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Original Article

Device-Associated Healthcare-Associated Infections (DA-HAI) and the caveat of multiresistance in a multidisciplinary intensive care unit

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ABSTRACT

Background: Device-Associated Healthcare-Associated Infections (DA-HAI), including Ventilator-Associated Pneumonia (VAP), Central-Line-Associated Blood Stream Infection (CLABSI), and Catheter-Related Urinary Tract Infection (CAUTI), are considered as principal contributors to healthcare hazard and threat to patient safety as they can cause prolonged hospital stay, sepsis, and mortality in the ICU. The study intends to characterize DA-HAI in a tertiary care multidisciplinary ICU of a teaching hospital in eastern India.

Methods: This prospective outcome-surveillance study was conducted among 2157 ICU patients of a 760-bedded teaching hospital in Eastern India. Clinical, laboratory and environmental surveillance, and screening of HCPs were conducted using the US Centers for Disease Control and Prevention (CDC)'s National Healthcare Safety Network (NHSN) definitions and methods.

Results: With 8824 patient/bed/ICU days and 14,676 device days, pooled average device utilization ratio was 1.66, total episodes of DA-HAI were 114, and mean monthly rates of DA-HAI, VAP, CLABSI, and CAUTI were 4.75, 2, 1.4, and 1.25/1000 device days. Most common pathogens isolated from DA-HAI patients were *Klebsiella pneumoniae* (24.6%), *Escherichia coli* (21.9%), and *Pseudomonas aeruginosa* (20.2%). All *Acinetobacter baumanii*, >80% *K. pneumoniae* and *E. coli*, and >70% *P. aeruginosa* were susceptible only to colistin and tigecycline. One *P. aeruginosa* isolate was panresistant.

Conclusion: Mean rates of VAP, CLABSI, and CAUTI were 14.4, 8.1, and 4.5 per 1000 device days, which are comparable with Indian and global ICUs. Patients and HCPs form important reservoirs of infection. Resolute conviction and sustained momentum in Infection Control Initiatives are an essential step toward patient safety.

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Introduction

Healthcare-associated infections (HAI) are infections acquired after 48 h of admission, up to 30 days of discharge and up to one year in case of implants; which were not evident or under incubation at the time of admission.[1] Ventilator-Associated Pneumonia (VAP), Central-Line-Associated Blood Stream Infections (CLABSI), and Catheter-Related Urinary Tract Infection (CAUTI) are the most commonly encountered Device-Associated Healthcare-Associated Infections (DA-HAI) and are considered as the principal contributors to healthcare hazard and threat to patient safety.

Patients in Intensive Care Unit (ICU) with multiple comorbidities are on artificial ventilation, inotropes, central venous catheterization/central-line, urinary catheterization, parenteral nutrition, and other supports, which render them susceptible to HAI.[2] Multidrug-resistant (MDR) pathogens persisting in ICU environment cause opportunistic infections, more so in association with the use of devices. DA-HAI leading to bacteremia and sepsis is the leading cause of prolonged hospital stay, enhanced commitment toward barrier nursing and patient isolation, morbidity, mortality, cost escalation, and reduction in bed availability.[3]

The incidence of DA-HAI depends on access to ICU, frequency and duration of use of devices, infection control practices, and immune constitution of patients. The rates of HAI in high-income countries' ICUs are approximately 5–10% vis-a-vis 2–10 times higher incidence in lower- and middle-income countries. Rates of HAI vary in different hospitals, different ICUs in the same hospital or same ICU at different periods, with higher rates in teaching hospitals.[2,4]

The National Patient Safety Goals purported by WHO World Alliance on Patient Safety in 2009 advocate focused control of DA-HAI mandating a strong policy, teamwork, supervision, surveillance, and administrative patronage. Ongoing surveillance of HAI helps characterize infections, etiology, sources, DA-HAI rates, and resistograms, thus forming a guideline for targeted interventions for patients, healthcare professionals (HCP), and institutional policies. This study intends to characterize DA-HAI (VAP, CLABSI, and CAUTI) in a multidisciplinary ICU of a tertiary-care hospital in Eastern India.

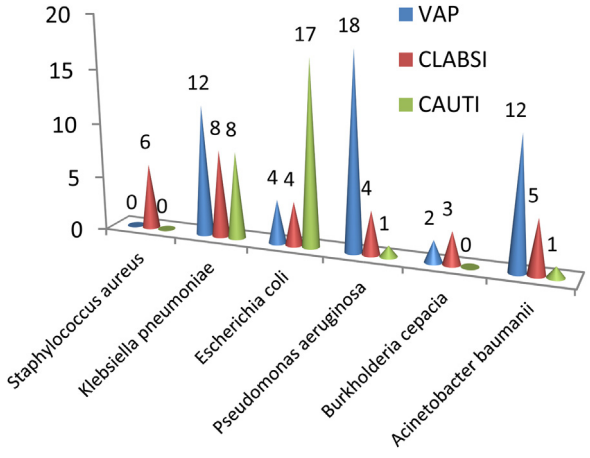

Fig. 1 – Organism profile of DA-HAI (VAP, CLABSI, and CAUTI) from ICU of a Teaching Hospital in Eastern India.

