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Device-associated infection rates in 398 intensive care units in Shanghai, China: International Nosocomial Infection Control Consortium (INICC) findings

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SUMMARY

Objectives: To determine device-associated healthcare-associated infection (DA-HAI) rates and the microorganism profile in 398 intensive care units (ICUs) of 70 hospitals in Shanghai, China.
Methods: An open-label, prospective, cohort, active DA-HAI surveillance study was conducted on patients admitted to 398 tertiary-care ICUs in China from September 2004 to December 2009, implementing the methodology developed by the International Nosocomial Infection Control Consortium (INICC). The data were collected in the participating ICUs, and uploaded and analyzed at the INICC headquarters on proprietary software. DA-HAI rates were registered by applying the definitions of the US Centers for Disease Control and Prevention (CDC) National Healthcare Safety Network (NHSN). We analyzed the rates of DAI-HAI, ventilator-associated pneumonia (VAP), central line-associated bloodstream infection (CLABSI), and catheter-associated urinary tract infection (CAUTI), and their microorganism profiles.
Results: During the 5 years and 4 months of the study, 391 527 patients hospitalized in an ICU for an aggregate of 3 245 244 days, acquired 20 866 DA-HAIs, an overall rate of 5.3% (95% confidence interval (CI) 5.3–5.4) and 6.4 (95% CI 6.3–6.5) infections per 1000 ICU-days. VAP posed the greatest risk (20.8 per 1000 ventilator-days, 95% CI 20.4–21.1), followed by CAUTI (6.4 per 1000 catheter-days, 95% CI 6.3–6.6) and CLABSI (3.1 per 1000 catheter-days, 95% CI 3.0–3.2). The most common isolated microorganism was *Acinetobacter baumannii* (19.1%), followed by *Pseudomonas aeruginosa* (17.2%), *Klebsiella pneumoniae* (11.9%), and *Staphylococcus aureus* (11.9%).
Conclusions: DA-HAIs in the ICUs of Shanghai pose a far greater threat to patient safety than in ICUs in the USA. This is particularly the case for the VAP rate, which is much higher than the rates found in developed countries. Active infection control programs that carry out infection surveillance and implement prevention guidelines can improve patient safety and must become a priority.

1. Introduction

Surveillance of device-associated healthcare-associated infection (DA-HAI) in the intensive care unit (ICU) represents a prominent tool in hospital infection control and quality assurance in many industrialized countries, including the USA.[1] In this respect, the US Centers for Disease Control and Prevention (CDC) Study of the Efficacy of Nosocomial Infection Control (SENIC) has reported that surveillance plays a leading role in the reduction of DA-HAIs.[2]

Similarly, it has been increasingly reported in scientific studies that DA-HAIs pose the primary threat to patient safety in the ICU, and are among the principal causes of patient morbidity and mortality.[3–5] The CDC's previous National Nosocomial Infection Surveillance System (NNIS) and current National Healthcare Safety Network (NHSN) have established standardized criteria for DA-HAI surveillance.[6,7] This standardized surveillance method allows infection control practitioners (ICPs) to determine DA-HAI rates per 1000 device-days, which can be used as benchmarks among different healthcare centers. It also provides ICPs with an in-depth look at the institutional problems they are confronted with, so that they can design an effective strategy to solve them. The device utilization (DU) ratio constitutes an extrinsic risk factor for DA-HAI.[8] The DU ratio also comprises a marker for severity of illness in patients vis-à-vis patient susceptibility to DA-HAI.In the context of an expanded framework for DA-HAI control, it is in high-income countries that most of the relevant studies of ICU-acquired infections have been conducted;[9] in the developing countries,

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the scientific literature reporting on DA-HAI rates by means of using standardized definitions is scarce.[10–18]

The International Nosocomial Infection Control Consortium (INICC) was founded in 1998, after selected hospitals from Latin America were invited to participate in the project to measure DA-HAI using standardized definitions and methodology.[19] Shortly afterwards, other hospitals located in different parts of the world joined the Consortium. At present, the INICC comprises a worldwide network with hospitals in 40 countries of Latin America, Asia, Africa, and Europe.[10–18]

On a monthly basis, healthcare facilities send data to the INICC, which are then entered into an international database. Hospital members of the INICC provide general medical and surgical inpatient services to adults and children hospitalized in the ICUs.

