

Burden and Risk Factors of Healthcare-Associated Infections in a Pediatric Intensive Care Unit: A Prospective Study from India

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ABSTRACT

Background: Healthcare-associated infections (HAIs) contribute significantly to morbidity and mortality in pediatric intensive care units (PICUs), especially in low- and middle-income countries. This study aimed to evaluate the incidence, spectrum, risk factors, and outcomes of HAIs in an Indian tertiary care PICU.

Methods: A six-month prospective observational study included children aged 1 month–18 years, admitted ≥ 48 hours and infection-free at baseline. HAIs were diagnosed using CDC/NHSN criteria. Demographic, clinical, and device-related variables were analyzed.

Results: Among 444 admissions, 247 patients (1,783 patient-days) were eligible. The crude infection rate was 9.7%. Gastroenteritis (50%) was the most frequent HAI, followed by pneumonia and bloodstream infections (16.7% each). Younger age, central venous catheters (OR 7.82, $p=0.022$), and mechanical ventilation (OR 10.48, $p=0.013$) were independent risk factors. Device-associated infection rates were 52.6/1,000 central line and 25.6/1,000 ventilator days. HAIs significantly prolonged PICU and hospital stay ($p<0.001$), though mortality was unaffected.

Conclusion: HAIs remain a major burden in PICUs, particularly among younger and device-dependent patients. Strict infection control and timely device removal are essential to improve outcomes.

Keywords: Hospital Acquired infection, PICU, Pediatrics, Infections.

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INTRODUCTION

Healthcare-Associated Infections (HAIs) remain a critical challenge in modern medicine, particularly in Paediatric Intensive Care Units (PICUs), where they significantly contribute to morbidity, mortality, prolonged hospitalisation, increased healthcare expenditure, and the emergence of antimicrobial resistance (AMR) [1,2].

The historical context of HAIs dates back to 1847 when Ignaz Semmelweis first demonstrated the importance of hand hygiene in reducing puerperal fever. However, broader recognition of nosocomial infections did not gain momentum until the early 20th century. Over time, extensive research has underscored the substantial burden of HAIs in intensive care settings, with bloodstream infections (BSIs), ventilator-associated pneumonia (VAP), and catheter-associated urinary tract infections (CAUTIs) identified as the most prevalent forms [3].

Paediatric patients are uniquely vulnerable to HAIs due to a range of intrinsic and extrinsic factors, including prematurity, low birth weight, immature immune

responses, malnutrition, and the requirement for prolonged intensive care. Furthermore, the frequent use of invasive devices such as central venous catheters, endotracheal tubes, and urinary catheters creates additional avenues for infection [4].

Despite advancements in infection prevention and control (IPC) practices, HAIs continue to pose a major public health concern, particularly in low- and middle-income countries (LMICs) like India. Challenges such as inadequate healthcare infrastructure, insufficient IPC implementation, and limited surveillance systems hinder effective containment of HAIs [5]. Studies such as those by Klevens et al. (2007) have reported high incidences of catheter-related bloodstream infections (CRBSIs) and VAP in PICU settings, reinforcing the necessity for strict adherence to aseptic protocols [6].

In India, reports by Gupta et al. (2011) and Dasgupta et al. (2015) have revealed alarmingly high HAI rates in tertiary care hospitals, with device-associated infections playing a major role in adverse clinical outcomes [7,8]. Additionally,

Burden and Risk Factors of Healthcare-Associated Infections in a Pediatric Intensive Care Unit: A Prospective Study from India

the increasing prevalence of multidrug-resistant (MDR) organisms, as noted by Gandra et al. (2018), further complicates both treatment and infection control efforts [9]. Globally, the incidence of HAIs in intensive care settings ranges from 6.1% to 15.1%, whereas in India it is notably higher—ranging from 10.5% to 19.5% [10]. Given the significant clinical and economic burden of HAIs in PICUs, particularly in resource-limited settings, there is an urgent need for context-specific epidemiological data.

