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Emerging Problems in Infectious Diseases

Device-associated infections in the pediatric intensive care unit at the American University of Beirut Medical Center

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Abstract

Introduction: Device-associated healthcare-associated infections (DA-HAIs) are the principal threat to patient safety in intensive care units (ICUs). The primary objective of this study was to identify the most common DA-HAIs in the pediatric intensive care unit (PICU) at the American University of Beirut Medical Center (AUBMC). Length of stay (LOS) and mortality, antimicrobial resistance patterns, and suitability of empiric antibiotic choices for DA-HAIs according to the local resistance patterns were also studied.

Methodology: This was a retrospective study that included all patients admitted to the PICU at AUBMC between January 2007 and December 2011. All patients admitted to the PICU having a placed central line, an endotracheal tube, and/or a Foley catheter were included. Data was extracted from the patients' medical records through chart review. A total of 22 patients were identified with 25 central line-associated bloodstream infections (CLABSI), 25 ventilator-associated pneumonia (VAP), and 9 catheter-associated urinary tract infections (CAUTIs). The causing organisms, their resistance patterns, and the appropriateness of empiric antimicrobial therapy were reported.

Results: Gram-negative pathogens were found in 53% of the DA-HAIs, Gram-positive ones in 27%, and fungal organisms in 20%. A total of 80% of *K. pneumonia* isolates were extended-spectrum beta-lactamases (ESBL) producers, and 30% of *Pseudomonas* isolates were multidrug resistant. No methicillin-resistant *Staphylococcus aureus* (MRSA) or vancomycin-resistant enterococci (VRE) were isolated. Based on culture results, the choice of empiric antimicrobial therapy was appropriate in 64% of the DA-HAIs.

Conclusions: After the care bundle approach is adopted in our PICU, DA-HAIs are expected to decrease further.

Key words: device-associated infections; healthcare-associated infections; CLABSI; VAP; CAUTI; PICU.

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Introduction

Healthcare-acquired infections (HAIs) are a major cause of morbidity and mortality, prolonged hospital stays, and greater healthcare costs worldwide. The extensive use of invasive devices in patients in intensive care units (ICUs) puts them at a particularly increased risk of infection. The leading causes of death in non-cardiac intensive care units (ICUs) are infections and sepsis [1]. In most hospitals, the ICU-acquired infections account for more than 20% of all nosocomial infections [2]. The point prevalence for pediatric intensive care unit (PICU)-acquired infections in the United States ranges around 12%–15% among patients in PICUs [3].

Device-associated healthcare-associated infections (DA-HAI) are the principal threat to patient safety in the ICUs, complicating patient care in both low- and high-income countries [4]. The implications include prolonged hospital stay, long-term disability, increased resistance of microorganisms to antibiotics, massive additional financial burden for healthcare systems, high costs for patients and their families, and unnecessary deaths. In medical and surgical PICUs in the US, the rate of central line-associated bloodstream infections (CLABSIs) is 1.43 per 1,000 central line-days [5]. The rate of urinary catheter-associated urinary tract infections (CAUTIs) is 2.71 per 1,000 urinary catheter-days and that of ventilator-associated pneumonia (VAP) is 0.77 per 1,000 ventilator-days [5].

The World Health Organization (WHO) assessed the rates of DA-HAIs in the ICUs of low- and middle-income countries in a systematic review [4]. The rate of CLABSI was 12.2 per 1,000 central line-days, CAUTI was 12.2 per 1,000 urinary catheter-days, and VAP was 23.9 per 1,000 ventilator-days. Another study from the Philippines investigated the rates of DA-HAI in nine adult, pediatric, and neonatal ICUs of three hospital members of the International Nosocomial Infection Control Consortium (INICC) and found that the rate of CLABSI was 4.6 per 1,000 central line-days, CAUTI was 4.2 per 1,000 urinary catheter-days, and VAP was 16.7 per 1,000 ventilator-days [6].