In China, published data on DA-HAI rates are not available in the English language. The findings of the present study in Shanghai form an integral part of the INICC and reflect the outcome surveillance data that were systematically collected.

2. Methods

2.1. Setting

This study was carried out in 398 ICUs of 70 hospitals, from September 2004 to December 2009. The hospitals have an infection control team composed of physicians and ICPs with experience in infection control. The infection control teams include at least one full time physician and several infection control nurses. The nurses involved are all professionals and work full-time in infection control. They are responsible for collecting information from patients, and once a DAI is suspected, they report it to the physician for an immediate diagnosis. The ICPs listed in Table 1 work full time, but at each hospital there are also several part-time nurses who also collaborate in the diagnosis of DAI. The ICPs in Shanghai are all trained by the Municipal Infection Control Center. This center provides training courses twice a year, and each course lasts approximately 3–5 days. The performances of the ICPs in these 70 hospitals are assessed by the Municipal Infection Control Center each year.

The clinical microbiology laboratory provides in vitro susceptibility testing of clinical isolates using standardized methods. All the hospitals analyzed the samples in their own microbiology laboratories. This analysis included routine culture of the specimens and conventional phenotypic identification using automated machines (BD Phoenix or VITEK 2) or API strips. The sensitivity of the microorganisms was defined by the automated machines (BD Phoenix or VITEK 2) or by drug sensitive slips method.

The nurse-to-patient ratio is 2–2.5:1 in the participating ICUs, as required by the Quality Control Center of Critical Medicine and Infection Control. The institutional review boards of the hospitals approved the study protocol. Patient confidentiality was protected by codifying the recorded information, making it only identifiable to the infection control team.

Table 1
Features of the participating hospitals, Shanghai, 2004–2009

Variable	Hospital (N = 70)	n (%)
Type of hospital	Academic	33 (47%)
	Public	37 (53%)
Complexity level	Level 2	36 (51%)
	Level 3	34 (49%)
Number of ICPs	1 ICP	34 (49%)
	2–3 ICPs	28 (40%)
	>3 ICPs	8 (11%)

ICP, infection control practitioner.

Fifty-one percent of the participating hospitals are categorized as 'complexity level 2' (which means that they are hospitals in medium-size cities, counties, or districts, with more than 100 beds, but fewer than 500), and 49% as 'complexity level 3' (general or comprehensive hospital at the national, provincial, or city level, with more than 500 beds) (Table 1)

2.2. Surveillance

On a daily basis, data were collected by the infection control teams prospectively from all the patients admitted to the ICUs by means of specifically designed forc the DA-HAI definitions provided by the CDC-NNIS and CDC-NHSN.[6,7]

ICUs were stratified into types according to the patient population: adult ICU or pediatric ICU.

The identity of all INICC Shanghai hospitals is confidential, in accordance with the INICC Charter.

Device-days consisted of the total number of central line (CL)-days, urinary catheter (UC)-days, or mechanical ventilator (MV)-days.

2.3. DA-HAI rate calculations

Outcomes measured during the surveillance period included the incidence density rate of central line-associated blood stream infection (CLABSI; number of CLABSI divided by 1000 CL-days and multiplied by 1000); catheter-associated urinary tract infection (CAUTI; number of CAUTI divided by 1000 UC-days and multiplied by 1000); and ventilator-associated pneumonia (VAP; number of VAP divided by 1000 MV-days and multiplied by 1000).

DU ratios were calculated by dividing the total number of device-days by the total number of bed-days.[20]

2.4. Statistical analysis

EpiInfo version 6.04b (CDC, Atlanta, GA, USA) and SPSS 16.0 (SPSS Inc. an IBM company, Chicago, IL, USA) were used to perform the data analysis.

Chi-square analyses for dichotomous variables and the t-test for continuous variables were used to analyze baseline differences among rates. Relative risk (RR) ratios, 95% confidence intervals (CIs), and p-values were determined for all outcomes. The level of significance was set at $p < 0.05$.

3. Results

During the 5 years and 4 months of the study, 391 527 patients hospitalized in an ICU for an aggregate of 3 245 244 days acquired 20 866 DA-HAIs, an overall rate of 5.3% (95% CI 5.3–5.4) of DA-HAIs and 6.4 (95% CI 6.3–6.5) DA-HAIs per 1000 ICU-days. The characteristics of the 398 ICUs at INICC Shanghai hospitals that contributed data to this report are shown in Table 1.