Materials and methods

This prospective outcome-surveillance study was conducted among all patients admitted to multidisciplinary 14-bedded ICU of a 760-bedded tertiary-care teaching and referral hospital in Eastern India over a period of 24 months from June 2014 to May 2016, after approval from Hospital Ethics Committee. All good clinical practice and laboratory guidelines were observed. Patients staying less than 48 h, testing positive for infections within 48 h, and showing evidence of existing infections on admission were excluded.

Surveillance of DA-HAI was conducted by the Infection Control Team (ICT) under the aegis of Hospital Infection Control Committee (HICC) using the US Centers for Disease Control and Prevention (CDC)'s National Healthcare Safety Network (NHSN) definitions and methods.[5] Surveillance included clinical surveillance, laboratory surveillance, environmental surveillance, and screening of HCPs in ICU.

1. Clinical surveillance, conducted every morning during ICU rounds, included patient's clinicodemographic profile, diagnosis, date of admission to ICU, fever/hypothermia, abnormal leukocyte counts, use of ventilator, central-line or urinary catheter, and date of transfer/discharge/death. Daily surveillance data recorded in the HICC register was perused by a clinical microbiologist.
2. Laboratory surveillance included baseline and intuitive cultures interpreted as per NHSN-CDC guidelines to arrive at the diagnosis of DA-HAI including VAP, CLABSI, and CAUTI. Baseline surveillance cultures were requested before use of devices such as endotracheal cultures immediately after tracheostomy, blood cultures on admission to ICU, and urine cultures before catheterization. Clinical intuitive cultures were requested after 48 h of use of device. Paired blood cultures after positive culture screen from BacT/ALERT® 3D blood culture system (bioMérieux, France) were aerobically incubated in O_2 at 37 °C for 18–120 h. Positive blood cultures, urine obtained after clamping the catheter, and endotracheal aspirate were aerobically incubated at 37 °C for 24 h on solid media. Both standard and automated methods were used for identification. Colony characteristics, Gram staining, motility, carbon source utilization, and enzymatic activity were correlated with results from Vitek-2 compact (bioMérieux, France) automated system which was also used for determining Minimal Inhibitory Concentrations (MIC). Identification percentage >85% was taken as cutoff for final validation. Non-repeat positive cultures with antibiograms were taken into account for profiling of isolates and antimicrobial susceptibility. Quality control was performed by testing *Escherichia coli* ATCC 25922, *Staphylococcus aureus* ATCC 25923 and *Pseudomonas aeruginosa* ATCC 27853.
3. VAP was diagnosed by positive endotracheal aspirate cultures in a mechanically ventilated patient with at least one of CDC qualifying criteria of new onset of purulent sputum production or change in character of sputum, pathogen cultured from blood, or positive culture from endotracheal aspirate, with corroborative chest radio-