Since 1985, the Centers for Disease Control and Prevention (CDC) has established the efficacy of infection surveillance and control programs in reducing nosocomial infections in the United States [7]. Implementation of such programs reduced nosocomial infections by 32%. The DA-HAI surveillance played an important role in reducing the rates of HAIs and improving hospital infection control and quality assurance in developed countries [8,9]. National surveillance systems for HAIs exist in several high-income countries but are virtually nonexistent in most low- and middle-income countries.

In a study of PICUs from 16 countries with limited resources, the INICC found that lower-middle-income countries had higher rates of CLABSI, VAP, and CAUTI than did upper middle-income countries: 12.2 vs. 7.0 per 1,000 central line-days, 9.0 vs. 5.4 per 1,000 ventilator-days, and 5.9 vs. 3.7 per 1,000 urinary catheter-days, respectively [10]. In a Thai PICU, the rate of HAIs was 28.3 per 1,000 patient-days [11]. In a Brazilian PICU, the rate of VAPs was 27.1 per 1,000 ventilator-days [12]. In a Peruvian PICU, the rates of BSIs, VAPs and UTIs were 18.1 per 1,000 central venous catheter (CVC)-days, 7.9 per 1,000 endotracheal tube (ETT)-days, and 5.1 per 1,000 urinary catheter-days respectively [13]. The findings of the INICC in Egypt from two PICUs were 22.8 DA-HAIs per 1,000 ICU-days, 18.8 CLABSIs per 1,000 line-days, and 31.8 VAPs per 1,000 ventilator-days [14]. In a Tunisian PICU, the rate of CVC-associated infections was 14.8 per 1,000 catheter-days [15].

Very few studies describe the pattern of DA-HAIs in PICUs in the Middle East region, or in Lebanon specifically. The aim of this study was to identify the most common types of DA-HAIs in the PICU at the American University of Beirut Medical Center (AUBMC). Secondary aims included assessing the length of stay (LOS) and mortality, as well as studying the antimicrobial resistance pattern and the adequacy of empiric antibiotic choices for DA-HAIs according to the local resistance patterns. We also discuss the benefits of the adopted Institute for Healthcare Improvement bundles of interventions that are aimed at minimizing DA-HAIs.

Methodology

Setting and study design

AUBMC is a tertiary-care center in Beirut and a major referral center for Lebanon and its neighboring countries. The pediatric ICU consists of an eight-bed closed unit that admits surgical and medical pediatric and adolescent patients (up to 21 years of age) and accepts referral from other hospitals. A team of house staff officers runs the unit under the supervision of a pediatric intensivist. The nurse-to-patient ratio during the study period was 1:1–2. The Infection Control and Prevention Program (ICPP) collects data on all DA-HAI in all the closed units, including the PICUs. Data is obtained from the microbiology laboratory, the radiology department, and by reviewing patients' charts on a daily basis. The adult ICUs at AUBMC have been members of the INICC for many years. The approval of an infectious diseases specialist is required for the use of broad-spectrum antimicrobial agents.

This was a retrospective study that included all patients admitted to the PICU at AUBMC between January 2007 and December 2011. Data was extracted from the patients' medical records. Inclusion criteria included having at least one of a placed central line, endotracheal tube, or Foley catheter. Among all patients admitted to the PICU during the time period of the study, the ICPP identified 31 patients as having DA-HAIs. A total of 5 patients were excluded from the study because they had a missing chart or a large portion of unavailable data. Chart review was done for 26 patients only, 4 of whom were excluded later for not meeting the set definitions of CLABSI, VAP, and/or CAUTI at any point during their stay in the PICU. The discrepancy in the number of DA-HAIs in this study compared with ICPP regarding the 4 excluded patients was due to the fact that the infection developed during their hospital stay but not during their stay in the PICU.

The institutional review board at AUBMC approved this study protocol.

Definitions of DA-HAIs

When an infection met the criteria of a DA-HAI in areas of the hospital other than the PICU and the patient was later transferred to the PICU, the infection was not considered in this analysis. The definitions of CLABSI, VAP, and CAUTI were adapted from those of the CDC

[16-18]. CLABSI is a primary bloodstream infection that is attributed to the use of a central line. VAP is a pneumonia related to ventilator placement, and CAUTI is a UTI related to placement of an indwelling catheter. The first CDC criterion for any of the three infections is that they must have occurred at least on the second day of placement of the respective device. Second, if the device was removed after two days of placement or more, an infection occurring, at most, on the day following the removal of the device was also considered to be associated with the respective device.