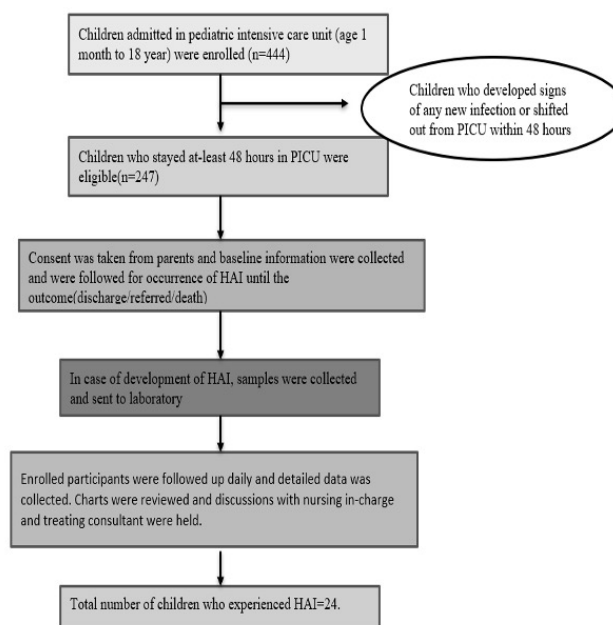
The present study aims to comprehensively evaluate the epidemiology of HAIs in a tertiary care PICU in Delhi, with a focus on incidence rates, microbial profiles, associated risk factors, and patient demographics. This research seeks to generate evidence that can inform IPC strategies and support policy development for infection control in paediatric critical care settings.

MATERIALS AND METHODS

A prospective observational study was conducted over a six-month period in the Department of Paediatrics at a tertiary care teaching hospital. Ethical approval was obtained from the Institutional Ethics Committee prior to initiation. All children admitted to the Paediatric Intensive Care Unit (PICU) during the study period were screened for eligibility.

Children aged 1 month to 18 years who remained in the PICU for at least 48 hours and did not exhibit any signs of infection at the time of admission or within the first 48 hours of stay were considered eligible. Written informed consent was obtained from the caregivers prior to enrolment. Patients were excluded if they developed infection within the initial 48 hours or showed persistence or progression of the pre-existing infection for which they were admitted.

Data were collected using a pre-structured, pre-tested case record form. Daily follow-up was conducted until the final clinical outcome (discharge or death). Detailed documentation included demographic information, clinical signs and symptoms, anthropometric measurements, physical examination findings, laboratory and radiological investigations, therapeutic interventions, and the use of invasive devices.



The study flow is depicted in **Figure 1**.

Figure 1. Flow of the study

Data were reviewed regularly for completeness, accuracy, and consistency. When a new infection was clinically suspected, relevant investigations were ordered based on presenting symptoms and at the discretion of the treating paediatrician and PICU team. All Healthcare-Associated Infections (HAIs) were diagnosed in accordance with the Centers for Disease Control and Prevention/National Healthcare Safety Network (CDC/NHSN) surveillance definitions [11].

RESULTS

Over the six-month study period, a total of 444 children were admitted to the Paediatric Intensive Care Unit (PICU). Of these, 247 children who stayed for ≥ 48 hours were enrolled in the study, contributing to 1,783 patient-days in total.

Baseline Characteristics (n = 247):

The mean age of the enrolled children was 4.49 ± 4.82 years, with ages ranging from newborn to 16 years. Most of them (60.7%) were between 1 month and 5 years, while the rest (39.3%) were in the 5 to 18 years age group. The male-to-female ratio was 1.57:1.

The most common reason for PICU admission was infectious illness requiring close monitoring (36.4%), followed by respiratory distress (32.8%), central nervous system (CNS) conditions (16.6%), and circulatory issues like shock and dehydration (9.7%).

