EPIDEMIOLOGY AND TRENDS OF IMPORTANT PEDIATRIC HEALTHCARE-ASSOCIATED INFECTIONS AT SIRIRAJ HOSPITAL, THAILAND

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Abstract. There is limited data about the epidemiology of pediatric healthcare-associated infections (HAIs) in Thailand. The aim of this retrospective study was to evaluate the incidence and trends in pediatric HAI over a 5-year period at Siriraj Hospital, a tertiary care center in Bangkok, Thailand, in order to guide preparation for and management of HAI in this population. The study was conducted from 2009 to 2013. All episodes of HAI defined by the National Healthcare Safety Network (NHSN) were included in the study. During the study period, 1,685 episodes of HAI occurring among 1,482 patients were recorded. The incidences were: ventilator-associated pneumonia (VAP) 6.33/1,000 ventilator-days; central line-associated bloodstream infections (CLABSI) 5.06/1,000 catheter-days; hospital-acquired pneumonia (HAP) 2.02/1,000 patient-days; blood stream infection without intravenous catheter (BSI) 1.24/1,000 patient-days; and gastroenteritis (GE) 0.9/1,000 patient-days. The most common organism found in GE infections was rotavirus (76.9%). One-third (30.8%) of HAP were caused by viruses, with RSV identified as the causative pathogen in 45% of all respiratory virus infections. *Acinetobactor baumannii* and *Stenotrophomonas maltophilia* were the most common bacterial causes of VAP and HAP, respectively, while coagulase negative Staphylococci was the major cause of BSI and CLABSI. Most HAIs occurred in children aged < 1 year. Neonatal wards had a 2-fold and 4-fold decreasing trend for BSI and CLABSI, respectively, but a 5-fold increasing trend for rotavirus GE. No changes in incidences were seen in any other wards during the study period. The data from this study show the changes in pediatric HAI and point out the need to improve infection control strategies and compliance with policies.

Keywords: epidemiology, healthcare-associated infection, pediatric, Thailand

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INTRODUCTION

Healthcare-associated infections (HAIs) are preventable, but prevention requires continuous multidisciplinary interventions. Most HAI epidemiologic data is from developed countries; little data has been reported from developing countries (Raza *et al*, 2004; Pittet *et al*, 2008; Allegranzi *et al*, 2011). The World Health Organisation reported a higher prevalence of HAI from 1995 to 2010 from developing countries (5.7-19.1%) than developed countries (3.5-12%) (WHO, 2011).

Young children are at higher risk of developing a HAI than adults due to their immature immune systems. There are fewer reports of HAI among pediatric patients, especially from developing countries. The epidemiology of HAI in pediatric patients differs from adult patients (Posfay-Barbe *et al*, 2008). For example, viral gastroenteritis (GE) and respiratory tract infections (RTI) are more common among children than adults (Buettcher and Heininger, 2010; Sidler *et al*, 2012).

The aim of this study was to determine the epidemiology of HAI among pediatric patients at Siriraj Hospital, the largest tertiary hospital in Thailand. The results of this study will assist in developing infection control policies and add to the knowledge of HAI in pediatric patients in Thailand.

MATERIALS AND METHODS

This retrospective study was conducted at Siriraj Hospital, a 2,200 bed university-based national referral center located in Bangkok. The hospital has 350 tertiary care pediatric beds. The children included in this study were hospitalized in three general pediatric wards, one general neonatal ward, three pediatric intensive care units (PICUs) and one neonatal intensive care unit (NICU).

Surveillance of HAI is routinely conducted by the Hospital Infection Control Department in these wards. We retrospectively analysed data from 1 January 2009 to 31 December 2013. Nosocomial outbreaks were included in the analysis.

Routine HAI surveillance and monitoring was conducted twice a week during the study period. The definition of HAI used for this study was obtained from the US National Healthcare Safety Network (NHSN) of the US Centers for Disease Control and Prevention (CDC) (Horan *et al*, 2008; CDC 2013a,b). A HAI is defined as a new onset infection occurring beginning 48 or more hours after admission to the hospital. The definitions for each type of HAI in this study are summarized in Table 1.

The viral etiology of respiratory tract infections (RTI) was identified using a nasopharyngeal or tracheal washing sample for immunofluorescent assay for 7 common respiratory viruses: influenza A and B, parainfluenza 1, 2, and 3, adenovirus, and respiratory syncytial virus (RSV). For patients with influenza-like illness or episodes that developed during influenza outbreaks, respiratory samples were also sent for a rapid test and/or a reverse transcription polymerase chain reaction testing for influenza. Stool samples were obtained from patients with GE and examined for rotavirus antigen detection using an immunochromatography assay and bacterial pathogen culture. For patients with hospital acquired pneumonia (HAP) or ventilator associated pneumonia (VAP), endotracheal or lower respiratory tract samples obtained from bronchoalveolar lavage, pleural effusion, or lung tissue were sent for bacterial culture. Blood cultures were routinely obtained in patients

Table 1
Definitions of specific healthcare-associated infections.

