. a: Pearson Chi-Square test; b: Student's *t*-test; †: Rate in percentile. Bold text indicates statistically different values.

Table 2. VAP rates and utilization ratio for the different pediatric units pre- and during the COVID-19 pandemic.

		2017-2019	2020-2022	χ^2	*p*	IRR	IRR 95% CI
Global	MV days (mean days, SD)	4.83 ± 0.88	6.34 ± 1.41	0.523	0.191[b]		
	†Utility ratio of MV	**0.90**	**1.30**	**935.171**	**0.000[a]**		
	VAP Rate/1000 device-days	**5.90**	**2.49**		**0.000[c]**	2.367	1.611~3.480
NICU	MV days (mean days, SD)	4.64 ± 0.95	7.52 ± 3.36	4.524	0.226[b]		
	†Utility ratio of MV	**2.32**	**5.74**	**2263.946**	**0.000[a]**		
	VAP Rate/1000 device-days	**2.73**	**0.13**		**0.004[c]**	**20.764**	**2.658~162.203**
ICU	MV days (mean days, SD)	7.15 ± 2.70	8.35 ± 1.75	1.241	0.554[b]		
	†Utility ratio of MV	**24.52**	**29.10**	**107.150**	**0.000[a]**		
	VAP Rate/1000 device-days	**8.16**	**2.97**		**0.001[c]**	**2.614**	**1.479~4.620**
SICU	**MV days (median, range)**	**2.81 ± 0.03**	**4.91 ± 0.85**	**-2.087**	**0.037[d]**		
	†Utility ratio of MV	**26.17**	**23.42**	**16.866**	**0.000[a]**		
	VAP Rate/1000 device-days	7.22	10.97		0.208[c]	0.658	0.344~1.262

MV: mechanical ventilation; VAP: ventilator-associated pneumonia. NICU: neonatal intensive care units; ICU: general intensive care units; SICU: surgical intensive care units. a: Pearson Chi-Square test; b: Student's *t*-test; c: Poisson distribution, d: Independent-Samples Mann-Whitney U Test, †: Rate in percentile. Bold text indicates statistically different values.

IRRs between the two periods was evaluated. In addition, the SPSSAU data science analysis platform (https://spssau.com/) was also utilized for statistical analysis.

Results

HAI Rates

During the COVID-19 pandemic, the total number of hospital admissions increased by approximately 17.7%. Notably, the reduction in the HAI rate, which amounted to 33.7%, was statistically significant. Across all ICUs, the number of admissions decreased by about 20.6%. Globally, the episodes of HAIs declined by 21.8%. In all ICU units, a more substantial reduction of approximately 39.2% was observed. A significant decrease in the HAI rate was recorded for the overall patient population, as well as in the NICU and SICU. However, no significant change was detected in the general ICU. Furthermore, the overall LOS in hospitals was significantly shortened, and no remarkable variation was found across all ICUs. Detailed data are presented in Table 1.

VAP

This section examines the utilization ratio of Mechanical Ventilation (MV) and the rates of VAP across different ICUs before and during the pandemic. During the pandemic, there was a general increase in the duration of MV, which was accompanied by a rise in the utilization ratio. Globally, the VAP rate decreased by 57.8%. Specifically, in the NICU, the VAP rate witnessed a substantial decline of 95.2%, representing the most significant reduction among all units. In the general ICU, the VAP rate decreased by 63.5%. Conversely, in the SICU, the VAP rate increased by 52.1%, making it the only unit to experience an upward trend in VAP cases. These findings suggest that the NICU achieved the lowest VAP rate. For a comprehensive analysis, additional details are presented in Table 2.

CLABSI

Table 3 presents data regarding central venous catheter (CVC) days, catheter utilization rates, and CLABSI across different pediatric healthcare units before and during the COVID-19 pandemic. Specifically, catheter utilization increased significantly in all ICUs. The most substantial increase was observed in the SICU, where the rate soared from 15.42 to 55.71. Although CVC days decreased in most units, both the

Table 3. CLABSI rates and utilization ratio for the different pediatric units pre- and during the COVID-19 pandemic.