The overall CLABSI rate was 3.1 (95% CI 3.0–3.2). The highest CLABSI rate was found in the medical ICUs: 4.3 per 1000 CL-days (95% CI 3.7–5.0), and the lowest rates in the burn ICUs and trauma ICUs (0.0 and 1.1 per 1000 CL-days, respectively). The difference between the medical and trauma ICUs was significant (RR 0.86, 95% CI 1.71–8.72, $p = 0.0004$). The DU ratio of CL was higher in trauma ICUs at 0.41, than in the medical ICUs at 0.18 ($p < 0.001$) (Tables 2 and 3).

The VAP rate was 20.8 (95% CI 20.4–21.1) in all the ICUs combined. The highest VAP rate was found in the trauma ICUs: 39.2 per 1000 MV-days (95% CI 33.5–45.5), and the lowest in the burn ICUs: 7.5 per 1000 MV-days (95% CI 0.1–40.9). However, the difference in the VAP rates between these ICUs was not significant

Table 2
Pooled means and 95% confidence intervals of the distribution of central line-associated blood stream infection rates (per 1000 central line-days) by type of adult and pediatric ICU.

Type of ICU	No. of ICUs	No. of patients	No. of CLABSI	CL-days	Pooled mean CLABSI rate	95% CI
Burn ICU	8	169	0	351	0.0	-
Cardiothoracic ICU	48	61 189	332	166 943	2.0	1.8–2.2
Coronary care ICU	59	88 287	190	59 337	3.2	2.7–3.7
General ICU	47	64 707	719	198 871	3.6	3.4–3.9
Medical ICU	53	24 664	164	38 207	4.3	3.7–5.0
Neurosurgical ICU	43	26 944	145	64 521	2.2	1.9–2.6
Pediatric ICU	19	17 365	68	19 462	3.5	2.7–4.4
Respiratory ICU	48	10 668	84	30 598	2.7	2.2–3.4
Surgical ICU	64	95 491	870	251 631	3.5	3.2–3.7
Trauma ICU	9	2043	6	5394	1.1	0.4–2.4
Overall	398	391 527	2578	835 315	3.1	3.0–3.2

ICU, intensive care unit; CLABSI, central line-associated blood stream infection; CL, central line; CI, confidence interval.

Table 3
Pooled means and 95% confidence intervals of central line utilization ratios by type of adult and pediatric ICU

Type of ICU	No. of ICUs	CL-days	Patient-days	Pooled mean DUR	95% CI
Burn ICU	8	351	663	0.53	0.49–0.57
Cardiothoracic ICU	48	166 943	416 574	0.40	0.39–40.1
Coronary care ICU	59	59 337	691 444	0.09	0.08–0.09
General ICU	47	198 871	655 734	0.30	0.30–0.30
Medical ICU	53	38 207	213 547	0.18	0.18–0.18
Neurosurgical ICU	43	64 521	235 930	0.27	0.27–0.28
Pediatric ICU	19	19 462	195 671	0.10	0.09–0.10
Respiratory ICU	48	30 598	123 524	0.25	0.24–0.25
Surgical ICU	64	251 631	699 138	0.36	0.36–0.36
Trauma ICU	9	5394	13 019	0.41	0.41–0.43
Overall	398	835 315	3 245 244	0.26	0.26–0.26

ICU, intensive care unit; CL, central line; DUR, device use ratio; CI, confidence interval.

Table 4
Pooled means and 95% confidence intervals of the distribution of ventilator-associated pneumonia rates (per 1000 mechanical ventilator-days) by type of adult and pediatric ICU

Type of ICU	No. of ICUs	No. of patients	No. of VAP	MV-days	Pooled mean VAP rate	95% CI
Burn ICU	8	169	1	134	7.5	0.1–40.9
Cardiothoracic ICU	48	61 189	975	78 901	12.4	11.6–13.1
Coronary care ICU	59	88 287	437	25 507	17.1	16.0–18.8
General ICU	47	64 707	4103	165 007	24.9	24.1–25.6
Medical ICU	53	24 664	535	25 219	21.2	19.5–23.1
Neurosurgical ICU	43	26 944	1487	63 360	23.5	22.3–24.7
Pediatric ICU	19	17 365	220	20 806	10.6	9.2–12.1
Respiratory ICU	48	10 668	676	31 186	21.7	20.0–23.4
Surgical ICU	64	95 491	2626	126 230	20.8	20.2–21.6
Trauma ICU	9	2043	164	4186	39.2	33.5–45.5
Overall	398	391 527	11 224	540 536	20.8	20.4–21.1

ICU, intensive care unit; VAP, ventilator associated pneumonia; MV, mechanical ventilator; CI, confidence interval.