Type of healthcare-associated infections	Definition
Gastroenteritis	New onset acute diarrhea and/or nausea, vomiting and/or abdominal pain with or without fever after at least 48 hours hospitalization.
Hospital-acquired pneumonia (HAP)	New onset after at least 48 hours of hospitalization of fever or hypothermia with lower respiratory tract symptoms and/or respiratory difficulty and/or worsening of blood gas results, and new pulmonary infiltrations on chest X-ray in non-intubated children. In neonates, pulmonary conditions diagnosed by attending neonatologists that might mimic HAP and perinatal-acquired infections were excluded.
Ventilator-associated pneumonia (VAP)	Pneumonia that occurring at least 2 calendar days after endotracheal intubation or within 2 calendar days after endotracheal extubation. Among neonates, pulmonary conditions that were diagnosed by the attending neonatologist that might mimic VAP or perinatal-acquired infections were excluded.
Blood stream infections (BSI)	New onset fever and with at least 1 positive blood culture specimen for general pathogens or at least 2 specimens for common skin flora. Among neonates, a single positive blood culture specimen for common skin flora with clinical sepsis diagnosed by the attending neonatologist was also defined as a BSI.
Central line-associated bloodstream infections	A BSI occurring 2 calendar days following central venous catheter placement or within 2 calendar days after central venous catheter removal.

Definition from Horan *et al* (2008); CDC (2013a,b).

with VAP, HAP, suspected blood stream infections without an intravenous catheter (BSI) and suspected central line-associated bloodstream infections (CLABSI). A single blood culture that grew coagulase negative staphylococci without compatible clinical symptoms was not considered to be a BSI or a CLABSI.

The diagnosis of HAI was made by the attending physician and the infection control surveillance team. All pediatric wards in the study hospital are open wards with multiple patients per room except for the pediatric cardiac intensive care unit (CCU) which has single patient rooms. Only patients with identifiable pathogens were included in the analysis for CLABSI and BSI, because a definite diagnosis could not be established base on clinical symptoms alone. However, the diagnoses of GE and pneumonia were made base on clinical symptoms and chest radiography. It is difficult to obtain lower respiratory tract specimens from children with HAP if the patient is not intubated. Therefore, in order to prevent

underestimation of the incidences of GE, HAP and VAP due to insufficient laboratory investigations, all patients with GE, HAP, and/or VAP were included whether the etiological agent was identified or not.

The incidence, trend, patients' age, and etiologic agents were analyzed for common HAI that found in most wards including GE, HAP, VAP, BSI, and CLABSI. Incidence of non-device-associated HAI was presented as the rate per 1,000 patient-days. The incidence rates for VAP and CLABSI were presented as the rate per 1,000 ventilator-days and catheter-days, respectively. Denominators were calculated from the number of patients hospitalized, who were on a ventilator or who had a central venous catheter during the study period. The denominators used to calculate the incidences of HAP and BSI were calculated from the patient-days minus the ventilator-days or catheter-days, respectively. The device utilization ratio was obtained by dividing the number of device-days by the number of patient-days for each ward during the study period. Proportions, percentages, medians and ranges were calculated using Microsoft Excel 2013 software (Redmond, WA).

The protocol for this study was approved by the Siriraj Institutional Review Board (SIRB), Faculty of Medicine, Siriraj Hospital, Mahidol University.

RESULTS

During the 5-year study period, 18,500 patients were hospitalized in the studied wards and 1,685 episodes of HAI occurred among 1,482 patients including: GE (160, 9.5%), HAP (295, 17.5%), VAP (200, 11.9%), BSI (171, 10.1%), CABSI (199, 11.8%), necrotizing enterocolitis (NEC) (201, 11.9%), skin and soft tissue infections (SSTI) (170, 10.1%), urinary tract infections (UTI) (84, 5.0%), catheter-related urinary tract infections (CAUTI) (46, 2.7%), upper respiratory tract infections (46, 2.7%), eye infections (28, 1.7%), omphalitis (21, 1.2%), surgical site infections (SSI) (20, 1.2%), peritonitis (12, 0.7%), central nervous system (CNS) infection (11, 0.7%), ear infections (7, 0.4%), oral cavity infections (5, 0.3%) and others (9, 0.53%). Proportions of HAI types are presented in Fig 1.

The baseline characteristics of the patients with the 5 most common HAI that found in most wards are shown in Table 2. Most BSI occurred in the general neonatal wards, while episodes of VAP and CLABSI occurred mainly in the intensive care units. Most of HAI occurred among patients aged < 1 year (696, 67.9%).