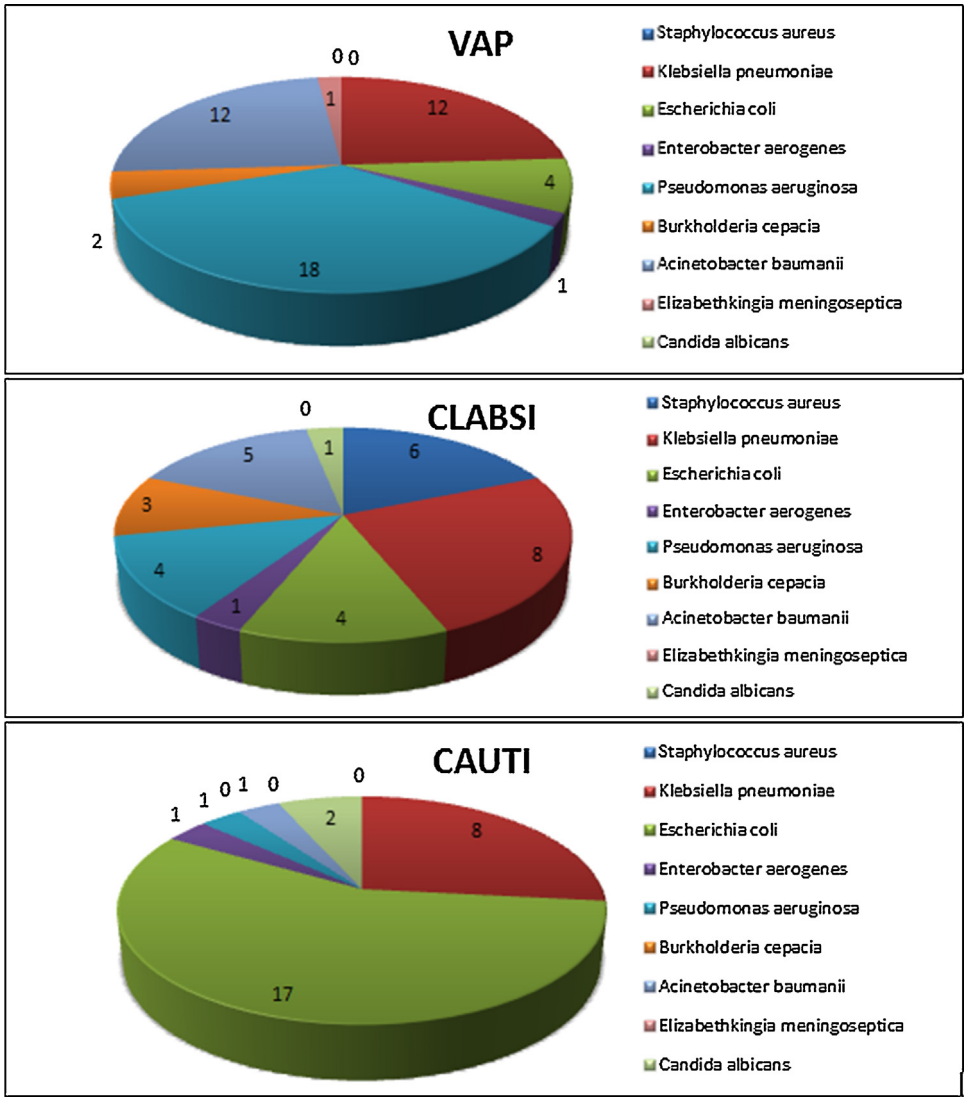

Fig. 2 – Organism distribution of DA-HAI (VAP, CLABSI, and CAUTI) from ICU of a Teaching Hospital in Eastern India.

graph showing new, persistent or progressive infiltrate, consolidation, cavitation, or pleural effusion. Clinical correlates included fever >38 °C or hypothermia <35.5 °C, blood leukocytosis >10,103/mm^3 or leucopenia <3103/mm^3. Purulent secretions with >25 neutrophils and <10 squamous epithelial cells per high power field or >5% cells with intracellular bacteria in Gram Stain along with growth corresponding to >10^5 colony forming units per ml (CFU/ml) of sample after 1 in 1000 dilution were correlated.

4. CLABSI was diagnosed by positive paired blood cultures revealing the same pathogen concurrently from existing central-line and peripheral vein after 48 h of catheterization, with >10^5 CFU growth in central-line two hours faster than growth from peripheral sample, indicating source as central-line, in the absence of an infection at another site. Clinical correlates were similar to VAP. Coagulase negative Staphylococci growing within 48 h with positive clinical correlates were considered.
5. CAUTI was diagnosed from urine sample of patients having catheter in situ or catheter removed within 7 days, either with growth of not more than two pathogens corresponding to 10^5 CFU/ml of urine, along with clinical correlates of fever >38 °C, urgency or suprapubic tenderness, or positive dipstick analysis for leukocyte esterase or nitrate, pyuria ≥10 leukocytes/ml, pathogens seen on Gram stain, clinical diagnosis, or initiation of appropriate therapy for UTI.
6. The data from clinical and laboratory surveillance was independently analyzed by a clinical microbiologist under the following parameters. Any patient admitted to ICU or exposed to devices for 24 h or part thereof was calculated for full day.
   (a) Patient/bed/ICU days, calculated by multiplying number of patients with total admission days in ICU.
   (b) Device-days, calculated by multiplying the use of devices (ventilator, central-line or urinary catheter) by days of use in all patients.
   (c) Device utilization ratios, calculated by dividing the total number of device-days by the total patient/bed/ICU days.

(d) Pooled average length of stay for all patients and after acquiring VAP/CLABSI/CAUTI.
(e) Rates of DA-HAI, calculated by dividing episodes of VAP/CLABSI/CAUTI by respective device-days multiplied by 1000 to be expressed in terms of rates per 1000 device-days.
(f) Crude mortality rate for all patients and after VAP/CLABSI/CAUTI.
(g) Microbiological profile, frequency, resistograms with MICs for DA-HAI.
(h) Comparison of rates of VAP/CLABSI/CAUTI with benchmarking parameters, Indian and global ICUs.

7. Environmental surveillance, conducted fortnightly after cleaning and decontamination procedures, included ICU air handling unit vent air exposure cultures; surface and fomite swab cultures from bed rails, bedside trolleys, intravenous fluid frames and bottles, monitoring devices, stethoscopes, switches, telephone receivers, computer peripherals, and door-handles. Disinfectant solutions were screened by in-use test.
8. Screening of HCPs for Methicillin resistant *S. aureus* (MRSA) was conducted fortnightly through swabs from nostrils and fingertips. HCPs carrying MRSA were shifted out of ICU followed by MRSA eradication by 2% topical intranasal mupirocin twice a day and 2% chlorhexidine wash twice a day for seven days.
9. Didactic lectures and demonstrations on infection control policies and practices including sterilization and disinfection, biomedical waste, standard precautions, hand hygiene, and occupational hazards were targeted fortnightly for nursing, ancillary, and housekeeping staff.
10. Data was presented quarterly in the HICC meet with Heads/Officers of departments, centers, medical stores, and logistics in attendance. Suggestions were worked and reviewed in subsequent meetings. Quarterly returns were submitted.

Results

The study included a total of 2157 patients admitted to 14-bedded multidisciplinary ICU of a tertiary-care teaching hospital in Eastern India over a period of 24 months, of which 1188 patients stayed for more than 48 h (55.1%, monthly mean 49.5 ± standard deviation 13.89 with 95% Confidence Interval/CI 48.7–50.3%). The specialty distributions of patients included 19% neurology, 15% cardiology, 12% cardiology, 10% neurosurgery, and rest other specialties. Average nurse:patient ratio in the ICU was 1:2. A two-tier Infection Control Program (ICP) and patient safety protocol included restricted entry by biometric identification system, availability of bedside alcohol-based hand rubs, and bundles of care for prevention of VAP/CLABSI/CAUTI. Average monthly ICU occupancy was 89.88 ± 14 (95% CI 59.5–122.3) patients. The total patient/bed/ICU days were 8824, monthly average 367.7 ± 40.9 (95% CI 366.8–368.5). The total device utilization days were 14,676, monthly average 611.5 ± 116.3 (95% CI 609.6–613.4). Pooled average device utilization ratio was 1.66 (Ventilator 0.4, Central-Line 0.46, and Urinary Catheter 0.80) (Table 1).