		2017-2019	2020-2022	χ^2	*p*	IRR	IRR 95% CI
Global	CVC days (mean days, SD)	15.74 ± 7.78	7.27 ± 0.34	4.776	0.133[b]		
	†Catheter utilization ratio	**3.42**	**13.97**	**87249.164**	**0.000[a]**		
	CLABSI rate/1000 device-days	0.24	0.44	-1.843	0.065[c]	0.539	0.280~1.040
NICU	CVC days (mean days, SD)	30.66 ± 1.03	26.51 ± 3.67	4.654	0.132[b]		
	†Catheter utilization ratio	**11.79**	**15.30**	**766.337**	**0.000[a]**		
	CLABSI rate/1000 device-days	0.21	0.35	-0.758	0.449[c]	0.622	0.182 ~ 2.125
ICU	CVC days (median, range)	7.3 (7.2-11.3)	9.2 (7.7-9.2)	-0.664	0.507[d]		
	†Catheter utilization ratio	**14.58**	**31.20**	**1577.443**	**0.000[a]**		
	CLABSI rate/1000 device-days	0.33	0.33		0.983[c]	1.027	0.093 ~ 11.327
SICU	**CVC days (mean days, SD)**	**4.61 ± 0.38**	**5.74 ± 0.48**	**0.260**	**0.033[b]**		
	†Catheter utilization ratio	**15.42**	**55.71**	**2959.975**	**0.000[a]**		
	CLABSI rate/1000 device-days	0	1.32		0.988[c]	—	—

CVC: central venous catheter; CLABSIs: central-line-associated blood stream infections; NICU: neonatal intensive care units; ICU: general intensive care units; SICU: surgical intensive care units. a: Pearson Chi-Square test; b: Student's *t*-test; c: Poisson distribution, d: Independent-Samples Mann-Whitney U Test, †: Rate in percentile. Bold text indicates statistically different values.

Table 4. CAUTI rates and utilization ratio for the different pediatric units pre- and during the COVID-19 pandemic.

		2017-2019	2020-2022	χ^2	*p*	IRR	IRR 95% CI
Global	UC days (mean days, SD)	4.83 ± 0.23	5.09 ± 0.22	0.000	0.217[b]		
	†Urinary Catheter Utilization ratio	2.32	2.35	2.251	0.133[a]		
	CAUTI rate /1000 device-days	1.44	1.89		0.181[c]	0.762	0.511 ~ 1.135
NICU	UC days (median, range)	2.8(2.0-2.8)	2.3 (2.2-2.4)	0.664	0.507[d]		
	†Urinary Catheter Utilization ratio	**0.15**	**0.33**	**102.899**	**0.000[a]**		
	CAUTI rate /1000 device-days	0	0		—	—	—
ICU	UC days (mean days, SD)	5.77 ± 0.684	7.46 ± 1.643	2.318	0.175[b]		
	†Urinary Catheter Utilization ratio	**21.64**	**23.01**	**10.936**	**0.001[a]**		
	CAUTI rate /1000 device-days	2.26	0.88		0.113[c]	2.553	0.801 ~ 8.140
SICU	UC days (median, range)	4.2(3.9-4.4)	4.6(4.6-5.2)	0.429	0.079 [d]		
	†Urinary Catheter Utilization ratio	58.28	59.59	2.976	0.085[a]		
	CAUTI rate /1000 device-days	0.61	1.23		0.318[c]	0.494	0.123 ~ 1.974

CAUTIs: catheter-associated urinary tract infections; UC: urinary catheter; NICU: neonatal intensive care units; ICU: general intensive care units; SICU: surgical intensive care units. a: Pearson Chi-Square test; b: Student's *t*-test; c: Poisson distribution, d: Independent-Samples Mann-Whitney U Test, †: Rate in percentile. Bold text indicates statistically different values.

general ICU and the SICU witnessed an increase. Notwithstanding the overall increase in catheter utilization, the CLABSI rate did not show significant changes in most units. For a comprehensive understanding of these findings, refer to Table 3.