When looking at final diagnoses, respiratory infections topped the list (30.3%), followed closely by complex infections such as dengue and scrub typhus (29.1%). Other

Burden and Risk Factors of Healthcare-Associated Infections in a Pediatric Intensive Care Unit: A Prospective Study from India

diagnoses included gastrointestinal (14.9%), neurological (12.9%), sepsis (6.4%), asthma (3.2%), and miscellaneous causes (4.8%).

The average PICU stay was 3.88 ± 2.57 days, while the overall hospital stay averaged 7.22 ± 4.00 days.

Outcomes and Device Use:

Most of the children (89.5%) were successfully discharged. A small proportion (9.7%) either left against medical advice (LAMA) or were referred elsewhere, and 0.8% unfortunately passed away during their hospital stay.

Device use in this cohort was relatively limited: Foley catheters were used in 2.4% of patients, PICC lines in 1.6%, central lines in 2.8%, and mechanical ventilation in 2.4%. Only 0.8% had an intercostal drain inserted. Across the cohort, there were 45 Foley catheter days, with a device utilisation (DU) ratio of 4.7%. Central line and ventilator days were 38 and 39, respectively, each with a DU ratio of 4%. The mean duration of mechanical ventilation was 6.5 days. Overall, 16.6% of children ($n = 41$) received ventilatory support—14.2% with non-invasive ventilation and 2.4% with mechanical ventilation.

Healthcare-Associated Infections (HAIs):

Out of the 247 children enrolled, 24 (9.7%) developed a healthcare-associated infection (HAI), diagnosed using CDC/NHSN definitions [17]. On average, HAIs appeared around 6.08 ± 3.02 days after admission.

Among the HAIs observed, gastroenteritis was the most common, seen in 50% (12/24) of cases. This was followed by pneumonia and bloodstream infections (both 16.7%, 4/24 each), clinical sepsis (12.5%, 3/24), and urinary tract infection (4.2%, 1/24). The clinical profile of these patients is shown in **Figure 2**.

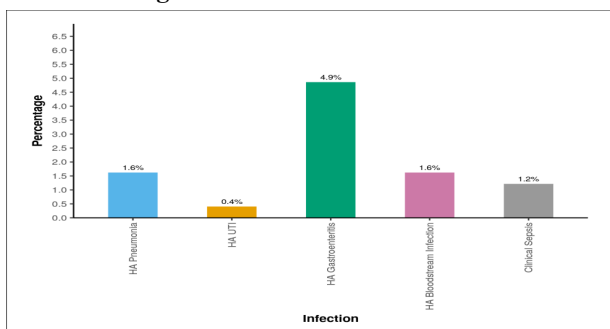


Figure 2. Clinical Profile of HAI

Healthcare-Associated Infection Rates and Risk Factors

The overall Crude Infection Rate (CIR) in the study cohort was 9.7%. When broken down by site, the CIRs were as follows: pneumonia – 1.6%, gastroenteritis – 4.8%, bloodstream infections – 1.6%, clinical sepsis – 1.21%, and urinary tract infections (UTI) – 0.4%.

Among the 24 patients who developed HAIs, 16.7% (4/24) had a positive blood culture. Of these, two cases (8.3%)

were classified as central line-associated bloodstream infections (CLABSI), and the other two (8.3%) were hospital-acquired bloodstream infections (HA-BSI). The pathogens identified in the CLABSI cases were *Coagulase-negative Staphylococcus aureus* and *Candida albicans*, while both HA-BSI cases were caused by *Acinetobacter baumannii*.

In one patient (4.2%), a urine culture yielded growth of *Escherichia coli*. Chest X-ray findings were significant in 16.7% (4/24) of the HAI group, and an equal proportion had raised inflammatory markers, prompting initiation or escalation of antimicrobial therapy.

A statistically significant association was observed between **age** and the risk of developing HAIs ($p = 0.026$). The mean age of children who developed HAIs was 2.96 ± 4.24 years, compared to 4.65 ± 4.85 years in those who did not—suggesting that younger children were more susceptible. The male-to-female ratio among HAI cases was 2:1, although this difference was not statistically significant ($p > 0.05$).