Microbiological testing

The standard practice at the PICU for patients with clinical suspicion of infection in the presence of a device is to obtain specimens for microbiology analysis. Qualitative cultures were performed on peripheral or central blood, deep tracheal aspirate, or sputum, and quantitative cultures were done on sterile urine samples. Standard methods were used for identification of microorganisms. Antimicrobial susceptibility testing was performed on isolates and determined by the disk-diffusion method based on the report from the Clinical and Laboratory Standards Institute on interpretation and quality control aspects published each year [19].

Length of stay and mortality calculations

The hospital LOS was calculated as the total number of days from admission to the hospital to discharge from the hospital or death. The PICU LOS was calculated as the total number of days spent in the PICU, even if intermittently, during the hospital admission. Due to the debatable cutoff values in the literature, the adopted definition of prolonged PICU stay was, by convention, more than 14 days in the PICU. The crude mortality rate was calculated as the percentage of deaths among the total number of patient with DA-HAIs in the PICU. Excess LOS and excess mortality were not derivable with the data available.

Antimicrobial coverage

Effective antimicrobial coverage for a DA-HAI was defined as initiation of an empiric antimicrobial agent to which the bacteria turned out to be sensitive. Empiric therapy was defined as the initiation of treatment soon after the culture specimen was obtained but before the physician in charge was informed of a positive culture result, which included the result of a Gram stain.

Statistical analysis

Microsoft Excel was used for data entry and management. The Statistical Package for Social Sciences (SPSS, Chicago, USA) program, version 20.0 for Windows, was used for data analysis. The descriptive statistics reported for continuous variables included the mean and standard deviation (SD) for the overall sample. For subgroups, only the median was reported because of the distribution of small numbers of patients. No tests of comparison were conducted.

Results

Characteristics of the study population

The study population comprised all patients with DA-HAIs over the span of 5 years (n = 22), 10 of whom (45.5%) were females, 6 were (27.3%) immunocompromised, and 16 (72.7%) had a prolonged hospital stay. The detailed individual characteristics of the patients are listed in Table 1. The patients' ages ranged between 3 days and 20 years, with a median of 16.8 months and a mean of 5.0 ± 6.7 years (mean ± SD). The overall median (and mean ± SD) for the hospital LOS and PICU LOS were, respectively, 54 (74 ± 70) and 32 (44 ± 46) days. The LOS distributions were skewed to the right – *i.e.*, the medians were smaller than the means – because two chronic patients stayed in the PICU for 131 and 207 days. In total, 17 patients had more than one DA-HAI. The total number of DA-HAIs was 59, distributed among the 22 patients as follows: 25 CLABSIs in 15 patients, 25 VAPs in 16 patients, and 9 CAUTIs in 7 patients. Mortality was observed in 8 patients (36.4%) out of 22 (Table 1). Tables 2 and 3 show the LOS and crude mortality for the different types of DA-HAIs.

Microorganism profile, bacterial resistance, and antimicrobial coverage

Gram-negative pathogens were found in 53% of the DA-HAIs, Gram-positive ones in 27%, and fungal organisms in 20%.

DA-HAIs were caused by coagulase-negative staphylococci (22.0%), *Candida* species (18.7%), *Klebsiella* species (16.9%), *Pseudomonas* species (11.9%), *Escherichia coli* (10.2%), and *Enterobacter* species (6.8%). *Staphylococcus aureus* and *Acinetobacter* species were isolated in two DA-HAIs each. *Serratia marcescens*, *Stenotrophomonas maltophila*, *Enterococcus* species, and *Trichosporon asahii* were isolated in one DA-HAI each (Table 4).

All *Klebsiella* species isolates were resistant to ampicillin, but sensitive to imipenem and cefoxitin. A total of 80% of *K. pneumonia* isolates were extended-spectrum beta-lactamase (ESBL) producers. In four of the cases, empiric antimicrobial therapy was appropriate.