There were 177,689 patient-days, 31,593 ventilator-days, and 39,305 catheter-days among these device associated infections. The incidence rates for each HAI by ward type are summarized in Table 3. Ratios for device utilization in the general neonatal ward, general pediatric ward, NICU, and PICU were 0, 0.04, 0.62, and 0.61 for ventilators, and 0.08, 0.08, 0.60, and 0.67 for central venous catheters, respectively. There was occasional use of mechanical ventilators on general pediatric wards, mostly for transitional care or for chronic pulmonary disease that required long-term ventilator use, but there were no ventilators use on general neonatal wards. The PICU had a slightly higher incidence of VAP than the NICU (7.78; 95% CI: 6.4-9.3 *vs* 5.38; 95% CI: 4.2-6.8/1,000 ventilator-days), but had a slightly lower incidence of CLABSI than the NICU (4.57; 95% CI: 3.6-5.7 *vs.* 5.58;95% CI: 4.4-7.0/1,000 catheter-days). The differences between the PICU and NICU; however, were not significant.

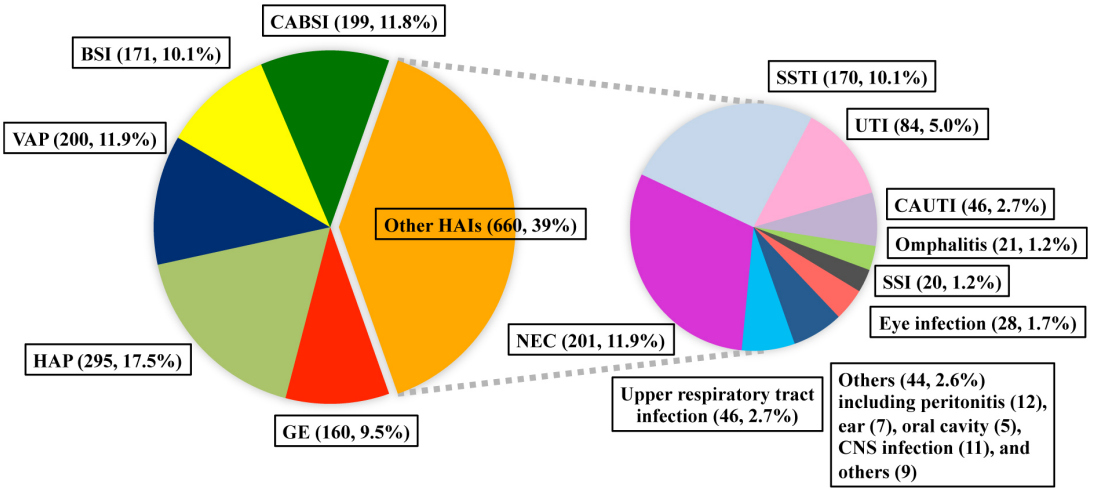

Fig 1–Proportions of common healthcare-associated infections among pediatric patients at Siriraj Hospital from 2009 to 2013 (*n*, %). HAI, healthcare-associated infection; GE, gastroenteritis; HAP, hospital acquired pneumonia; VAP, ventilator associated pneumonia; BSI, blood stream infections; CABSI, catheter associated blood stream infections; NEC, necrotizing enterocolitis; SSTI, skin and soft tissue infections; UTI, urinary tract infections; CAUTI, catheter associated urinary tract infections; SSI, surgical site infections; CNS, central nervous system.

There were no significant changes in incidence of HAI over the study period in the pediatric wards and the PICU. However, there was a significant increase in the incidence of GE (from 0.79 in 2009 to 4.13 in 2013) in the general neonatal wards over the study period due to a nosocomial rotavirus outbreak in 2013, and a significant decreased in the incidence of BSI (from 2.33 in 2009 to 1.17 in 2013) and CLABSI (from 12.2 in 2009 to 3.13 in 2013) in the NICU and general neonatal wards over the study period (Fig 2). A rotavirus GE outbreak occurred in the neonatal ward resulting in nearly half the rotavirus GE patients during 2013 (28 newborn infants) being due to this outbreak which took about 3 months to control.

The episodes of HAI and their causative pathogens are summarized in Table 4. The top 5 organisms causing HAI are shown in Fig 3. RSV and parainfluenza were the most common causes of HAP (30.8%), followed by *Pseudomonas aeruginosa* (9.8%). We found *Acinetobacter baumannii* (38%) was the most common cause of VAP.

Rotavirus was the most common cause of GE (76.9%) in the general pediatric ward and general neonatal ward, followed by *Salmonella* GE (13.1%). The most common cause of BSI and CLABSI was methicillin resistant coagulase-negative staphylococci (MRCNS).

Rates of antimicrobial resistance were high. Fourteen of 39 isolates (35.9%) of *S. aureus* obtained from blood cultures or lower respiratory tract specimens were methicillin resistant (MRSA). Carbapenem resistance occurred in 65.4% of *A. baumannii* isolates and 16.4% of *P. aeruginosa* isolates. ESBL production was found in 65.9% of *K. pneumoniae* and 51.4% of *E. coli* isolates.