No significant association was found between the **nutritional status** (including anthropometric parameters and haemoglobin levels) and the risk of acquiring HAIs ($p > 0.05$).

In addition to device use and age, several clinical parameters also showed a statistically significant association with the occurrence of healthcare-associated infections ($p < 0.05$). These included the indication for PICU admission, the underlying diagnosis, the total duration of hospital stay, and the length of stay in the PICU. These details are further elaborated in

Table 1. Association between healthcare-associated infection and indications of PICU admission, duration of stay, diagnosis, and outcome.

Variable	Parameter	Onset of New Infection		Difference (95% CI)	Significance
		Yes (n = 24)	No (n = 223)		
Indications for PICU Admission	Respiratory Distress	13 (54.17%)	68 (30.49%)	23.67% (2.84% to 44.50%)	$\chi^2 = 4.488$, $p = 0.023$
	Circulatory Issues	2 (8.33%)	22 (9.87%)	-1.53% (-13.26% to 10.19%)	$\chi^2 = 0.000$, $p = 1.000^f$

Burden and Risk Factors of Healthcare-Associated Infections in a Pediatric Intensive Care Unit: A Prospective Study from India

				10.20 (%)	
	CNS Issues	3 (12.50%)	38 (17.04%)	- 4.54 % (- 18.66 % to 9.58 %)	$\chi^2 = 0.078$, p = 0.775 ^f
	Acute Abdomen	1 (4.17%)	2 (0.90%)	3.27 % (- 4.82 % to 11.36 %)	$\chi^2 = 0.167$, p = 0.265 ^f
	Infectious Disease	5 (20.83%)	85 (38.12%)	- 17.28 % (- 34.74 % to 0.17 %)	$\chi^2 = 2.098$, p = 0.119 ^f
	Metabolic Emergencies	0 (0.00%)	5 (2.24%)	- 2.24 % (- 4.19 % to - 0.30 %)	$\chi^2 = 0.000$, p = 1.000 ^f
	Others	0 (0.00%)	3 (1.35%)	- 1.35 % (- 2.86 % to 0.17 %)	$\chi^2 = 0.000$, p = 1.000 ^f
PICU Stay (Days) PICU Stay (Hours)	Mean \pm SD	6.96 \pm 5.30	3.55 \pm 1.81	3.41 (1.16 to 5.65)	W = 3948.500, p = <0.001 ^m
	Mean \pm SD	166.92 \pm 127.06	89.27 \pm 74.91	77.64 (23.21 to	W = 3931.500, p =

				132.0 (8)	<0.001 ^m
Duration of Stay (Days)	Mean \pm SD	12.38 \pm 7.08	6.66 \pm 3.05	5.71 (2.70 to 8.73)	W = 4231.500, p = <0.001 ^m
Use of Antibiotics	Not Used	0 (0.00%)	34 (15.25%)	- 15.25 % (- 19.96 % to - 10.53 %)	$\chi^2 = 3.056$, p = 0.054 ^f
Diagnosis	Used	24 (100.00%)	189 (84.75%)	15.25 % (10.53% to 19.96%)	$\chi^2 = 3.056$, p = 0.054 ^f
	Respiratory Infection	13 (61.90%)	62 (31.96%)	29.95 % (8.16% to 51.73%)	$\chi^2 = 6.221$, p = 0.008 ^f
	Asthma	0 (0.00%)	8 (4.12%)	- 4.12 % (- 6.92 % to - 1.33 %)	$\chi^2 = 0.117$, p = 1.000 ^f
	Gastrointestinal	1 (4.76%)	31 (15.98%)	- 11.22 % (- 21.68 % to - 0.75 %)	$\chi^2 = 1.101$, p = 0.328 ^f
	Neurological	0 (0.00%)	0 (0.00%)	0.00 % (0.00% to	$\chi^2 = \text{Nan}$, p = 1.000 ^f