Total ventilator days, mean monthly ventilator days, and ventilator utilization ratio were 3501, 145.9 ± 49.9 (95% CI 144.2–147.5), and 0.4 ± 0.1 (95% CI 0.31–0.48). Total central-line days, mean monthly central-line days, and central-line utilization ratio were 4031, 167.9 ± 50.5 (95% CI 166.5–169.5), and 0.46 ± 0.14 (95% CI 0.38–0.54). Right subclavian was used for most patients, internal jugular was avoided in neurosurgery patients, and femoral catheterization was utilized for rapid access. Total urinary-catheter days, mean monthly urinary-catheter days, and urinary-catheter utilization ratio were 7144, 297.7 ± 67.8 (95% CI 296.1–299.2), and 0.80 ± 0.14 (95% CI 0.74–0.87).

The total episodes of DA-HAI, mean monthly episodes, and rate were 114, 4.7 ± 1.7 (95% CI 4.4–5.1), and 7.94 ± 3.3 (95% CI 7.5–8.4). Total episodes of VAP, mean monthly episodes, and rate were 50 (43.8% of DA-HAI), 2.1 ± 1.1 (95% CI 1.8–2.4), and 14.35 ± 8.1/1000 ventilator days (95% CI 13.5–15.2). Total episodes of CLABSI, mean monthly episodes, and rate were 34 (29.8% of DA-HAI), 1.4 ± 0.9 (95% CI 1.1–1.7), and 8.1 ± 4.9/1000 central-line days (95% CI 7.4–8.8). Total episodes of CAUTI, mean monthly episodes, and rate were 29 (25.4% of DA-HAI), 1.32 ± 1.2 (95% CI 0.88–1.76), and 4.55 ± 5.2/1000 urinary catheter days (95% CI 3.6–5.5) (Table 1).

Pooled unadjusted average length of stay (LOS) of all patients was 4.09 ± 2.9 (95% CI 3.1–6.2) days. Pooled average LOS after acquiring DA-HAI, VAP, CLABSI, and CAUTI were 6.12, 6.95, 5.68, and 5.73 days. Crude unadjusted mortality in ICU was 33.5%. Crude unadjusted mortality in patients with DA-HAI, VAP, CLABSI, and CAUTI was 4.9%, 30%, 1.6%, and 0.3% of total deaths in ICU.

Most common pathogens isolated from DA-HAI patients were *Klebsiella pneumoniae* (24.6%), *Escherichia coli* (21.9%) and *Pseudomonas aeruginosa* (20.2%). *Acinetobacter baumanii* comprised 15.8% of all infections (Figs. 1 and 2). All *Acinetobacter baumanii*, > 80% *Klebsiella pneumoniae* and *Escherichia coli*, and >70% *Pseudomonas aeruginosa* were susceptible only to colistin and tigecycline. Higher MIC values for tigecycline were seen in some *Klebsiella pneumoniae* isolates. *Enterobacter aerogenes* was susceptible to ciprofloxacin, colistin and tigecycline. One *Pseudomonas aeruginosa* isolate was panresistant. *Burkholderia cepacia* and *Elizabethkingia meningoseptica* exhibited susceptibility only to cotrimoxazole. All Staphylococcus aureus isolates were MRSA, susceptible only to vancomycin, linezolid and rifampicin. *Candida albicans* were resistant only to fluconazole (Table 2).

Environmental surveillance revealed coagulase negative staphylococci, aerobic spore bearers, and *K. pneumoniae* susceptible to all antimicrobials. Average prevalence of MRSA was 31.67% among detected Staphylococci from HCPs. MRSA eradication was confirmed through subsequent repeat cultures. The surveillance parameters and rates of DA-HAI have been compared with benchmarking data, ICUs in India, and other countries (Table 3).

Discussion

The occurrence of HAI among patients and HCPs in ICU is a healthcare hazard as it may lead to cross-infections and further transmission to lower dependency units, other healthcare facilities, and the community through patient transfers and discharge. The source of HAI can be patients,

Table 1 – Device-Associated Healthcare-Associated Infections (DA-HAI) in a multidisciplinary tertiary intensive care unit of a teaching hospital in eastern India.