Table 1. Detailed characteristics of all patients included in this study.

#	Age	Gender	Source of admission	Reason for PICU admission	Primary diagnosis	Immune deficiency (ID)	Hospital LOS	PICU LOS	CLABSI	VAP	CAUTI	Death
1	3 days	Male	OH	Pre/post-op	Pulmonary valve atresia	No	72	56	0	1	0	No
2	28 days	Male	ED	Pre/post-op	Interrupted aortic arch	No	56	56	0	1	0	No
3	4 months	Male	Floor	Respiratory	Hereditary neuropathy	No	210	207	1	2	1	Yes
4	4.5 months	Male	OH	Respiratory	Pulmonary hypertension	No	131	131	2	1	0	Yes
5	6 months	Female	Post-op	Post-op	Coarctation of aorta	No	8	7	1	1	0	Yes
6	6 months	Male	OH	Respiratory	Down syndrome + atrioventricular canal	No	69	44	2	2	0	No
7	7 months	Male	ED	Pre/post-op	Brain tumor	Chemotherapy	55	48	1	1	1	No
8	8.5 months	Female	ED	Respiratory	Pneumonia	No	35	35	3	0	0	No
9	8.5 months	Female	CSU	Post-op	Truncus arteriosus	No	31	28	0	3	1	Yes
10	10.5 months	Female	Post-op	Post-op	Acute bronchiolitis + immunodeficiency	Primary immunodeficiency	296	25	3	0	0	No
11	11.5 months	Female	OH	Respiratory	Werdnig-Hoffmann + RDS	No	59	59	0	1	1	No
12	21 months	Male	Floor	Respiratory	Guillain-Barre syndrome	No	49	48	1	3	0	No
13	23 months	Male	Post-op	Post-op	Interrupted aortic arch	No	48	30	1	1	0	No
14	3.25 years	Male	CSU	Post-op	Atrioventricular canal	No	13	9	3	1	0	Yes
15	5.5 years	Male	CSU	Post-op	Tetralogy of Fallot	No	22	11	1	0	0	No
16	6 years	Male	Floor	Post-op	Single ventricle	No	52	50	0	4	0	Yes
17	6 years	Female	OH	Respiratory	Burn	No	64	24	0	1	2	No
18	8 years	Male	Floor	Respiratory	Crohn's disease + febrile neutropenia	Bone marrow failure + steroids	179	57	0	1	1	Yes
19	14 years	Female	Post-op	Post op	PNET	Chemotherapy	52	26	1	1	2	No
20	17 years	Female	Floor	Septic shock	Leukemia (AML)	Leukemia (AML)	27	1	1	0	0	No
21	20 years	Female	ED	Respiratory	TTP	No	33	9	1	0	0	No
22	20 years	Female	BMT	Respiratory	Osteosarcoma + myelofibrosis	Chemotherapy + myelofibrosis	58	13	3	0	0	Yes
		10 Females	**5 OH**	**11 Surgical**	**9 Cardiac**	**6 IC**	**(days)**	**(days)**	**25**	**25**	**9**	**8**

ED: Emergency Department; PICU: pediatric intensive care unit; LOS: length of stay; CLABSI: central line-associated bloodstream infection; VAP: ventilator-associated pneumonia; CAUTI: catheter-associated urinary tract infection; OH: outside hospital; CSU: cardiac surgery unit; BMT: bone marrow transplant unit; RDS: respiratory distress syndrome; PNET: primitive neuroectodermal tumor; TTP: thrombotic thrombocytopenia purpura

Table 2. Length of stay, prolonged stay, and crude mortality in patients with different DA-HAIs.