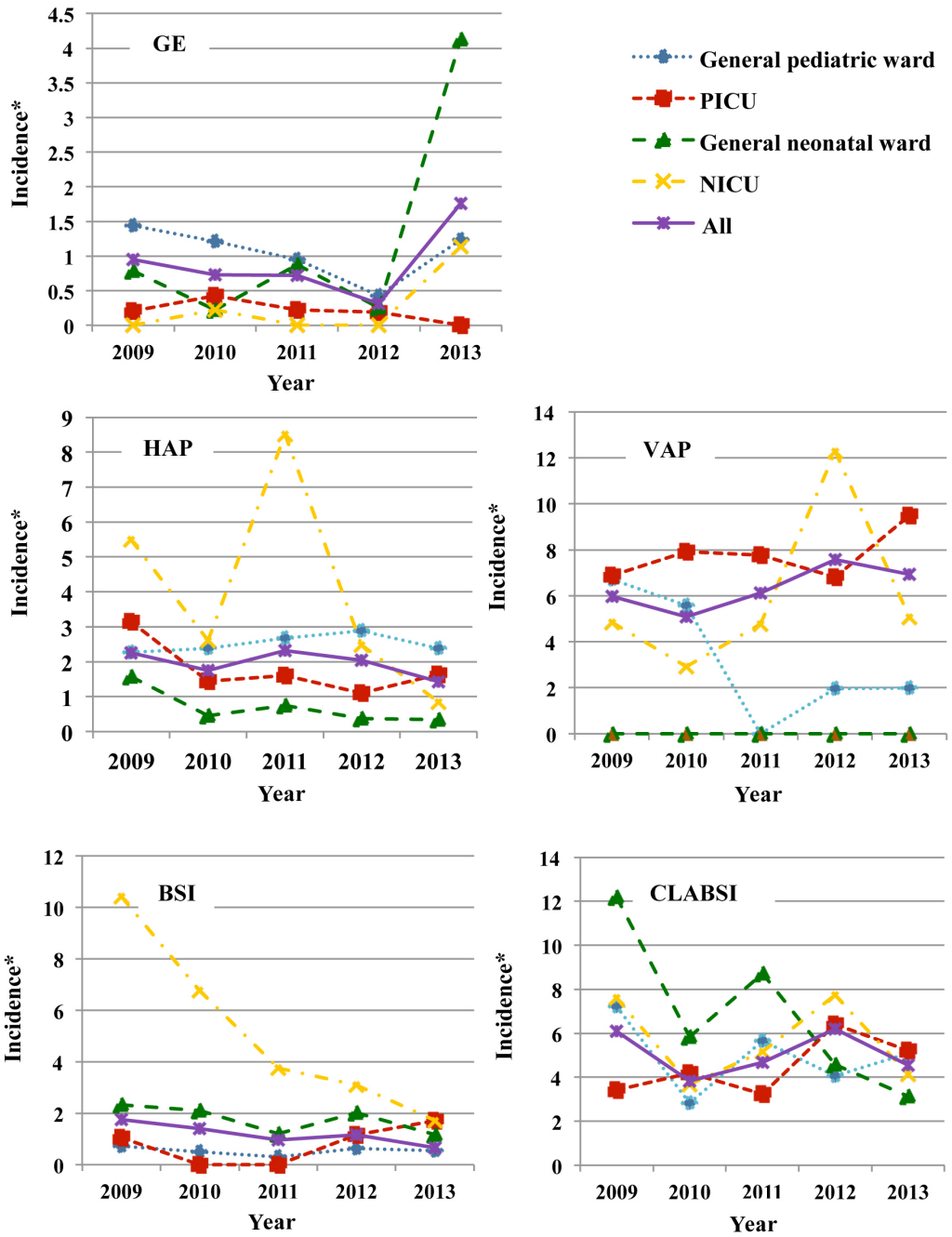

Fig 2–Incidence of common healthcare-associated infections by ward and year among pediatric patients at Siriraj Hospital from 2009 to 2013. *Incidence of GE, HAP, and BSI = episodes/1,000 patient-days; incidence of VAP = episodes/1,000 ventilator-days; incidence of CLABSI = episodes/1,000 catheter-days. GE, gastroenteritis; HAP, hospital-acquired pneumonia; VAP, ventilator-associated pneumonia; BSI, blood stream infections; CLABSI, central line-associated blood stream infections; NICU, neonatal intensive care unit; PICU, pediatric intensive care unit.

Table 2
Characteristics of common healthcare-associated infections among pediatric patients at Siriraj Hospital from 2009 to 2013.