S No	Month/year	Pooled data							VAP				CLABSI				CAUTI			
		No of patients admitted	Patients staying >48 h (%)	Patient/ bed days	Device days	Device utilization ratio	Episodes of DA-HAI	Overall rate of DA-HAI	Ventilator days	Ventilator utilization ratio	Episodes of VAP (%)	Rate of VAP	Central line days	Central line utilization ratio	Episodes of CLABSI (%)	Rate of CLABSI	Urinary catheter days	Urinary catheter utilization ratio	Episodes of CAUTI (%)	Rate of CAUTI
1	June 14	64	44 (68.7)	336	452	1.35	4	8.8	119	0.35	2 (50)	16.8	114	0.34	0	0	219	0.65	2 (50)	9.1
2	July 14	87	54 (62.1)	385	625	1.62	3	4.8	166	0.43	2 (66.7)	12	115	0.30	1 (33.3)	8.7	344	0.89	0	0
3	August 14	85	57 (67.1)	402	729	1.81	7	9.6	175	0.44	3 (42.8)	17.1	203	0.50	2 (28.6)	9.8	351	0.87	2 (28.6)	5.7
4	September 14	87	48 (55.2)	374	637	1.70	5	7.8	127	0.34	2 (40)	15.7	329	0.88	3 (60)	9.1	181	0.48	0	0
5	October 14	83	61 (73.5)	407	727	1.79	3	4.1	106	0.26	2 (66.7)	18.9	202	0.50	1 (33.3)	4.9	419	1.03	0	0
6	November 14	104	62 (59.6)	430	707	1.64	4	5.7	144	0.33	3 (75)	20.8	183	0.43	1 (25)	5.4	380	0.88	0	0
7	December 14	93	60 (64.5)	426	686	1.61	3	4.4	150	0.35	2 (66.7)	13.3	161	0.38	1 (33.3)	6.2	375	0.88	0	0
8	January 15	85	53 (62.4)	423	753	1.78	5	6.6	181	0.43	3 (60)	16.5	187	0.44	1 (20)	5.3	385	0.91	1 (20)	2.6
9	February 15	84	37 (44)	351	603	1.72	4	6.6	152	0.43	0	0	144	0.41	2 (50)	13.9	307	0.87	2 (50)	6.5
10	March 15	104	34 (35.8)	392	443	1.13	1	2.3	118	0.30	0	0	79	0.20	0	0	246	0.63	1 (100)	4
11	April 15	74	54 (73)	374	587	1.57	4	6.8	103	0.28	2 (50)	19.4	169	0.45	1 (25)	5.9	315	0.84	1 (25)	3.2
12	May 15	75	38 (55.9)	333	659	1.98	5	7.6	189	0.57	3 (60)	15.8	168	0.50	1 (20)	5.9	302	0.91	1 (20)	3.3
13	June 15	84	31 (36.9)	300	471	1.57	6	12.7	101	0.34	3 (50)	29.7	224	0.75	3 (50)	13.4	146	0.49	0	0
14	July 15	116	23 (19.8)	359	551	1.53	5	9.1	142	0.40	3 (60)	21.1	123	0.34	0	0	286	0.80	2 (40)	7
15	August 15	106	86 (81.1)	415	705	1.70	7	9.9	151	0.36	3 (42.8)	19.8	203	0.49	2 (28.5)	9.8	351	0.85	2 (28.6)	5.7
16	September 15	88	60 (68.2)	289	398	1.38	6	15.1	45	0.16	0	0	145	0.50	1 (16.7)	6.9	208	0.72	5 (83.3)	24
17	October 15	105	56 (53.3)	352	529	1.50	5	9.5	122	0.35	3 (60)	24.6	142	0.40	1 (20)	7	265	0.75	1 (20)	3.8
18	November 15	88	31 (35.2)	285	430	1.51	2	4.7	93	0.33	0	0	109	0.38	1 (50)	9.2	228	0.80	1 (50)	4.4
19	December 15	100	49 (49)	356	662	1.86	5	7.6	163	0.46	2 (40)	12.3	183	0.51	1 (20)	5.5	316	0.89	2 (40)	6.3
20	January 16	108	65 (60.2)	401	556	1.39	8	14.4	153	0.38	3 (37.5)	19.6	139	0.35	3 (37.5)	21.6	264	0.66	2 (25)	7.6
21	February 16	110	56 (50.9)	361	642	1.78	8	12.5	152	0.42	3 (37.5)	19.7	182	0.50	2 (25)	11	308	0.85	3 (37.5)	9.7
22	March 16	82	42 (51.2)	361	868	2.40	5	5.7	321	0.89	2 (40)	6.2	218	0.60	2 (40)	9.2	329	0.91	1 (20)	3
23	April 16	80	37 (46.2)	348	654	1.88	5	7.6	179	0.51	2 (40)	11.2	166	0.48	2 (40)	12	309	0.89	1 (20)	3.2
24	May 16	65	50 (76.9)	364	602	1.65	4	6.6	149	0.41	2 (50)	13.4	143	0.39	2 (50)	14	310	0.85	0	0
	Total	2157	1188	8824	14,676	–	114	–	3501	–	50	–	4031	–	34	–	7144	–	29	–
	Average	89.88	49.50	367.67	611.50	1.66	4.75	7.94	145.88	0.40	2.08	14.35	167.96	0.46	1.42	8.13	297.67	0.80	1.32	4.55
	SD	14.03	13.89	40.88	116.31	0.25	1.73	3.26	49.98	0.13	1.06	8.06	50.49	0.14	0.88	4.91	67.81	0.14	1.21	5.15
	95% CI	59.47	48.71	366.81	609.62	1.58	4.43	7.48	144.22	0.31	1.79	13.50	166.40	0.38	1.12	7.44	296.09	0.87	0.88	3.59
		120.28	50.29	368.52	613.38	1.74	5.07	8.40	147.53	0.48	2.38	15.20	169.52	0.54	1.71	8.81	299.24	0.74	1.76	5.52

VAP – Ventilator-Associated Pneumonia, CLABSI – Central-Line-Associated Blood Stream Infections, CAUTI – Catheter Related Urinary Tract Infection.