	CLABSI (15 patients)	VAP (16 patients)	CAUTI (7 patients)
Hospital LOS (days)	49 (8–296)	6 (8–210)	59 (31–210)
PICU LOS (days)	26 (1–207)	2 (7–207)	48 (24–207)
Prolonged stay (%)	60%	87.5%	100%
Crude mortality	33.3%	43.8%	42.9%

DA-HAI: device-associated healthcare-associated infections; CLABSI: central line-associated bloodstream infection; VAP: ventilator-associated pneumonia; CAUTI: catheter-associated urinary tract infection; PICU: pediatric intensive care unit; Length of stay (LOS) is the median number of days (range). Prolonged stay in different DA-HAIs is the percentage of patients who stayed for more than 14 days in the PICU out of all PICU patients with DA-HAIs). Crude mortality is the proportion of deaths among patients with DA-HAIs.

Table 3. LOS and mortality in patients with short and prolonged PICU stays.

	Short stay (6 patients)	Prolonged stay (16 patients)
Hospital LOS (days)	25 (8–58)	58 (31–296)
PICU LOS (days)	10 (1–13)	48 (24–207)
Crude mortality	50%	31.2%

PICU: pediatric intensive care unit; LOS: length of stay; LOS is the median number of days and range in patients with short and prolonged (defined as > 14 days by convention) PICU stays. Crude mortality was calculated as the number of deaths divided by the total number of patients.

Table 4. Distribution of microorganisms per site of infection.

Microorganism	CLABSI	VAP	CAUTI
Coagulase-negative *Staphylococcus*	9	4	0
Escherichia coli	3	1	2
Klebsiella pneumoniae	3	4	3
Non-*albicans Candida*	3	2	1
Candida albicans	2	2	1
Enterococcus species	1	0	0
Acinetobacter baumanii	1	0	0
Stenotrophomonas maltophilia	1	0	0
Staphylococcus aureus	1	1	0
Trichosporon asahii	1	0	0
Pseudomonas aeruginosa	0	4	2
Enterobacter aerogenes	0	2	0
Enterobacter cloacae	0	2	0
Acinetobacter anitratus	0	1	0
Serratia marcescens	0	1	1
Pseudomonas paucimobilis	0	1	0

CLABSI: central line-associated bloodstream infection; VAP: ventilator-associated pneumonia; CAUTI: catheter-associated urinary tract infection.

Table 5. Proportions of correctly covered bacteria through empiric antibiotic therapy in patients with CLABSI, VAP, and CAUTI.

Microorganism	CLABSI	Correctly covered	VAP	Correctly covered	CAUTI	Correctly covered
Coagulase-negative *Staphylococcus*	9	7	4	1	0	0
Escherichia coli	3	3	1	1	2	2
Klebsiella pneumoniae	3	2	4	2	3	1
Enterococcus species	1	1	0	0	0	0
Acinetobacter baumanii	1	0	0	0	0	0
Stenotrophomonas maltophilia	1	0	0	0	0	0
Staphylococcus aureus	1	1	1	1	0	0
Pseudomonas aeruginosa	0	0	4	2	2	1
Enterobacter aerogenes	0	0	2	2	0	0
Enterobacter cloacae	0	0	2	0	0	0
Acinetobacter anitratus	0	0	1	1	0	0
Serratia marcescens	0	0	1	1	0	0
Pseudomonas paucimobilis	0	0	1	1	0	0

CLABSI: central line-associated bloodstream infection; VAP: ventilator-associated pneumonia; CAUTI: catheter-associated urinary tract infection.

Table 6. Proportions of correctly used antibiotics in empiric therapy.

Aminoglycosides (12)	**9**	**75%**
Carbapenems (20)	14	70%
Cephalosporins (11)	3	27.3%
Fluoroquinolones (2)	0	0%
Glycopeptides (17)	13	76.5%
Penicillins/β-lactamase inhibitors (2)	2	100%
Overall (64)	**41**	**64.1%**

Example: Of the 12 prescriptions of aminoglycosides, 75% correctly covered the corresponding device-associated healthcare-associated infections (DA-HAI).

One of the two remaining sensitive *K. pneumoniae* DA-HAIs was covered with appropriate antibiotics.