HAI	GE	HAP	VAP	BSI	CLABSI	Total *n* (%)
Number of episodes, *n* (%)	160 (15.6)	295 (28.8)	200 (19.5)	171 (16.7)	199 (19.4)	1,025 (100)
Male, *n* (%)	79 (49.4)	143 (48.5)	117 (58.5)	85 (49.7)	97 (48.7)	521 (50.8)
Ward types, *n* (%)						
General wards	149 (25.5)	249 (42.6)	13 (2.2)	121 (20.7)	53 (9)	585 (100)
Neonatal wards	55 (30.4)	32 (17.7)	0 (0)	76 (42)	18 (9.9)	181 (100)
Pediatric wards	94 (23.3)	217 (53.7)	13 (3.2)	45 (11.1)	35 (8.7)	404 (100)
Intensive care units	11 (2.5)	46 (10.5)	187 (42.5)	50 (11.4)	146 (33.1)	440 (100)
NICU	6 (2.8)	29 (13.2)	70 (32)	43 (19.6)	71 (32.4)	219 (100)
PICU	5 (2.3)	17 (7.7)	117 (52.9)	7 (3.2)	75 (33.9)	221 (100)
Age in months						
Median age (range)	5 (0.03-168)	9 (0.03-180)	2.5 (0.03-204)	0.27 (0.03-192)	2 (0.03-204)	3 (0.03-204)
Age group, *n* (%)						
Age ≤1 month	58 (15.4)	55 (14.6)	76 (20.2)	111 (29.5)	76 (20.2)	376 (100)
Age 1-12 months	55 (17.2)	105 (32.8)	66 (20.6)	25 (7.8)	69 (21.6)	320 (100)
Age 1-5 years	42 (18.8)	96 (43)	32 (14.3)	21 (9.4)	32 (14.3)	223 (100)
Age >5 years	5 (4.7)	39 (36.8)	26 (24.5)	14 (13.2)	22 (20.8)	106 (100)
Specimen submitted, *n* (%)	158 (16.5)	237 (24.7)	194 (20.2)	171 (17.8)	19 (20.8)	959 (100)
Pathogen identified	148 (17.1)	166 (19.3)	177 (20.6)	171 (19.9)	199 (23.1)	861 (100)

HAI, healthcare-associated infection; GE, gastroenteritis; HAP, hospital-acquired pneumonia; VAP, ventilator-associated pneumonia; BSI, blood stream infections; CLABSI, central line-associated blood stream infections; NICU, neonatal intensive care unit; PICU, pediatric intensive care unit; *n*, number.

Table 3
Incidence of common healthcare-associated infections among pediatric patients at Siriraj Hospital by ward type from 2009 to 2013.

Ward type		HAI					Remarks
		GE	HAP	VAP	BSI	CLABSI	
General neonatal wards	Episodes, *n*	55	32	0	76	18	42,506 patient-days
	Incidence[a]	1.29	0.75	0	1.94	5.49	0 ventilator-days
							3,281 catheter-days
							42,506 patient-days (HAP)[b]
							39,225 patient-days (BSI)[b]
General pediatric wards	Episodes, *n*	94	217	13	45	35	89,511 patient-days
	Incidence[a]	1.05	2.52	3.67	0.55	5.07	3,543 ventilator-days
							6,902 catheter-days
							85,968 patient-days (HAP)[b]
							82,609 patient-days (BSI)[b]
NICU	Episodes, *n*	6	29	70	43	71	21,127 patient-days
	Incidence[a]	0.28	3.58	5.38	5.12	5.58	13,020 ventilator-days
							12,722 catheter-days
							8,107 patient-days (HAP)[b]
							8,405 patient-days (BSI)[b]
PICU	Episodes, *n*	5	17	117	7	75	24,545 patient-days
	Incidence[a]	0.2	1.79	7.78	0.86	4.57	15,030 ventilator-days
							16,400 catheter-days
							9,515 patient-days (HAP)[b]
							8,145 patient-days (BSI)[b]
All wards	Episodes, *n*	160	295	200	171	199	17,7689 patient-days
	Incidence[a]	0.9	2.02	6.33	1.24	5.06	31,593 ventilator-days
	(95% CI)	(0.77-1.05)	(1.80-2.26)	(5.51-7.27)	(1.06-1.43)	(4.41-5.82)	39,305 catheter-days
							14,6096 patient-days (HAP)[b]
							13,8384 patient-days (BSI)[b]

[a]Incidence of GE, HAP and BSI = episodes / 1,000 patient-days; incidence of VAP = episodes / 1,000 ventilator-days; incidence of CLABSI = episodes / 1,000 catheter-days.
[b]The denominators of HAP and BSI incidences were calculated from patient-days minus ventilator-day or catheter-day, respectively.
GE, gastroenteritis; HAP, hospital-acquired pneumonia; VAP, ventilator-associated pneumonia; BSI, blood stream infections; CLABSI, central line-associated blood stream infections; NICU, neonatal intensive care unit; PICU, pediatric intensive care unit; *n*, number.