CAUTI

Table 4 presents a comparison of urinary catheter days, catheter utilization ratios, and CAUTI rates across different pediatric healthcare units before and during the pandemic. The analysis reveals no significant differences in urinary catheter days and CAUTI rates among all units during the pre-and during the pandemic periods. However, it is notable that there was a significant increase in catheter utilization ratios in both the NICU and the general ICU. For a more in-depth exploration of these findings, refer to Table 4.

MDROs

Table 5 presents data regarding the number of antibiotic susceptibility tests (AST), the prevalence of multidrug-resistant organisms (MDROs), and the detection rates of MDROs across different units before and during the pandemic. Overall, during the pandemic, there was a notable increase in the detection of MDROs; Nevertheless, in ICUs, the detection numbers decreased. Specifically, the incidence rate of MDROs in the general ICU increased significantly from 29.8% to 42.3%, whereas the incidence rates in other ICUs remained largely stable.

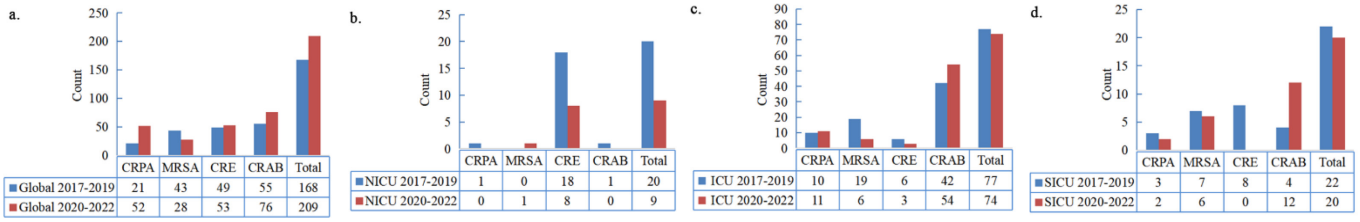
Based on Figure 1a, the microorganism analysis reveals an increase in MDROs, especially among Gram-negative bacteria. Specifically, there were 4 strains of carbapenem-resistant Enterobacteriaceae (CRE), 31 strains of carbapenem-resistant Pseudomonas aeruginosa (CRPA), and 21 strains of carbapenem-resistant *Acinetobacter baumannii* (CRAB). In contrast, there was a decrease in Gram-positive bacteria. For instance, there were 15 strains of methicillin-resistant Staphylococcus aureus (MRSA). Additionally, vancomycin-resistant enterococci (VRE) were not detected. The percentage of CRPA increased by 12.4%, and that of CRAB increased by 3.0%. Conversely, the percentage of MRSA decreased by 12.2%, and that of CRE decreased by 4.0%, as shown in Figure 2a.

Table 5. Analysis of MDROs for the different pediatric units pre- and during the COVID-19 pandemic.

	2017-2019	2020-2022	χ^2	*p*
AST (N)				
Global	884	1,019		
NICU	112	84		
ICU	258	175		
SICU	103	89		
MDROs (N)				
Global	168	209		
NICU	20	9		
ICU	77	74		
SICU	22	20		
†Incidence Rate of MDROs (%)				
Global	19.00	20.50	0.676	0.411[a]
NICU	17.86	10.70	1.943	0.163[a]
ICU	**29.80**	**42.30**	**7.106**	**0.008[a]**
SICU	21.40	22.50	0.035	0.852[a]

AST: Antimicrobial susceptibility testing; MDRO: Multidrug-resistant organisms. Incidence Rate of MDROs = (MDROs/AST) *100. a: Pearson Chi-Square test; †: Rate in percentile. Bold text indicates statistically different values.