Table 5
Pooled means and 95% confidence intervals of mechanical ventilator utilization ratios by type of adult and pediatric ICU

Type of ICU	No. of ICUs	MV-days	Patient-days	Pooled mean DUR	95% CI
Burn ICU	8	134	663	0.20	0.17–0.23
Cardiothoracic ICU	48	78 901	416 574	0.19	0.18–0.19
Coronary care ICU	59	25 507	691 444	0.04	0.04–0.04
General ICU	47	165 007	655 734	0.25	0.25–0.25
Medical ICU	53	25 219	213 547	0.12	0.11–0.12
Neurosurgical ICU	43	63 360	235 930	0.27	0.27–0.27
Pediatric ICU	19	20 806	195 671	0.11	0.10–0.11
Respiratory ICU	48	31 186	123 524	0.25	0.25–0.25
Surgical ICU	64	126 230	699 138	0.18	0.18–0.18
Trauma ICU	9	4186	13 019	0.32	0.31–0.33
Overall	398	540 536	3 245 244	0.17	0.17–0.17

ICU, intensive care unit; DUR: device use ratio; MV, mechanical ventilator; CI, confidence interval.

Table 6
Pooled means and 95% confidence intervals of the distribution of catheter-associated urinary tract infection rates (per 1000 urinary catheter-days) by type of adult and pediatric ICU

Type of ICU	No. of ICUs	No. of patients	No. of CAUTI	UC-days	Pooled mean CAUTI rate	95% CI
Burn ICU	8	169	0	452	0.0	-
Cardiothoracic ICU	48	61 189	206	144 694	1.4	1.2–1.6
Coronary care ICU	59	88 287	1050	82 220	12.8	12.0–13.6
General ICU	47	64 707	2596	297 760	8.7	8.4–9.1
Medical ICU	53	24 664	637	67 243	9.5	8.7–10.2
Neurosurgical ICU	43	26 944	585	129 187	4.5	4.2–4.9
Pediatric ICU	19	17 365	39	14 742	2.6	1.9–3.6
Respiratory ICU	48	10 668	331	41 392	8.0	7.2–8.9
Surgical ICU	64	95 491	1550	312 618	5.0	4.7–5.2
Trauma ICU	9	2043	70	7707	9.1	7.1–11.5
Overall	398	391 527	7064	1 098 015	6.4	6.3–6.6

ICU, intensive care unit; CAUTI, catheter-associated urinary tract infection; UC, urinary catheter; CI, confidence interval.

Table 7
Pooled means and 95% confidence intervals of urinary catheter utilization ratios by type of adult and pediatric ICU

Type of ICU	No. of ICUs	UC-days	Patient-days	Pooled mean DUR	95% CI
Burn ICU	8	452	663	0.68	0.65–0.72
Cardiothoracic ICU	48	144 694	416 574	0.35	0.35–0.35
Coronary care ICU	59	82 220	691 444	0.12	0.12–0.12
General ICU	47	297 760	655 734	0.45	0.45–0.46
Medical ICU	53	67 243	213 547	0.31	0.31–0.32
Neurosurgical ICU	43	129 187	235 930	0.55	0.55–0.56
Pediatric ICU	19	14 742	195 671	0.08	0.07–0.08
Respiratory ICU	48	41 392	123 524	0.34	0.33–0.34
Surgical ICU	64	312 618	699 138	0.45	0.45–0.45
Trauma ICU	9	7707	13 019	0.59	0.58–0.60
Overall	398	1 098 015	3 245 244	0.34	0.34–0.34

ICU, intensive care unit; DUR, device use ratio; UC, urinary catheter; CI, confidence interval.