Table 4
Causative pathogens for common healthcare-associated infections among pediatric patients at Siriraj Hospital from 2009 to 2013.

Identified pathogen	HAIs; *n*[a] (%) (*n*=1,025)	Overall rank	GE; *n*[a] (%) (*n*=160)	HAP; *n*[a] (%) (*n*=295)	VAP; *n*[a] (%) (*n*=200)	BSI; *n*[a] (%) (*n*=171)	CLABSI; *n*[a] (%) (*n*=199)
MRCNS	169 (16.5)	1	0	0	0	81 (47.4)	88 (44.2)
Acinetobacter baumannii	133 (13.0)	2	0	17 (5.8)	76 (38)	10 (5.8)	30 (15.1)
Rotavirus	123 (12)	3	123 (76.9)	0	0	0	0
Klebsiella pneumoniae	82 (8)	4	0	18 (6.1)	18 (9)	22 (12.9)	24 (14.6)
Pseudomonas aeruginosa	67 (6.5)	5	0	29 (9.8)	29 (14.5)	4 (2.3)	5 (2.5)
Stenotrophomonas maltophilia	50 (4.9)	6	0	6 (2.0)	40 (20)	1 (0.6)	3 (1.5)
Respiratory syncytial virus	45 (4.4)	7	0	41 (13.9)	4 (2)	0	0
Escherichia coli	35 (3.4)	8	0	13 (4.4)	5 (2.5)	9 (5.3)	8 (4.0)
Parainfluenza	33 (3.2)	9	0	33 (11.2)	0	0	0
Candida spp	32 (3.1)	10	0	0	11 (5.5)	6 (3.5)	15 (7.5)
Staphylococcus aureus	25 (2.4)	11	0	5 (2.4)	13 (6.5)	4 (2.3)	3 (1.5)
Salmonella	23 (2.2)	12	21 (13.1)	0	0	2 (1.2)	0
Gram-negative non-fermenters	18 (1.8)	13	0	1 (0.3)	8 (4)	4 (2.3)	5 (2.5)
Enterobacter spp	17 (1.7)	14 (tie)	0	6 (2.0)	5 (2.5)	6 (3.5)	0
Enterococcus spp	17 (1.7)	14 (tie)	0	0	0	4 (2.3)	13 (6.5)
MRSA	14 (1.4)	15	0	2 (0.7)	8 (4)	1 (0.6)	3 (1.5)
Influenza	13 (1.3)	16	0	13 (4.4)	0	0	0
Unidentifiable pathogen	98 (9.6)	-	10 (6.3)	71 (24.1)	17 (34)	0	0
Other organisms[b]	82 (8.0)	-	7 (4.4)	10 (3.4)	18 (9)	22 (12.9)	25 (12.6)

[a]*n* indicates the number of HAI episodes, with some episodes having more than one pathogen identified.
[b]Other organisms (82) included: *Serratia* spp (8), Adenovirus (4), *Streptococcus pneumoniae* (2), *Vibrio* spp (1), *Shigella* spp (1), *Aeromonas* spp (1), *Morganella* spp (1), *Streptococcus pyogenes* (1), *Haemophilus influenzae* (1), *Clostridium difficile* (1), and others (61).
HAI, healthcare-associated infection; GE, gastroenteritis; HAP, hospital-acquired pneumonia; VAP, ventilator-associated pneumonia; BSI, blood stream infections; CLABSI, central line-associated blood stream infections; *n*, number; MRCNS, methicillin-resistant coagulase-negative staphylococci; MRSA, methicillin-resistant *Staphylococcus aureus*; *n*, number.

DISCUSSION

The knowledge about pediatric HAI in developing countries and in this region is limitedly available. We collected the 5-year HAI episodes in pediatric wards and conducted further detailed analysis on GE, HAP, VAP, BSI and CLABSI which were the most common HAI and responsible for about 60% of pediatric patients with HAI during the study period at the study hospital.

HAP was the most common HAI identified in this study, followed by VAP, BSI, and CLABSI. Nearly 30% of all HAI were either HAP or VAP. Most studies from developed and developing countries report the most common pediatric HAI to be bloodstream infection, followed by pneumonia (Stover *et al*, 2001; Grohskpof *et al*, 2002; Urrea *et al*, 2003; Tantracheewathorn *et al*, 2007; Becerra *et al*, 2010). Those reports, however, were primarily from studies conducted in the ICU. Our