Figure 1. Numbers of the multidrug-resistant bacteria for the different pediatric units pre- and during the COVID-19 pandemic. **a.** Overall number of strains of multidrug resistant bacteria detected in hospitalized children; **b.** No. of strains of multidrug-resistant bacteria detected in NICUs; **c.** No. of strains of multidrug-resistant bacteria detected in ICUs; **d.** No. of strains of multidrug-resistant bacteria detected in the SICUs.



	CRPA	MRSA	CRE	CRAB	Total
Global 2017-2019	21	43	49	55	168
Global 2020-2022	52	28	53	76	209

	CRPA	MRSA	CRE	CRAB	Total
NICU 2017-2019	1	0	18	1	20
NICU 2020-2022	0	1	8	0	9

	CRPA	MRSA	CRE	CRAB	Total
ICU 2017-2019	10	19	6	42	77
ICU 2020-2022	11	6	3	54	74

	CRPA	MRSA	CRE	CRAB	Total
SICU 2017-2019	3	7	8	4	22
SICU 2020-2022	2	6	0	12	20

Figures 1b and 2b indicate that CRE had the highest detection percentage in the NICU, reaching approximately 90%. However, during the pandemic, the number of MDROs in NICUs significantly decreased. There was a notable decline in CRE strains (10 strains) and a slight increase in MRSA (1 strain).

In Figures 1c and 2c, the analysis of pre-and during-pandemic MDROs in the general ICUs shows that the predominant strain was CRAB, with a 19% increase in the count of CRAB strains. Conversely, the percentage of MRSA decreased by 17% during the pandemic.

The SICU demonstrated a significant shift in multi-resistant strains before and during the pandemic. Before the pandemic, CRE and MRSA were the predominant strains. However, during the pandemic, CRAB and MRSA became the dominant strains. Notably, CRE was not detected during the pandemic, as depicted in Figures 1d and 2d.

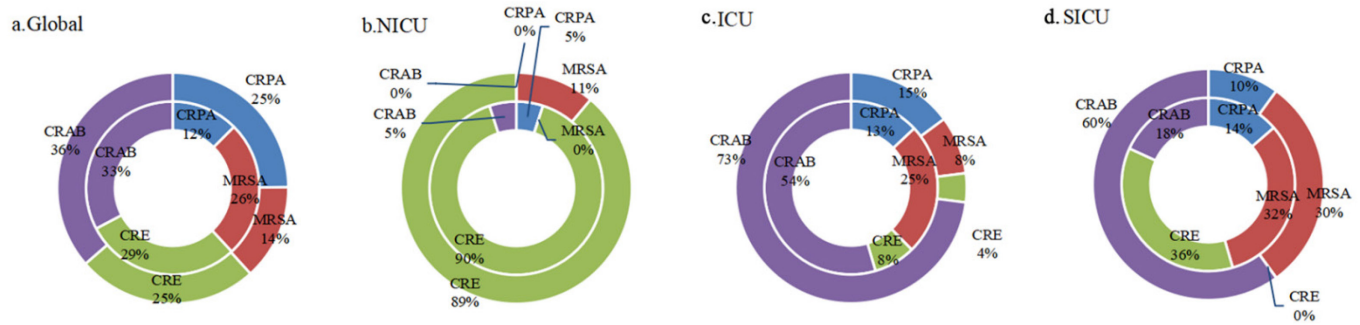
Discussion

This study aimed to explore the HAI rates in pediatric hospitals, with a focus on various ICU settings during the pre-pandemic and pandemic periods of COVID-19. We observed a significant reduction in the overall HAI rate, especially in the VAP rate across most ICU units. Notably, the counts of MDROs also decreased in ICUs. For the first time, we determined that the dominant strains of multidrug-resistant bacteria differed among different ICU units: the NICU was predominantly affected by CRE, while the general ICU had a predominance of CRAB. During the pandemic, the dominant strains in the SICU shifted from CRE to CRAB.