($p = 0.06$). The highest MV DU ratio was found in the trauma ICUs: 0.32 (Tables 4 and 5).

The overall CAUTI rate was 6.4 (95% CI 6.3–6.6). The highest CAUTI rate was found in the coronary care ICUs: 12.8 per 1000 UC-days (95% CI 12.0–13.6), and the lowest rates in the burn and cardiothoracic ICUs: 0.0 and 1.4 per 1000 UC-days, respectively. The difference between coronary care and cardiothoracic ICUs was significant regarding the CAUTI rate ($p < 0.001$) and the UC DU ratio (0.12 in coronary care ICUs compared to 0.35 in cardiothoracic ICUs, $p < 0.001$). The highest UC DU ratio was found in the burn ICUs: 0.68. (Tables 6 and 7).

Table 8 shows the DA-HAI rates stratified by hospital size. The highest CLABSI rate was found in the larger-size hospitals, whose rate (3.4 per 1000 CL-days) was significantly higher than that in the medium-size hospitals (2.2 per 1000 CL-days) (RR 1.57, 95% CI 1.43–1.73, $p < 0.001$). The CAUTI rate, however, was higher in the smaller-size hospitals (8.0 per 1000 UC-days) than in the larger ones (5.6 per 1000 UC-days) (RR 1.44, 95% CI 1.34–1.55, $p < 0.01$). VAP rates were similar for all hospital sizes.

Table 9 shows the evolution of DA-HAI rates by year. It is noteworthy that the VAP rate improved over the years, decreasing from 26.0 (24.0–28.2) in 2004 to 15.8 (15.1–16.5) in 2009; this reduction of 39% was significant (RR 0.61, 95% CI 0.55–0.66, $p < 0.01$). The CAUTI rate also declined, from 7.4 to 4.9 (RR 0.67, 95% CI 0.59–0.75, $p < 0.001$). However, CLABSI rates remained stable. We also noticed that the overall VAP rate was higher in the

Table 8
Pooled means and 95% confidence intervals of the distribution of device-associated infection rates (per 1000 invasive device-days) by hospital size

Hospital size	No. of patients	CLABSI rate (95% CI)	VAP rate (95% CI)	CAUTI rate (95% CI)
200–500 beds	51 854	3.4 (3.0–3.7)	20.2 (19.1–21.4)	8.0 (7.5–8.6)
501–800 beds	144 796	2.2 (2.0–2.4)	20.9 (20.2–21.6)	7.5 (7.2–7.7)
≥801 beds	194 877	3.5 (3.4–3.7)	20.8 (20.3–21.3)	5.6 (5.4–5.7)

CI, confidence interval; CLABSI, central line-associated blood stream infection; VAP, ventilator associated pneumonia; CAUTI, catheter-associated urinary tract infection.

Table 9
Pooled means and 95% confidence intervals of the distribution of device-associated infection rates (per 1000 invasive device-days) by year

Hospital size	No. of patients	CLABSI rate (95% CI)	VAP rate (95% CI)	CAUTI rate (95% CI)
2004	18 335	3.0 (2.4–3.6)	26.0 (24.0–28.2)	7.4 (6.7–8.2)
2005	65 080	2.5 (2.3–2.8)	23.2 (22.2–24.2)	7.2 (6.8–7.6)
2006	69 010	2.8 (2.5–3.1)	23.6 (22.7–24.7)	7.4 (7.0–7.8)
2007	80 841	2.7 (2.2–3.0)	22.3 (21.5–23.2)	6.4 (6.1–6.7)
2008	78 012	4.3 (4.0–4.6)	19.0 (18.1–19.8)	6.4 (6.1–6.7
2009	80 249	3.0 (2.7–3.2)	15.8 (15.1–16.5)	4.9 (4.6–5.2)

CI, confidence interval; CLABSI, central line-associated blood stream infection; VAP, ventilator associated pneumonia; CAUTI, catheter-associated urinary tract infection.