Burden and Risk Factors of Healthcare-Associated Infections in a Pediatric Intensive Care Unit: A Prospective Study from India

				0.00 (%)	
	Complicated Infections	6 (28.57%)	66 (34.02%)	- 5.45% (- 25.89% to 14.99%)	$\chi^2 = 0.067$, $p = 0.808^f$
	Blood Stream Infection	1 (4.76%)	15 (7.73%)	- 2.97% (- 12.82% to 6.88%)	$\chi^2 = 0.003$, $p = 1.000^f$
	Surgical	0 (0.00%)	2 (1.03%)	- 1.03% (- 2.45% to 0.39%)	$\chi^2 = 0.000$, $p = 1.000^f$
	Others	0 (0.00%)	5 (2.58%)	- 2.58% (- 4.81% to - 0.35%)	$\chi^2 = 0.000$, $p = 1.000^f$
Neurological	Endocrine	0 (0.00%)	5 (2.58%)	- 2.58% (- 4.81% to - 0.35%)	$\chi^2 = 0.000$, $p = 1.000^f$
	Infectious	2 (66.67%)	10 (34.48%)	32.18% (- 23.90% to 88.26%)	$\chi^2 = 0.221$, $p = 0.540^f$
	Non-Infectious	1 (33.33%)	19 (65.52%)	- 32.18%	$\chi^2 = 0.221$, $p = 0.540^f$

				(- 88.26% to 23.90%)	$p = 0.540^f$
Outcome	Discharge	22 (91.67%)	199 (89.24%)	2.43% (- 9.35% to 14.21%)	$\chi^2 = 0.000$, $p = 1.000^f$
	LAMA/Refer	2 (8.33%)	22 (9.87%)	- 1.53% (- 13.26% to 10.20%)	$\chi^2 = 0.000$, $p = 1.000^f$

PICU: Pediatric intensive care unit, CI: confidence interval, LAMA: leave against medical advice

When it came to **patient outcomes**, there was no statistically significant difference between those with and without HAIs. Among the 24 HAI cases, 91.6% (22/24) were discharged, while 8.3% (2/24) were either referred or left against medical advice (LAMA). In the non-HAI group, 89.2% (199/223) were discharged, 9.8% (22/223) went LAMA or were referred, and 0.9% (2/223) died. Although the death rate was slightly higher in the non-HAI group, this difference did not reach statistical significance ($p > 0.05$) (see Table 1).

The use of medical assistive devices was found to be significantly associated with the development of healthcare-associated infections (HAIs), as detailed in **Table 2**. Specifically, the insertion of central lines ($\chi^2 = 5.550, p = 0.022$), placement of endotracheal tubes ($\chi^2 = 7.156, p = 0.013$), and need for mechanical ventilation ($\chi^2 = 7.156, p = 0.013$) were all significantly linked to a higher risk of HAI acquisition.

Table 2. Association between use of medical devices and healthcare associated infection

Parameters	Onset of New Infection		
	Yes (n = 24)	No (n = 223)	
Time of Onset (Days)	5.87 ± 3.06	7.67 ± 2.52	0.192 ¹
Foleys (Yes)	3 (12.5%)	3 (1.3%)	0.013
Foleys (Days)	9.00 ± 2.00	6.00 ± 3.00	0.233 ⁴
PICC Line (Yes)	1 (4.2%)	3 (1.3%)	0.337 ³
PICC Line (Days)	3.00 ± 0	2.33 ± 0.58	0.617 ¹

Burden and Risk Factors of Healthcare-Associated Infections in a Pediatric Intensive Care Unit: A Prospective Study from India