Our findings suggested an overall increase in total admissions, likely reflecting the elevated demand for healthcare resources during the pandemic. However, some studies have reported a decline in pediatric hospitalizations during the early stages of the COVID-19 pandemic [17,18]. Additionally, our study revealed that hospitals have effectively reduced HAI rates globally, particularly in the NICU and SICU. In Iran, a 19.75% decrease in the total rate of HAIs was reported during the COVID-19 outbreak (p = 0.02) [19]. In PICUs in Turkey, The infection rate was higher before the pandemic (5.12) compared to during the pandemic (4.52) [10]. Another study indicated a decline in the NICU HAI rate from 8.43 to 5.66 [20]. These findings imply that aggressive infection prevention and control measures, including the use of personal protective equipment, improved ventilation, and strict hygiene protocols, can be effective in reducing HAIs.

The current study observed an overall increase in

Figure 2. Component ratio of the multidrug-resistant bacteria for the different pediatric units pre- and during the COVID-19 pandemic. **a.** Percentages of overall composition of multidrug-resistant bacteria in hospitalized children; **b.** Percentage composition of multidrug-resistant bacteria in NICUs; **c.** Percentage composition of multidrug-resistant bacteria in ICUs; **d.** Percentage composition of multidrug-resistant bacteria in SICUs. Note: Inner ring-pre COVID-19, outer ring-During COVID-19.



the duration of mechanical ventilation. However, the VAP rates declined across most units, with the NICU showing the most substantial reduction. These findings are in line with those of Ceparano *et al.,* who reported a decreased incidence of VAP in NICUs (3.0% vs. 0.4%, $p = 0.019$) [11]. Conversely, the VAP rate increased in SICUs. This increase might be associated with the rising trend of CRAB within the SICU. Prior exposure to carbapenems (for more than 7 days) independently elevated the risk of developing VAP [21].

The COVID-19 pandemic led to an increase in the isolation rates of CRAB, CRPA, and CRE. Conversely, the incidence of MRSA decreased, underscoring the escalating issue of multidrug resistance. This trend is consistent with findings reported by CHINET in 2022 [22]. In South Korea, studies have shown an overall increase in MDROs, with CRAB and CRPA demonstrating an upward trend following the onset of the COVID-19 pandemic [23]. Notably, a substantial degree of heterogeneity was observed in the prevalence of resistant strains and resistance rates across different studies. Most studies (55.6%) indicated a 10.4% to 40.9% reduction in the rate of CRPA infections during the pandemic. In contrast, 54.5% of studies reported an increase in MRSA infections and colonization, with rates rising from 4.6% to 170.6% [24].

We discovered that the counts of MDROs declined in various ICUs. In Italy, during the pandemic, the prevalence of MDR Gram-negative bacteria carriage decreased in the NICUs in Palermo [25]. The most frequently detected pathogens in pediatric ICUs were *Enterobacteriaceae*, *Pseudomonas aeruginosa*, and *Staphylococcus aureus* [26]. In general ICUs, CRAB strains were the most prevalent during both the pre-pandemic and pandemic periods. In the SICUs, MRSA is one of the primary pathogens responsible for surgical site infections (SSI) [27]. However, during the pandemic, we observed a significant change in the SICU. The main MDRO strain shifted from MRSA to CRAB. These findings imply that although the pandemic might have had a positive impact on certain drug-resistant strains, it also promoted the emergence and spread of CRAB in SICUs [28]. This outcome calls for particular attention to potential mechanisms of CRAB transmission among various ICUs.