Table 10
Comparison of DA-HAI rates (per 1000 device-days) in the ICUs of the International Nosocomial Infection Control Consortium (INICC) Shanghai hospitals and the US National Healthcare Safety Network (US NHSN)

	INICC Shanghai, China 2004–2009 Pooled mean (95% CI)	INICC 2004–2009 Pooled mean (95% CI)	US NHSN 2006–2008 Pooled mean (95% CI)
Medical ICU			
CLABSI	4.3 (3.7–5.0)	14.7 (13.8–15.6)	1.9 (1.8–2.0)
CAUTI	9.5 (8.7–10.2)	6.3 (5.8–6.8)	3.9 (3.7–4.2)
VAP	21.2 (19.5–23.1)	7.7 (7.1–8.3)	2.2 (2.0–2.4)
Surgical ICU			
CLABSI	3.5 (3.2–3.7)	5.0 (4.7–5.4)	2.3 (2.2–2.4)
CAUTI	5.0 (4.7–5.2)	5.0 (4.7–5.4)	4.3 (4.1–4.5)
VAP	20.8 (20.2–21.6)	16.3 (15.7–17.0)	4.9 (4.6–5.1)
Pediatric ICU			
CLABSI	3.5 (2.7–4.4)	10.7 (9.9–11.5)	3.0 (2.8–3.2)
CAUTI	2.6 (1.9–3.6)	4.7 (4.1–5.5)	4.2 (3.8–4.7)
VAP	10.6 (9.2–12.1)	6.5 (5.9–7.1)	1.8 (1.6–2.1)

DA-HAI, device-associated healthcare-associated infections; ICU, intensive care unit; CI, confidence interval; CLABSI, central line-associated bloodstream infection; CAUTI, catheter-associated urinary tract infection; VAP, ventilator-associated pneumonia.

public hospitals as compared with the academic hospitals (29.5 vs. 17.4, $p < 0.01$), and was also higher in the medium-complexity hospitals as compared with the high-complexity ones (25.0 vs. 19.0, $p < 0.01$).

Table 10 compares overall rates of CLABSI, CAUTI, and VAP in the INICC Shanghai ICUs and CDC NHSN ICUs. (1) Although NHSN rates were lower in the medical and surgical ICUs for all infection types, in the pediatric ICUs, the CLABSI rates were similar and the CAUTI rate was higher in the NHSN than in this study (4.2 compared to 2.6 per 1000 UC-days).

Table 11 shows the distribution of the 9043 isolated pathogens involved in device-associated infections. *Acinetobacter baumannii* was the most common microorganism (19.1%), followed by *Pseudomonas aeruginosa*. This indicates that Gram-negative bacteria were the most frequent overall. *Staphylococcus aureus* was the most common organism in CLABSI patients and *Candida spp* in CAUTI patients.

Table 11
Distribution of pathogens involved in DA-HAI

Microorganism related to DA-HAI	CLABSI-related ($n = 845$)	VAP-related ($n = 6151$)	CAUTI-related ($n = 2047$)	Overall ($n = 9043$)
Acinetobacter baumannii	12.3%	25.4%	3.0%	19.1%
Pseudomonas aeruginosa	5.1%	23.5%	3.3%	17.2%
Klebsiella pneumoniae	6.9%	14.6%	5.8%	11.9%
Staphylococcus aureus	15.9%	15.0%	1.2%	11.9%
Candida spp	14.0%	1.4%	35.7%	10.4%
Escherichia coli	10.1%	5.1%	19.1%	8.7%
Enterococcus faecium	1.7%	0.0%	13.3%	3.2%
Stenotrophomonas spp	1.9%	4.2%	0.1%	3.1%
Enterobacter spp	3.3%	2.6%	2.4%	2.6%
Enterococcus faecalis	5.1%	0.0%	8.5%	2.4%
Other Staphylococcus	14.1%	0.2%	2.6%	2.0%
Other Gram-negative	2.2%	1.9%	1.3%	1.8%
Other Pseudomonas	1.3%	1.7%	0.7%	1.4%
Proteus spp	0.6%	1.2%	1.1%	1.1%
Flavobacterium spp	0.5%	0.9%	0.1%	0.7%
Streptococcus spp	1.7%	0.0%	0.7%	0.3%
Other pathogens	3.3%	2.1%	1.1%	2.2%

DA-HAI, device-associated healthcare-associated infections; CLABSI, central line-associated blood stream infection; VAP, ventilator-associated pneumonia; CAUTI, catheter-associated urinary tract infection.