Table 2 – Microorganism profile and resistogram from Device-Associated Healthcare-Associated Infections (DA-HAI) from ICU of a teaching hospital in eastern India.

Pathogens (*n* = 114)/DA-HAI/ antimicrobials	*Klebsiella pneumoniae* (*n* = 28) (24.6%)		*Escherichia coli* (*n* = 25) (21.9%)		*Enterobacter aerogenes* (*n* = 3) (2.6%)		*Pseudomonas aeruginosa* (*n* = 23) (20.2%)		*Acinetobacter baumanii* (*n* = 18) (15.8%)		*Burkholderia cepacia* (*n* = 5) (4.4%)		*Elizabethkingia meningoseptica* (*n* = 1) (0.9%)		*Staphylococcus aureus* (*n* = 6) (5.3%)		*Candida albicans* (*n* = 3) (2.6%)	
VAP	12		4		1		18		12		2		1		0		0	
CLABSI	8		4		1		4		5		3		0		6		1	
CAUTI	8		17		1		1		1		0		0		0		2	
Resistance	R (%)	MIC	R (%)	MIC	R (%)	MIC	R (%)	MIC	R (%)	MIC	R (%)	MIC	R (%)	MIC	R (%)	MIC	R (%)	MIC
Coamoxiclav	82.1	≥32	80	≥32	100	≥32	82.6	≥32	100	≥32	100	≥32	100	≥32	–	–	–	–
Ciprofloxacin	92.8	≥4	96	≥4	0	≥4	86.9	≥4	100	≥4	100	≥4	100	≥4	–	–	–	–
Ceftriaxone/oxacillin	82.1	≥64	80	≥64	100	≥64	82.6	≥64	100	≥64	100	≥64	100	≥64	100	≥4	–	–
Cefoperazone/subactam	82.1	≥64	80	≥64	100	≥64	82.6	≥64	100	≥64	100	≥64	100	≥64	–	–	–	–
Amikacin	82.1	≥64	60	≥64	100	≥64	69.5	≥64	100	≥64	100	≥64	100	≥64	–	–	–	–
Imipenem	82.1	≥16	52	≥16	100	4	69.5	2	100	≥16	100	≥16	100	≥16	–	–	–	–
Meropenem	82.1	≥16	52	≥16	100	8	69.5	8	100	≥16	100	4	100	≥16	–	–	–	–
Piperacillin-tazobactam	82.1	≥128	68	≥128	100	≥128	69.5	≥128	100	≥128	100	≥128	100	≥128	–	–	–	–
Cotrimoxazole	92.8	≥320	100	≥320	100	≥320	100	≥320	100	≥320	0	≤20	0	40	100	≥320	–	–
Colistin	0	≤0.5	0	≤0.5	0	≤0.5	4.3	≤0.5–≥8	0	≤0.5	100	≤0.5	100	≥16	–	–	–	–
Tigecycline	0	0.5–2	0	≤0.5	0	≤0.5	4.3	0.5–2	0	2	100	≤0.5	0	≥8	–	–	–	–
Vancomycin	–	–	–	–	–	–	–	–	–	–	–	–	–	–	0	1	–	–
Linezolid	–	–	–	–	–	–	–	–	–	–	–	–	–	–	0	2	–	–
Rifampicin	–	–	–	–	–	–	–	–	–	–	–	–	–	–	0	≤0.03	–	–
Fluconazole	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	66.7	≥2
Voriconazole	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	0	≤0.12
Amphotericin B	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	0	0.5
Flucytosine	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	0	≤1
Caspofungin	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	0	≤0.25
Micafungin	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	0	≤0.06

R – resistance, MIC – Mean Minimal Inhibitory Concentration in μg/ml for resistant isolates, *n* represents cumulative in the respective category.

Table 3 – Comparison of rates of DA-HAI (VAP, CLABSI, and CAUTI) from ICU of a teaching hospital in eastern India, with India and the World.