This study encompasses several limitations. First, it is a single-center study with a relatively small sample size. This factor may restrict the generalizability of the findings. Second, no investigations were carried out to evaluate hand hygiene compliance during the pandemic. Such studies could enhance our comprehension of the mechanisms underlying the observed decline in infection incidence. Third, the impact of HAIs on patient mortality and the transmission dynamics among drug-resistant bacteria were not explored. Understanding these aspects is pivotal for deciphering the elevated detection of CRAB in SICUs during the pandemic. Moreover, While COVID-19 admissions might account for the increase in hospitalizations and the augmented use of MV during the pandemic, this specific population was not analyzed in the present study. Consequently, further research is imperative to fill these gaps. Notwithstanding these limitations, this study offers valuable data regarding the alterations in HAI rates in pediatric hospitals in China during the COVID-19 pandemic. It remains of utmost importance to persistently implement effective infection prevention measures even after the conclusion of the pandemic.

Conclusions

The proper implementation of infection control protocols during the COVID-19 outbreak has been demonstrated to reduce the rates of HAIs. Particular attention should be given to the spread of CRAB in different ICUs.

Acknowledgements

The authors thank the Nosocomial Infection Control and Quality Improvement Centre at Children's Hospital of Soochow University for providing the original dataset.

Authors' contributions

All authors contributed to the concept and design of the study, and all authors interpreted the data. WX collected and analyzed the data.SM drafted the manuscript. Both authors reviewed the manuscript for important intellectual content. All authors revised the article and approved the final manuscript. SM is responsible for the integrity of the work as a whole.

Funding

The present work was supported by Grants from a Special research project on infection management (SZSYYXH-2023-YB2), Suzhou Youth Science and Education Project (KJXW2021049) and Jiangsu Province Preventive Medicine Research Program (Ym2023053).

Ethics approval and consent to participate

The study was approved by the Ethics Committee of the Children's Hospital of Soochow University (09/08/2023/2023CS203). All methods were carried out following relevant guidelines and regulations. Given the retrospective nature of the study, the Ethics Committee of the

Children's Hospital of Soochow University waived the need for informed consent.

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Conflict of interests

No conflict of interests is declared.