For the isolated *Pseudomonas* species, 28.6% were resistant to amikacin, ceftazidime, cefepime, ciprofloxacin, gentamicin, piperacillin/tazobactam, and tobramycin, while 42.9% were resistant to aztreonam and imipenem. Of six *P. aeruginosa* isolates, two were multidrug resistant (MDR), defined as resistant to β-lactams, carbapenems, aminoglycosides, and fluoroquinolones, and were not effectively covered empirically. Of the four sensitive isolates, only one was not effectively covered because no antimicrobial with pseudomonal coverage was given.

All of the six *E. coli* isolates were effectively covered with empiric antibiotics. Although four of them were ESBL producers, of the two isolates of *Acinetobacter* species, the *A. anitratus* isolate was sensitive and covered empirically effectively, while the *A. baumannii* isolate was MDR and empiric antibiotic coverage was ineffective. The two *S. aureus* isolates were methicillin sensitive and effectively covered empirically. There were no methicillin-resistant *Staphylococcus aureus* (MRSA) or vancomycin-resistant enterococci (VRE) isolated in any of the DA-HAIs in the PICU, although MRSA has been encountered in other units at AUBMC [20].

Overall, of the DA-HAIs of bacterial nature, around two-thirds – 61.3% of Gram-negative and 68.8% of Gram-positive isolates – were effectively covered with empiric therapy (Table 5). When aminoglycosides, carbapenems, and glycopeptides were used for empiric therapy, they were effective around three-quarters

Table 7. Detailed description of DA-HAIs, recovered organism, resistance, and effective coverage in empiric therapy for (a) CLABSIs, (b) VAPs, and (c) CAUTIs.

(7a) Central line-associated bloodstream infections.

DA-HAI	Device	Specimen	Patient	Organism	Resistance	Coverage
CLABSI	CVC	Blood	3	Coagulase-negative *Staphylococcus*	MR	Correct
CLABSI	CVC	Blood	4	Coagulase-negative *Staphylococcus*	MR	No
CLABSI	CVC	Blood	4	Coagulase-negative *Staphylococcus*	MR	Correct
CLABSI	CVC	Blood	5	*Escherichia coli*	ESBL	Correct
CLABSI	CVC	Blood	6	*Escherichia coli*	Sensitive	Correct
CLABSI	CVC	Blood	6	*Klebsiella pneumoniae*	Sensitive	Correct
CLABSI	Arterial line	Blood	7	Non-*albicans Candida*	.	.
CLABSI	CVC	Blood	8	*Candida albicans*	.	.
CLABSI	CVC	Blood	8	*Enterococcus* species	Sensitive	Correct
CLABSI	CVC	Blood	8	*Klebsiella pneumoniae*	ESBL	No
CLABSI	Arterial line	Blood	10	*Acinetobacter baumanii*	MDR	No
CLABSI	CVC	Blood	10	*Klebsiella pneumoniae*	ESBL	Correct
CLABSI	CVC	Blood	10	*Stenotrophomonas maltophilia*	TMP/SMX sensitive	No
CLABSI	CVC	Blood	12	Coagulase-negative *Staphylococcus*	MR	Correct
CLABSI	CVC	Blood	13	Non-*albicans Candida*	.	.
CLABSI	CVC	Blood	14	*Candida albicans*	.	.
CLABSI	Arterial line	Blood	14	Coagulase-negative *Staphylococcus*	MS	Correct
CLABSI	CVC	Blood	14	*Escherichia coli*	ESBL	Correct
CLABSI	CVC	Blood	15	Coagulase-negative *Staphylococcus*	MR	Correct
CLABSI	CVC	Blood	19	Coagulase-negative *Staphylococcus*	MR	Correct
CLABSI	CVC	Blood	20	Coagulase-negative *Staphylococcus*	MR	No
CLABSI	CVC	Blood	21	*Staphylococcus aureus*	MSSA	Correct
CLABSI	Arterial line	Blood	22	Non-*albicans Candida*	.	.
CLABSI	CVC	Blood	22	Coagulase-negative *Staphylococcus*	MR	Correct
CLABSI	CVC	Blood	22	*Trichosporon asahii*	.	.