Central Line (Yes)***	3 (12.5%)	4 (1.8%)	0.022 ³
Central Line (Days)	7.33 ± 1.53	4.00 ± 2.45	0.079 ⁴
ETT (Yes)***	3 (12.5%)	3 (1.3%)	0.013 ³
ETT (Days)	7.33 ± 1.53	5.67 ± 2.52	0.393 ⁴
ICD (Yes)	1 (4.2%)	1 (0.5%)	0.187 ³
ICD (Days)	8.00 ± 0	13.00 ± 0	1.000 ¹
Ventilation***			0.006 ³
None	16 (66.7%)	190 (85.2%)	
Non-Invasive Ventilation	5 (20.8%)	30 (13.5%)	
Invasive Ventilation	3 (12.5%)	3 (1.3%)	

PICC: Peripherally inserted central catheter, **ETT:** endotracheal tube, **ICD:** intercostal drain

DISCUSSION

In this prospective observational study, we analyzed 1,783 patient-days from 247 children admitted to a PICU, identifying a Crude Infection Rate (CIR) of 9.7% for healthcare-associated infections (HAIs) based on CDC/NHSN definitions. This rate is comparable to global reports where HAI prevalence in ICUs ranges from 6.1% to 23.6% (12–14). According to the World Health Organization, approximately 10% of hospitalized patients develop HAIs, with incidence being higher in low- and middle-income countries and among high-risk groups such as those admitted to intensive care units (15,16).

Gastroenteritis emerged as the most common HAI in our cohort, accounting for 50% of the cases—an unusual finding compared to other studies that often report bloodstream infections or pneumonia as the predominant types (17,18). Our results were consistent with those of Patil et al. (19), whereas studies from Ethiopia and the United States reported pneumonia and bloodstream infections as the more frequent types of HAIs (17,20). This discrepancy is likely influenced by regional variations in sanitation, hygiene practices, and circulating pathogens. Although viral diagnostics could not be performed in our setting, the diagnosis of gastroenteritis was based on clinical criteria as per CDC definitions, similar to a Polish study where rotavirus was identified as a key cause of HA-GE (21).

Bloodstream infections were observed in 16.7% of the HAI cases, including two CLABSI and two hospital-acquired BSI. The device-associated infection rate for central lines was 52.6 per 1,000 central line days, with a device utilization (DU) ratio of 4%. Among the seven children requiring central venous catheterization, three (42.9%) developed HAIs—two of which were CLABSI. These

findings mirror those of Nair et al. (22) and Tomar et al. (24), and are consistent with international studies such as that by Kandirli et al. (18), where *Acinetobacter baumannii*, *Coagulase-negative Staphylococcus* (CONS), and *Candida albicans* were the most frequently isolated organisms. Maqbool and Sharma (25) similarly found *Acinetobacter* spp. as the most common pathogen in CLABSI cases.

Pneumonia accounted for 16.7% of the HAIs, with one patient developing ventilator-associated pneumonia (VAP). The VAP rate was calculated at 25.6 per 1,000 ventilator days, with a mean ventilation duration of 6.5 ± 2.07 days. Of the patients mechanically ventilated for over 48 hours, 50% developed HAIs, including one case of VAP. These results align with findings by Venmugil and Kumar (26), as well as larger cohort studies by Awasthi et al. and Van Wyk et al. (27), which emphasize the elevated HAI risk associated with mechanical ventilation. These findings underline the importance of strict implementation of ventilator care bundles and timely weaning protocols.

Urinary tract infections were rare in our study, with only one case documented, unrelated to catheter use. Despite a Foley catheter DU ratio of 4.7%, three of the six catheterized patients developed HAIs, though none were classified as CA-UTIs. The low incidence may be a reflection of rigorous adherence to CAUTI prevention bundles in our PICU. Several studies have established Foley catheterization as a risk factor for CA-UTI, suggesting that evidence-based bundle protocols can significantly mitigate infection risk.