References

1. Cucinotta D, Vanelli M (2020) WHO declares COVID-19 a pandemic. Acta Bio Medica Atenei Parm 91: 157–160. doi: 10.23750/abm.v91i1.9397.
2. Morand A, Fabre A, Minodier P, Boutin A, Vanel N, Bosdure E, Fournier PE (2020) COVID-19 virus and children: what do we know? Arch Pediatr Organe Off Soc Francaise Pediatr 27: 117–118. doi: 10.1016/j.arcped.2020.03.001
3. Hoang A, Chorath K, Moreira A, Evans M, Burmeister-Morton F, Burmeister F, Naqvi R, Petershack M, Moreira A (2020) COVID-19 in 7780 pediatric patients: A systematic review. eClinicalMedicine 24: doi: 10.1016/j.eclinm.2020.100433.
4. Rosazza C, Alagna L, Bandera A, Biffi A, Ciciriello F, Gramegna A, Lucidi V, Marchisio PG, Medino P, Muscatiello A, Uceda Renteria S, Colombo C (2023) Severity of SARS-CoV-2 infection in a hospital population: a clinical comparison across age groups. Ital J Pediatr 49: 135. doi: 10.1186/s13052-023-01485-w.
5. Zhu L, Lu X, Chen L (2020) Possible causes for decreased susceptibility of children to coronavirus. Pediatr Res 88: 342. doi: 10.1038/s41390-020-0892-8.
6. Zhou Y, Hou Y, Shen J, Huang Y, Martin W, Cheng F (2020) Network-based drug repurposing for novel coronavirus 2019-nCoV/SARS-CoV-2. Cell Discov 6: 14. doi: 10.1038/s41421-020-0153-3.
7. Lin F, Jiang D-J, Zhang S, Yang Z, Zeng H-S, Liu Z-P, Yang L-Y (2024) Critically ill children with SARS-COV-2 Omicron infection at a national children medical center, Guangdong, China. 24: 254. doi: 10.1186/s12887-024-04735-w.
8. García-Salido A, de Carlos Vicente JC, Belda Hofheinz S, Balcells Ramírez J, Slöcker Barrio M, Leóz Gordillo I, Hernández Yuste A, Guitart Pardellans C, Cuervas-Mons Tejedor M, Huidobro Labarga B, Vázquez Martínez JL, Gutiérrez Jimeno M, Oulego-Erróz I, Trastoy Quintela J, Medina Monzón C, Medina Ramos L, Holanda Peña MS, Gil-Antón J, Sorribes Ortí C, Flores González JC, Hernández Palomo RM, Sánchez Ganfornina I, Fernández Romero E, García-Besteiro M, López-Herce Cid J, González Cortés R (2020) Severe manifestations of SARS-CoV-2 in children and adolescents: from COVID-19 pneumonia to multisystem inflammatory syndrome: a multicentre study in pediatric intensive care units in Spain. Crit Care 24: 1–13. doi: 10.1186/s13054-020-03332-4.
9. Kannan A, Pratyusha K, Thakur R, Sahoo MR, Jindal A (2023) Infections in critically ill children. Indian J Pediatr 90: 289–297. doi:10.1007/s12098-022-04420-9
10. İpek S, Şahin A, Gungor S, Yurttutan S, Güllü UU, Inal S, Demiray Ş, İpek S, Şahin A, Gungor S, Yurttutan S, Gullu UU, Inal S, Demiray ŞD (2022) Nosocomial infections in non-COVID-19 pediatric patients prior to and during the pandemic in a pediatric intensive care unit. Cureus 14: e21451. doi: 10.7759/cureus.21451
11. Ceparano M, Sciurti A, Isonne C, Baccolini V, Migliara G, Marzuillo C, Natale F, Terrin G, Villari P, The Collaborating Group null (2023) Incidence of healthcare-associated infections in a neonatal intensive care unit before and during the COVID-19 pandemic: a four-year retrospective cohort study. J Clin Med 12: 2621. doi: 10.3390/jcm12072621
12. Lee Y-M, Kim DY, Kim EJ, Park K-H, Lee MS (2023) Impact of COVID-19 pandemic on healthcare-associated infections at intensive care units in South Korea: data from the Korean national healthcare-associated infections surveillance system (KONIS). J Hosp Infect 138: 52–59. doi: 10.1016/j.jhin.2023.05.010
13. Bögli J, Güsewell S, Strässle R, Kahlert CR, Albrich WC (2023) Pediatric hospital admissions, case severity, and length of hospital stay during the first 18 months of the COVID-19 pandemic in a tertiary children's hospital in Switzerland. Infection 51: 439–446. doi: 10.1007/s15010-022-01911-x
14. Hyte M, Clark C, Pandey R, Redden D, Roderick M, Brock K (2023) How COVID-19 impacted CAUTI and CLABSI rates in Alabama. Am J Infect Control 52: 147–151. doi: 10.1016/j.ajic.2023.05.014
15. Witt LS, Howard-Anderson JR, Jacob JT, Gottlieb LB (2022) The impact of COVID-19 on multidrug-resistant organisms causing healthcare-associated infections: a narrative review. JAC-Antimicrob Resist 5: dlac130. doi: 10.1093/jacamr/dlac130
16. Su C, Zhang Z, Zhao X, Peng H, Hong Y, Huang L, Huang J, Yan X, Wu S, Bai Z (2021) Changes in prevalence of nosocomial infection pre- and post-COVID-19 pandemic from a tertiary Hospital in China. BMC Infect Dis 21: 693. doi: 10.1186/s12879-021-06396-x
17. Reid LD, Fang Z (2021) Changes in pediatric hospitalizations and in-hospital deaths in the initial period of the COVID-19 pandemic (April–September 2020), 13 states. In: Healthcare Cost and Utilization Project (HCUP) Statistical Briefs. Agency for Healthcare Research and Quality (US).
18. Chiabi A, Forgwei MN, Bissong M, Niba L, Abah JN, Nsame D (2022) Trends in pediatric hospitalizations and mortality during the COVID-19 pandemic in an urban setting in Cameroon. J Trop Pediatr 68: fmac026. doi: 10.1093/tropej/fmac026.
19. Jabarpour M, Dehghan M, Afsharipour G, Hajipour Abaee E, Mangolian Shahrbabaki P, Ahmadinejad M, Maazallahi M (2021) The impact of COVID-19 outbreak on nosocomial infection rate: a case of Iran. Can J Infect Dis Med Microbiol 2021: 6650920. doi: 10.1155/2021/6650920.
20. Avsar H, Bulbul A, Bas EK, Uslu HS, Unal ET, Divarci A, Tellioðlu AY, Atar G (2024) Secondary gains of strategies to prevent COVID-19 infection in neonatal intensive care unit: has the frequency of healthcare-associated infections decreased? Indian Pediatr 61: 243–247. doi: 10.1007/s13312-024-3184-2.
21. Wang X, Zheng M, Zhang Y, Gao Y, Jiang L, Huang S, Wang X, Su C, Niu W, Wu S, Bai Z (2024) Prior carbapenem