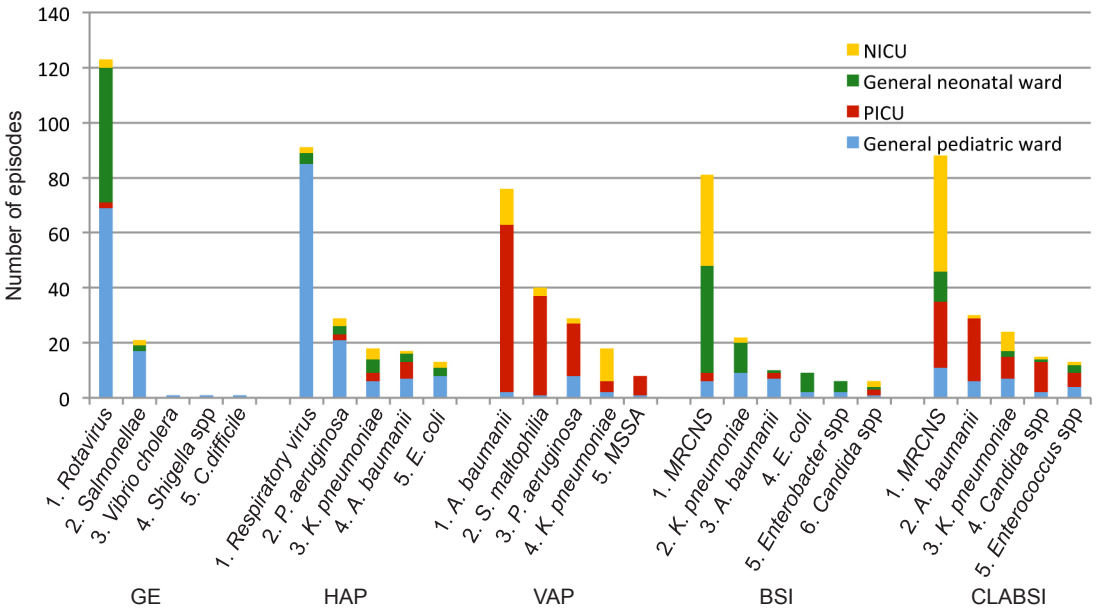

Fig 3–Distribution of the 5 most common identified pathogens of healthcare-associated infections among pediatric patients at Siriraj Hospital from 2009 to 2013. GE, gastroenteritis; HAP, hospital-acquired pneumonia; VAP, ventilator-associated pneumonia; BSI, blood stream infections; CLABSI, central line-associated blood stream infections; NICU, neonatal intensive care unit; PICU, pediatric intensive care unit; MSSA, methicillin sensitive *Staphylococcus aureus*; MRCNS, methicillin resistant coagulase negative staphylococci.

findings were consistent with the aforementioned findings when we considered only ICU data, BSI and CLABSI were the most common HAI among intensive care settings. We found HAP incidence to be very high and occurred mainly in general pediatric wards. Therefore HAP may be underestimated if general wards are not included in the analysis. Studies from Brazil, India, China, Taiwan, and Cambodia report HAP to be the most common HAI as well (Su *et al*, 2007; Gupta *et al*, 2011; Tao *et al*, 2012; Stoesser *et al*, 2013; da Silva *et al*, 2014).

In our study, we found high rates of VAP and CLABSI in the PICU and NICU. Korbkitjareon *et al* (2011) found bundling of infection control measures to be effective in reducing the incidence of HAI among adult patients at our study hospital. Incidence rates after intervention were then used as hospital benchmarks: 7 episodes VAP/1,000 ventilator-days and 3 episodes CLABSI/1,000 catheter-days. Compared to our hospital benchmarks in adult patients, the incidence of VAP in the NICU was lower and the incidences of CLABSI in both the NICU and the PICU were higher than the benchmarks. These findings concurred with studies from other countries stating the higher VAP rates and lower CLABSI rates among adult patients (Dudeck *et al*, 2013; Rosenthal *et al*, 2014). A meta-analysis of HAI among adult ICU patients in Southeast Asia (Ling *et al*, 2015) reported a higher incidence of VAP (14.7 episodes/1,000 ventilator-days; 95% CI: 11.7-17.7) and the same incidence

of CLABSI (4.7 episodes/1,000 catheter-days; 95% CI: 2.9-6.5) compared to our results.

Navoa-Ng *et al* (2011) reported the incidences of VAP in the NICU and the PICU in the Philippines of 0.44 and 12.8/1,000 ventilator-days, and of CLABSI in the NICU and the PICU of 9.6 and 8.2/1,000 catheter-days, respectively. We found lower rates of VAP in the PICU and lower rates of CLABSI in the PICU and the NICU.

The US CDC/NHSN reported the incidence rates VAP in the NICU and the PICU to be 0.2 and 0.8 episodes/1,000 ventilator-days, respectively (Dudeck *et al*, 2013) and for CLABSI, to be 0.6 and 1.4 episodes/1,000 catheter-days in NICU and PICU, respectively. The International Nosocomial Infection Control Consortium (INICC) reported the incidence rates for VAP and CLABSI in 57 PICUs and 38 NICUs (Rosenthal *et al*, 2014). Most of the ICUs in the report were located in developing countries. The pooled mean incidences of VAP were 10.7 and 7.9 episodes/1,000 ventilator-days for the NICU and the PICU, respectively. The pool mean incidences of CLABSI were 4.8 and 6.1 episodes/1,000 catheter-days for the NICU and the PICU, respectively. Our study found incidence rates of 3 to 30-fold higher than that reported by the CDC/NHSN and slightly lower incidence rates than that reported by the INICC.