Children who developed HAIs experienced significantly longer hospital and PICU stays. The mean hospital stay among these patients was 12.38 ± 7.08 days compared to 6.66 ± 3.05 days in non-HAI patients. Similarly, PICU stays were extended (6.96 ± 5.30 days vs. 3.55 ± 1.81 days), and both differences were statistically significant (p < 0.001). These findings are in line with those of Sodhi et al. (16) and Murni et al. (29), who also reported extended lengths of stay and increased care costs associated with HAIs.

Younger age was significantly associated with HAI acquisition. The mean age in the HAI group was 2.96 years, compared to 4.65 years among those who did not develop HAIs. Mohamed et al. (17) and de Mello MJ et al. (28) also found higher HAI susceptibility in children under five years, with infants and toddlers being at particular risk due to immunologic immaturity and greater exposure to invasive procedures.

Invasive device use was another significant factor. Central venous catheterization (p = 0.022), Foley catheterization (p = 0.013), and mechanical ventilation (p = 0.013) were all associated with higher HAI rates. The odds ratio for central

Burden and Risk Factors of Healthcare-Associated Infections in a Pediatric Intensive Care Unit: A Prospective Study from India

line use was 7.82 (95% CI: 1.64–37.31), and for Foley catheters and mechanical ventilation, it was 10.48 (95% CI: 1.99–55.19) each. These findings are consistent with earlier studies that show how devices compromise natural barriers and facilitate microbial entry, particularly through biofilm formation. Biofilms are implicated in the pathogenesis of CA-UTI, CLABSI, and VAP, contributing to persistent, treatment-resistant infections.

Length of PICU stay was both a contributor to and consequence of HAI, reflecting a cyclical burden on healthcare systems. Our findings are in agreement with those of Murni et al. (29), who found hospital stays beyond 7 days to be the strongest independent predictor of HAI, with additional risk from sepsis, catheter use, and non-standardized antibiotic therapy.

Although not statistically significant ($p = 0.0543$), all patients with HAI had received antibiotics, echoing existing literature linking indiscriminate antibiotic use with dysbiosis and increased susceptibility to opportunistic and multidrug-resistant pathogens (30,31). This highlights the need for strict antibiotic stewardship programs in PICU settings.

No significant association was found between nutritional status and HAI in our cohort, in contrast to studies that link malnutrition with impaired immunity and heightened infection risk. Fitzpatrick et al. (33) demonstrated that malnourished children, as measured by MUST scores, had a four-fold increased risk of HAI. Although our findings differed, routine nutritional assessment should still be prioritized, particularly in resource-limited settings.

Regarding outcomes, 89.5% of the enrolled children were discharged, 9.7% left against medical advice or were referred, and only 0.8% succumbed to their illness. The LAMA/refer group was primarily influenced by financial constraints—a common issue in LMICs. These outcomes are similar to previous Indian studies, such as one from central India reporting 80.2% discharges, 14.8% LAMA/referred cases, and 4.9% mortality (34).

While our study did not measure bundle compliance or implementation fidelity, our PICU follows standardized infection prevention protocols, including CAUTI and CLABSI bundles and strict hand hygiene. As highlighted in studies by Flanagan et al. (11), real-world challenges like staff shortages and non-adherence can limit the effectiveness of such protocols. Nevertheless, consistent application of evidence-based infection control measures remains essential in reducing the burden of HAIs in pediatric critical care settings.

CONCLUSION

Healthcare-associated infections continue to pose a significant challenge in PICUs, especially in resource-limited settings. Younger age, invasive device use, and

prolonged hospitalization were major risk factors. Gastroenteritis was the most common HAI, highlighting local epidemiological variation. Strengthening infection control practices, including timely device removal, adherence to care bundles, and improved surveillance, is essential to reduce HAI burden and improve pediatric outcomes.

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Burden and Risk Factors of Healthcare-Associated Infections in a Pediatric Intensive Care Unit: A Prospective Study from India

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Burden and Risk Factors of Healthcare-Associated Infections in a Pediatric Intensive Care Unit: A Prospective Study from India

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