exposure increases the incidence of ventilator-associated pneumonia in critically Ill children. BMC Infect Dis 24: 855. doi: 10.1186/s12879-024-09735-w.

22. Hu F, Wang M, Zhu D, Wang F (2020) CHINET efforts to control antimicrobial resistance in China. J Glob Antimicrob Resist 21: 76–77. doi: 10.1016/j.jgar.2020.03.007.
23. La Y, Hong JY, Lee HS, Lee EH, Lee KH, Song YG, Kim SB, Han SH (2022) Increase of multidrug-resistant bacteria after the COVID-19 pandemic in South Korea: Time-series analyses of a long-term multicenter cohort. J Infect 85: 702–769. doi: 10.1016/j.jinf.2022.09.026.
24. Abubakar U, Al-Anazi M, alanazi Z, Rodríguez-Baño J (2023) Impact of COVID-19 pandemic on multidrug resistant gram positive and Gram negative pathogens: a systematic review. J Infect Public Health 16: 320–331. doi: 10.1016/j.jiph.2022.12.022.
25. Graziano G, Notarbartolo V, Priano W, Maida CM, Insinga V, Rinaudo G, Russo A, Palermo R, Vitale F, Giuffrè M (2023) Surveillance of multidrug-resistant pathogens in neonatal intensive care units of Palermo, Italy, during SARS-CoV-2 Pandemic. Antibiot Basel Switz 12: 1457. doi: 10.3390/antibiotics12091457.
26. Folgori L, Bernaschi P, Piga S, Carletti M, Cunha FP, Lara PHR, Peixoto NC de C, Guimarães BGA, Sharland M, Silva ARA da, Atti MC degli (2016) Healthcare-associated infections in pediatric and neonatal intensive care units: impact of underlying risk factors and antimicrobial resistance on 30-day case-fatality in Italy and Brazil. Infect Control Hosp Epidemiol 37: 1302–1309. doi: 10.1017/ice.2016.185.
27. Samia NI, Robicsek A, Heesterbeek H, Peterson LR (2022) Methicillin-resistant staphylococcus aureus nosocomial infection has a distinct epidemiological position and acts as a marker for overall hospital-acquired infection trends. Sci Rep 12: 17007. doi: 10.1038/s41598-022-21300-6.
28. Sood G, Perl TM (2021) Outbreaks in health care settings. Infect Dis Clin North Am 35: 631–666. doi: 10.1016/j.idc.2021.04.006.