(70%–76.5%) of the time (Table 6). The combination of piperacillin/tazobactam was used for one DA-HAI, and it was an effective empiric treatment. The same applied for amoxicillin/clavulanate. In 27.3% of the DA-HAIs where cephalosporins were used, there was shortage on covering the DA-HAI-causing bacteria. In all the cases where a fluoroquinolone was used, there was failure in efficacious empiric therapy. Table 5 shows the details of effective empiric coverage of CLABSIs, VAPs, and CAUTIs separately.

Detailed descriptions of DA-HAIs, recovered organisms, resistance, and effective coverage in empiric therapy for CLABSIs, VAPs, and CAUTIs are shown in Tables 7a, 7b, and 7c, respectively.

Discussion

HAIs are harmful, costly, and preventable. A recent report by Patrick *et al*. confirmed the effectiveness of national efforts in decreasing HAIs in American pediatric and neonatal ICUs from 2007 until 2012 [21]. At AUBMC, a tertiary-care hospital in a developing country, over the five-year period of this study, 1,452 patients were admitted to the PICU, among whom only 31 patients developed DA-HAIs during their hospital stay. The number of patients who developed a DA-HAI during their admission to the PICU was 22. This low number of DA-HAIs may be explained by the CLABSI, CAUTI, and VAP bundles that are implemented at

(7b) Ventilator-associated pneumonias

DA-HAI	Device	Specimen	Patient	Organism	Resistance	Coverage
VAP	ETT	DTA	1	*Pseudomonas aeruginosa*	Sensitive	Correct
VAP	ETT	DTA	2	Coagulase-negative *Staphylococcus*	MR	Correct
VAP	ETT	DTA	3	*Enterobacter aerogenes*	Imipenem sensitive	Correct
VAP	ETT	DTA	3	*Enterobacter cloacae*	Imipenem sensitive	No
VAP	ETT	DTA	4	*Acinetobacter anitratus*	Sensitive	Correct
VAP	ETT	DTA	5	*Escherichia coli*	ESBL	Correct
VAP	ETT	DTA	6	*Enterobacter aerogenes*	Imipenem sensitive	Correct
VAP	ETT	DTA	6	*Staphylococcus aureus*	MSSA	Correct
VAP	ETT	DTA	7	*Pseudomonas aeruginosa*	Sensitive	Correct
VAP	ETT	DTA	9	Non-*albicans Candida*	.	.
VAP	ETT	DTA	9	*Klebsiella pneumoniae*	ESBL	No
VAP	ETT	DTA	9	*Serratia marcescens*	ESBL	Correct
VAP	ETT	Sputum	11	*Pseudomonas aeruginosa*	Sensitive	No
VAP	ETT	DTA	12	Coagulase-negative *Staphylococcus*	MS	No
VAP	ETT	DTA	12	*Enterobacter cloacae*	Imipenem sensitive	No
VAP	ETT	DTA	12	*Klebsiella pneumoniae*	Sensitive	No
VAP	ETT	Sputum	13	Non-*albicans Candida*	.	.
VAP	ETT	DTA	14	*Candida albicans*	.	.
VAP	ETT	DTA	16	*Candida albicans*	.	.
VAP	ETT	DTA	16	Coagulase-negative *Staphylococcus*	MR	No
VAP	ETT	DTA	16	*Klebsiella pneumoniae*	ESBL	Correct
VAP	ETT	DTA	17	*Pseudomonas aeruginosa*	MDR	No
VAP	ETT	DTA	18	*Pseudomonas paucimobilis*	Sensitive	Correct
VAP	ETT	DTA	18	Coagulase-negative *Staphylococcus*	MR	No
VAP	ETT	DTA	19	*Klebsiella pneumoniae*	ESBL	Correct

(7c) Catheter-associated urinary tract infections

DA-HAI	Device	Specimen	Patient	Organism	Resistance	Coverage
CAUTI	Foley	Urine	3	*Escherichia coli*	Sensitive	Correct
CAUTI	Foley	Urine	7	*Klebsiella pneumoniae*	ESBL	No
CAUTI	Foley	Urine	9	*Klebsiella pneumoniae*	ESBL	No
CAUTI	Foley	Urine	11	*Klebsiella pneumoniae*	ESBL	Correct
CAUTI	Foley	Urine	17	*Escherichia coli*	ESBL	Correct
CAUTI	Foley	Urine	17	*Pseudomonas aeruginosa*	MDR	No
CAUTI	Foley	Urine	18	*Candida albicans*	.	.
CAUTI	Foley	Urine	19	Non-*albicans Candida*	.	.
CAUTI	Foley	Urine	19	*Pseudomonas aeruginosa*	Sensitive	Correct