4. Discussion

It has been 30 years since the effectiveness of implementing an integrated infection control program focused on HAI surveillance was demonstrated. As reported in the many studies conducted in the USA, the incidence of HAI may be reduced by as much as 30%, enabling a feasible associated reduction in healthcare costs.[21] For more than 30 years, the CDC's NNIS/NHSN network has provided benchmark US ICU data on DAIs and antibiotic resistance, which have proven invaluable for researchers, and have served as an inspiration to the INICC program.[1,8,22–27] Initially, INICC surveillance was concentrated on DAI surveillance in the ICU, a healthcare setting with the highest HAI rates, in which patient safety is most seriously threatened, due to their critical condition and exposure to invasive devices.[28] In our study the most frequently isolated microorganism was *A. baumannii*, followed by *P. aeruginosa*. We had positive sputum culture results from 74% of all study patients with VAP, 25% of which were positive for *Acinetobacter sp*. In a previous study conducted in Hubei, China, *P. aeruginosa* was the most common microorganism, followed by *Escherichia coli* and *A. baumannii*.[29] In a different study also carried out in China in 2002, *A. baumannii* was the most common microorganism.[30]

The rate of device use in Shanghai ICUs is lower than that reported in US ICUs by the NNIS/NHSN system.[1,25,27] However, DA-HAI rates identified in Shanghai ICUs were higher than the published US rates (Table 9).[1,27] Although the difference in CLABSI and CAUTI is not considered significant, the VAP rate in Shanghai is particularly high in the ICUs in this study in comparison to the NNIS/NHSN rates. In a recent KISS (Krankenhaus Infektions Surveillance System) study in Germany, the VAP rate was 5.44, which is higher than that reported in the NHSN, but again still much lower than the rate found in our study.[31]

In the surgical ICUs of the Shanghai INICC network, the CLABSI rate was lower than the INICC pooled rates, the CAUTI rate was similar, and the VAP rate was higher. In the medical ICUs of the Shanghai INICC network, the CLABSI rate was lower than the INICC pooled rate, but the CAUTI rate and the VAP rate were higher. In the pediatric ICUs of the Shanghai INICC network, the CLABSI and CAUTI rates were lower than the INICC pooled rates and the VAP rate was higher.[13]

These higher DA-HAI rates may reflect the typical ICU situation in limited-resource countries as a whole.[32–34] Among the primary plausible causes, it should be mentioned that, in the majority of limited-resource countries, adherence to infection control programs is irregular.

Although few patients receive non-invasive ventilation in the ICU, device utilization rates are low in China. The severity of illness in patients is not frequently evaluated, so patients are not discharged from the ICU in a timely manner, which could partly explain the low utilization rate. To reduce the risk of infection in hospitalized patients, DA-HAI surveillance is of primary importance, because it effectively describes and addresses the importance and characteristics of the threatening situation created by DA-HAIs. This must be followed by the implementation of practices aimed at DA-HAI prevention and control. Additionally, participation in the INICC has played a fundamental role, not only in increasing the awareness of DAI risks in the INICC ICUs, but also in providing an exemplary basis for the institution of infection control practices. In many INICC ICUs, for example, the high incidence of DA-HAI has been reduced by carrying out targeted performance feedback programs for hand hygiene, and central-line, ventilator, and urinary catheter care.[15,35–41] Finally, to effectively control antibiotic resistance, the administration of anti-infectives must be restricted.

To compare a hospital's DA-HAI rates and DU ratios with the rates identified in this report, it is required that the hospital

concerned start collecting their data by applying the methods and methodology described by the CDC NHSN and INICC, and then calculate infection rates and DU ratios for the device-associated module.

The particular and primary application of these data is to serve as a guide for the implementation of prevention strategies and other quality improvement efforts locally, in order to help reduce DA-HAI rates to the minimum possible level.

To conclude, the data reported in this study strengthen the fact that DA-HAIs, particularly in ICU patients from low-income countries, must be regarded as a serious and often concealed threat to patient safety, as compared to the developed world. It is the primary objective of the INICC to foster infection control practices by facilitating elemental, feasible, and inexpensive tools and resources to tackle this problem effectively and systematically, leading to greater and stricter adherence to infection control programs and guidelines, and to the correlated reduction in DA-HAI and their adverse consequences in the ICUs participating in the INICC, as well as at any other healthcare facility in the developing world.

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