S. No.	Country/region	Year(s) of surveillance	No of hospitals/ ICUs	No of patients	No of patient/ bed/ICU days	VAP	CLABSI	CAUTI
Benchmarking parameters								
1	Present study	2014–16	1/1	2157	8824	14.4	8.1	4.5
2	INICC Rates[6]	2004–09	36/422	313,008	2,194,897	15.8	6.8	6.3
3	INICC Rates[7]	2007–12	43/503	605,310	3,338,396	16.8	4.9	5.5
4	US CDC-NHSN Rates[8]	2013	4567	–	18,910,558	0.6	0.5	0.7
5	US CDC-NHSN Rates[9]	2012	4444	–	19,177,288	1.6	1.3	2.6
Comparison within India								
6	AIIMS, Delhi[10]	–	1	–	–	31.4	3.4	11.3
7	Chandigarh[11]	2010–11	1/2	679	–	6.0	13.9	9.1
8	Pune[2]	2009–10	1/1	293	–	32	16	9
9	20 Indian cities[12]	2004–13	40/40	236,700	970,713	9.4	5.1	2.1
Comparison with lower middle income countries excluding India								
10	Eight countries[4]	2002–05	46/55	21,069	137,740	24.1	12.5	8.9
11	Turkey[13]	2003–12	29/63	94,498	647,316	21.4	11.1	7.5
12	China[14]	2004–09	70/398	391,527	3,245,244	20.8	3.1	6.4
13	Mongolia[15]	2013–15	3/3	467	2133	43.7	19.7	15.7
14	Brazil[16]	2003–06	3/5	1031	10,293	20.9	9.1	9.6
15	Philippines[17]	2005–09	9/9	4952	40,733	16.7	4.6	4.2
Comparison with upper middle income countries								
16	Iran[18]	2014	1/1	2584	16,796	7.9	5.8	9.0
17	Mexico[19]	2005	4/5	1055	–	21.8	23.1	13.4
Comparison with high income countries								
18	Argentina[20]	2003	6/6	–	–	46.3	30.3	18.5
19	Poland[21]	2007–10	1/1	847	9386	18.2	4.0	4.8
20	Saudi Arabia[22]	2004–11	1/1	–	–	4.5	10	8.2
21	Kuwait[23]	2013–15	7/7	3732	21,611	4.0	3.5	3.3
22	Korea[24]	2012	162/162	–	–	1.6	2.6	1.6

visitors, HCP, environmental reservoirs, and biomedical waste, which can be traced by ongoing surveillance programs and transmission reduced or stopped by appropriate intervention.

Surveillance programs on DA-HAI started with the US CDC-NHSN collaboration in 1988, now comprising 4567 hospitals inclusive of 34 US military hospitals.[5] The results of the surveillance were utilized for well-coordinated ICPs focused on DA-HAI, which brought forth reduction in incidence of DA-HAI by 30%, reduction in proportionate morbidity, mortality, and healthcare costs. The International Nosocomial Infection Control Consortium (INICC), started in 2008 in Argentina, coordinates a network of 250 ICUs from 38 countries in South America, Asia, Africa, and Europe, for surveillance of DA-HAI.[6,7] While INICC includes middle-income country ICUs, most of the work on DA-HAI has been carried out in high-income countries.[6,7]

Diagnosis of DA-HAI requires standardized protocols corroborating clinical and laboratory parameters with baseline and intuitive clinical correlates. Muted clinical response in critically ill patients can delay requisition of cultures from ICU. The recently approved CDC definitions on tiered ventilator-associated events comprising ventilator-associated condition, infection-related ventilator-associated condition, and possible and probable VAP, are likely to objectify surveillance of VAP through extensive monitoring of FiO_2 and PEEP; however, it is not intended for clinical management of patients. Standardization of definitions and criteria from US CDC-NHSN have streamlined diagnosis of DA-HAI along with benchmarking of ICU data on DA-HAI from both CDC-NHSN and INICC, facilitating comparison between hospitals and countries.

The current analysis has been classified as per latest World Bank classification of countries into low-, lower middle (India), upper middle and high-income countries. The rates of VAP/CLABSI/CAUTI are comparable to INICC benchmarks although much higher than US CDC-NHSN rates.[6–9] There is a great variation in the rates reported in India and the world. The range of VAP, CLABSI, and CAUTI rates in India has been 6–32, 3.4–16, and 2.1–11.3 per 1000 device-days respectively.[2,10–12] Among the lower middle income countries, the range of VAP, CLABSI, and CAUTI rates was 8.1–43.7, 3.1–19.7, and 4.1–20.3.[4,13–17] Even upper middle and high income countries have reported very high rates of 46.3, 30.3, and 18.5 for VAP, CLABSI, and CAUTI respectively.[18–24] However, countries such as Saudi Arabia and Kuwait, which are developing high-income countries, have low rates of DA-HAI, and the rates in Korea are closer to CDC-NHSN rates.[22–24] The LOS after DA-HAI and associated mortality vary due to patient transfer and discharge. While mortality associated with VAP, CLABSI, and CAUTI varies from 15 to 50%, 12 to 25%, and 7 to 35%, crude mortality in ICU is attributable to (a) Admissions of patients having undergone extensive traumatic or pathophysiological compromise who get referred through various echelons of care; (b) Geriatric clientele with multiple comorbidities in decompensated state; (c) Deteriorating patients of other wards being transferred to ICU for critical care, who could not be revived from cardiac arrest prior to demise.[4,6,25]

Most common pathogens causing HAI have been abbreviated as ESKAPE pathogens which include *Enterococcus faecium*, *S. aureus*, *K. pneumoniae*, *A. baumanii*, *P. aeruginosa*, *Enterobacter* species, and *E. coli*. *Serratia*, *Proteus*, *Citrobacter*, *Enterobacter*,

Morganella, *Hemophilus influenza*, coagulase negative Staphylococci, *Providencia stuartii*, and *Elizabethkingia meningoseptica* are also implicated in HAI, along with *Candida*, and *Trichosporon* which are common in patients on prolonged antibacterial therapy.[3,26,27] The magnitude of MDR including panresistance, as reported by this study as well as various studies, has reached alarming proportions and acts as a caveat to the conduct of ICP.[4–24] Multiple coexistent resistance phenotypes such as Modification of PBP (mecA) and Macrolide/Lincosamide/Streptogramin B resistance (MLSB) among Gram-positive bacteria as well as Extended Spectrum Beta Lactamases (ESBL), Metallo Beta Lactamases (MBL), AmpC, and Carbapenemase-resistant Enterobacteriaceae (CRE) in Gram-negative bacteria reduce treatment options to reserve antimicrobials which are expensive and further the development of antimicrobial resistance due to exposure and increased selection pressure.[3,27] Environmental surveillance revealing *K. pneumoniae* susceptible to all antimicrobials could not be correlated with any clinical isolates; however, such ICU flora have the potential to develop multidrug resistance.