DA-HAI: device-associated healthcare-associated infections CVC: central venous catheter; ETT: endotracheal tube; DTA: deep tracheal aspirate; ESBL: extended-spectrum beta-lactamase; MDR: multidrug resistant; MR: methicillin resistant; MS: methicillin sensitive; TMP/SMX: trimethoprim/sulfamethoxazole; MSSA: methicillin-sensitive *Staphylococcus aureus*.

AUBMC in all units, including the PICU. A systematic review published by Smulders *et al*. assessed the impact of implementation of central-line and ventilator bundles in PICU patients and found a significant decrease in the CLABSI or VAP rates after the implementation of the bundles [22].

In our study, VAP was the most common type of DA-HAI (25 new occurrences in 16 patients), followed by CLABSI (25 new occurrences in 15 patients) and CAUTI (9 new occurrences in 7 patients). These results are similar to those found in other developing countries, where VAP is the most common cause of DAIs, as compared to the high-income countries, where CAUTI is the most common type [4]. Benson *et al*. reported prevention of VAP over 33 consecutive months using a VAP bundle protocol along with the use of a polyurethane endotracheal tube, in addition to comprehensive education and the cooperation between physicians, nurses, and respiratory therapists [23]. Aligning with Benson *et al*.'s recommendations, more efforts directed toward monitoring of compliance to bundle elements should take place in the PICU at AUBMC to further decrease the rates of VAP and CLABSI.

Coagulase-negative *Staphylococcus* (9 CLABSI and 4 VAP) was the most common cause of DA-HAIs, followed by *Klebsiella* species (3 CLABSI, 4 VAP, and 3 CAUTI). This was different from the nosocomial infections among PICU patients in Alexandria, Egypt [24], where *Klebsiella* species were the most commonly isolated pathogens (46.7%), followed by *Pseudomonas aeruginosa* (16.6%). Another study in the Arab region of Tunis [15] showed *Staphylococcus aureus* to be the most common cause (26.8%) of nosocomial bloodstream infections, followed by *Klebsiella pneumoniae* (19.5%) and coagulase-negative staphylococci (17%). A study from Shanghai, China showed *Acinetobacter baumannii* (19.1%), followed by *Pseudomonas aeruginosa* (17.2%), *Klebsiella pneumoniae* (11.9%), and *Staphylococcus aureus* (11.9%) to be the most commonly isolated microorganisms in patients with DA-HAIs [25].

Empiric antimicrobial therapy in our patients was effectively initiated in most cases (65%) before knowledge of the final culture results and antimicrobial susceptibility. In our study, *Klebsiella* and *E. coli* species were ESBL producing in 80% and 67% of isolates, respectively. *Pseudomonas* species were multidrug resistant in 34% of the cases. In the Tunisian study, *Klebsiella* species produced ESBLs in 87.5% of cases [15].

Conclusions

One major limitation of this study was the small number of patients with DA-HAIs. However, such a small number indirectly indicates a low rate of DA-HAIs in the PICU at AUBMC. Still, we were not able to calculate the rates of CLABSI, CAUTI, and VAP per 1,000 device-days because the total device-day numbers were not available. Also, because of the low numbers, we could not generalize about the adequacy of antibiotic coverage. Subsequently, subset analysis by source of device (location of placement) and time-to-event survival analysis were both not possible for the same reason. These would better be derived from prospective studies with a larger number of patients. The second major limitation in our study was the unavailability of data on the total numbers of devices placed in patients admitted to the PICU. We are currently in the process of a prospective collection of data in order to document the most recent trend in DA-HAIs in AUBMC, especially after the implementation of bundles of care and hygiene.

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