The INICC reported a decreasing trend in the incidence of CLABSI in the NICU during the study period (2007-2012), but no changes were seen in the other HAIs (Rosenthal *et al*, 2014). In our study, the neonatal wards also had a decrease in bloodstream infection, with and without intravenous catheter overtime. This may be due to better respirators, intravenous catheters, and other medical devices that have become more widely available for neonatal use over the past decade.

More than half of all diarrheal HAI in children are viral (Posfay-Barbe *et al*, 2008; Cunliffe *et al*, 2010). In our study, rotavirus was the most common cause of GE, accounting for nearly 3 times more cases of GE than other causes. This is similar to a study by Lam *et al* (1989) from Hong Kong that found rotavirus to be 3.4 times more common than bacteria as the cause of nosocomial diarrhea in children. Other studies have also found rotavirus to be the most common cause of diarrheal HAI in developed and developing countries with proportion of causative organisms ranging from 50-75% infecting children primarity age < 5 years (Buettcher and Heininger, 2010; Cunliffe *et al*, 2010; Sidler *et al*, 2012; Ogilvie *et al*, 2012).

There were nosocomial associated outbreaks of rotavirus GE in 2012 and 2013 in neonatal wards of our study hospital. It took three months to control the 2013 outbreak despite strict contact precautions. A prolonged outbreak in the community may have contributed to the uncontrolled nosocomial outbreak that developed at our center. These outbreaks illustrate the highly contagiousness nature of rotavirus and the importance of persistent adherence to infection control practices.

We found RSV to be the most common causes of HAP, similar to a study from Canada (Vayalumkal *et al*, 2009). Children do not have good body secretions hygiene and have close contact with ward staff. These factors facilitate the spread of this virus in open pediatric wards, such as those in our hospital.

In our study, gram-negative bacilli were the most common bacterial cause

of HAP and VAP similar to the finding of other studies (Sritippayawan *et al*, 2009; Rosenthal *et al*, 2012; da Silva *et al*, 2014). About 40% of VAP and 15% of HAP in our study were due to *A. baumannii* and *P. aeruginosa,* similar to a study by Sritippayawan *et al* (2009) who conducted a cross-sectional survey of the PICU at another Thai university hospital and found *A. baumannii* (47%) and *P. aeruginosa* (24%) were the most common causes of VAP. A study of 8 PICUs from 5 developing countries found *P. aeruginosa* (57%) to be the most common cause of VAP, follow by *A. baumannii* (21%) (Rosenthal *et al*, 2012).

We found more carbapenem-resistant *A. baumannii* in pediatric wards and the PICU than in the neonatal ward and NICU. Two-thirds of *A. baumannii* isolates were carbapenem-resistant strains, similar to a report from another Thai university (Sritippayawan *et al*, 2009). Previous broad-spectrum antibiotic use is associated with increasing drug-resistance. We found a lower rate of carbapenem resistance among *P. aeruginosa* in our study than in a previous study from Thailand (Sritippayawan *et al*, 2009).

In our study, 45% of BSI and CLABSI were caused by MRCNS. This incidence is similar to those reported in other previous studies (30-65%) (Wisplinghoff *et al*, 2003; Henderson *et al*, 2013; da Silva *et al*, 2014). A study from northern Thailand found 70% bacteremia infections were due to gram-negative bacteria and 25% were due to gram-positive bacteria, with *Staphylococcus aureus* being identified as the most common gram-positive bacteria found in their study (Hongsuwan *et al*, 2014); however, all MRCNS isolated in that study were excluded as pathogens.

Our study had several limitations. First, it was a retrospective study that used routine surveillance data without systematic data verification. Second, laboratory detection of pathogens was made with routine technique available. There may have been pathogens not detected with routine testing. Additional viral pathogens may have been identified if other viral detection tests were available. HAP and VAP are often difficult to distinguish from other neonatal conditions, such as respiratory distress syndrome (RDS), meconium aspiration syndrome (MAS), transient tachypnea of the newborn (TTNB), bronchopulmonary dysplasia (BPD), and perinatal infections. This difficulty in differentiating conditions may have resulted in an over-reporting of HAI. However, we excluded those conditions if they were diagnosed by attending neonatologists. Finally, this study was conducted at a single center, so our results are not generalizable to other settings.

In conclusion, the information from this study is useful for guiding and improving infection control strategies and clinical management of pediatric HAI at the study hospital. VAP and CLABSI were the major HAIs among study subjects during the study period at our center. Continuous monitoring of HAI and continuous improving and adapting infection control strategies are need at the study hospital in the studied units.

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