The control of HAI mandates a strict infection control policy, ongoing surveillance of infections, monitoring of preventive practices, and overall administrative control, all of which are executed under the ambit of Hospital Infection Control Committee (HICC) in our hospital. The Head of the hospital leads a team steered by a clinical microbiologist keeping the hospital management, clinicians, ICU administrators, hospital epidemiologist, and nursing staff in a coherent team effectively committed to ICP through sterilization and disinfection procedures, two-tier approach, barrier nursing, hand hygiene, proper disposal of biomedical waste, and interactive teaching sessions. However, there is a scope of improving adherence to guidelines and bundles of care for devices in a multidisciplinary ICU. The study is limited by lack of assessment of risk factors, severity of illness, and complications such as sepsis. There are likely variations in efficiency of surveillance temporally due to (a) Infrastructural and logistic limitations such as increasing patient commitments in ICU, change of staff, rapid discharge/deaths/transfers; (b) Patient limitations and morbidity restricting early discharge from ICU, weaning-off from devices, deficiencies in patient, and attendant education; (c) Research limitations such as interpersonal variation in requesting intuitive cultures from ICU; (d) Microbiological limitations of timing of sample collection, detection of small colony variants, biofilms, single colony on plate, interpretation of semiquantitative cultures in patients exposed to antimicrobials before admission to ICU, sensitivity of culture-based methods, and heteroresistance.

The concept of HAI has wider ramifications. DA-HAI is pertinent not only in ICU settings, but also other managed care facilities including home-based hospital care (HBHC), ambulatory care, critical-access hospitals, disease-specific care, long-term care, office-based surgery, and behavioral healthcare. While DA-HAI in ICU focuses on VAP, CLABSI, and CAUTI, implantable cardiac, orthopedic, intrauterine devices, and external devices such as endoscopes and humidifiers also cause HAI. Non-device-associated HAI are also increasingly being encountered.[28]

Surveillance methodology for DA-HAI is evolving to standardized active real-time electronic surveillance through cross-platform infection control software for validation and quality control of hospital epidemiology database including emerging pathogens and resistograms. Automated camera-aided process surveillance of hand hygiene opportunities, which forms the most effective strategies to control HAI as well as emerging antimicrobial resistance, is mandated. While resistograms form a guideline for formulating guided prescription policies curbing empiricism and facilitating antimicrobial stewardship efforts, molecular epidemiology studies help trace clonal expansion, and antimicrobial impregnated catheters and antimicrobial lock techniques improve patient safety.[3]

The National Patient Safety Goals purported by WHO World Alliance on Patient Safety in 2009 emphasize role of HAI in all unanticipated death or major permanent loss of function. There is also an emphasis on implementing evidence-based practices to prevent HAI due to MDR pathogens in acute care hospitals along with patients' active involvement in their own care as a patient safety strategy. HAI have been categorized as 'never events' by the National Quality Forum, with farfetched effects toward mandatory reporting of HAI, creation of performance benchmarks, notification to patients and patient safety organizations, and treatment cost waivers coupled with implementing disincentives in insurance payments to hospitals. However, there is a Policy-Practice Gap (PPG) possibly due to Knowledge, Attitude, Practices, and Behavior (KAPB) gap between policy makers and healthcare providers as infections are inevitable despite the best of practices owing to unpredictable infection dynamics, and HAI can never be classified as 'never events'.[29]

While Indian ICUs have been networked under INICC, the Armed Forces Medical Services are traversing through an opportunistic model which can be replicated by standardizing surveillance parameters in networked Armed Forces hospitals to enhance patient safety parameters.

The future of infection control beckons point of care diagnostic technologies, zero-error prevention strategies, and surveillance with modern mathematical and statistical modeling including logistic regression, receiver operating curves, and Artificial Neural Networks.[30] Nevertheless, the sociotechnical context and macroergonomics of patient-centered care remain important elements in infection control and patient safety.

Conclusion

The rates of VAP, CLABSI, and CAUTI of our center are comparable to average unadjusted rates in India, lower middle, upper middle and high-income countries. Rates are, however, much higher than US CDC-NHSN and Korea. Patients and HCPs form important reservoirs of infection. One-third HCPs may harbor MRSA which can be eradicated by topical mupirocin.

Resolute conviction and sustained momentum in Infection Control Initiatives targeted at ongoing surveillance and suitable interventions is an essential step toward patient safety. Reiteration of policy interventions to focus on patient education, device use, and antimicrobial stewardship; human resource interventions to focus on behavioral modification for

hand hygiene and biomedical waste disposal; and procedural interventions regarding bundles of care, barrier nursing, and two-tier approach in infection control need to be emphasized time and again.

Conflicts of interest

The authors have none to declare.

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