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Socioeconomic impact on device-associated infections in pediatric intensive care units of 16 limited-resource countries: International Nosocomial Infection Control Consortium findings

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Objectives: **We report the results of the International Nosocomial Infection Control Consortium prospective surveillance study from January 2004 to December 2009 in 33 pediatric intensive care units of 16 countries and the impact of being in a private vs. public hospital and the income country level on device-associated health care-associated infection rates. Additionally, we aim to compare these findings with the results of the Centers for Disease Control and Prevention National Healthcare Safety Network annual report to show the differences between developed and developing countries regarding device-associated health care-associated infection rates.**

Patients and Methods: **A prospective cohort, active device-associated health care-associated infection surveillance study was conducted on 23,700 patients in International Nosocomial Infection Control Consortium pediatric intensive care units. The protocol and methodology implemented were developed by International Nosocomial Infection Control Consortium. Data collection was performed in the participating intensive care units. Data uploading and analyses were conducted at International Nosocomial Infection Control Consortium headquarters on proprietary software. Device-associated health care-associated infection rates were recorded by applying Centers for Disease Control and Prevention National Healthcare Safety Network device-associated infection definitions, and the impact of being in a private vs. public hospital and the income country level on device-associated infection risk was evaluated.**

Interventions: **None.**

Measurements and Main Results: **Central line-associated bloodstream infection rates were similar in private, public, or academic hospitals (7.3 vs. 8.4 central line-associated bloodstream infection per 1000 catheter-days [$p < .35$ vs. 8.2; $p < .42$]). Central line-associated bloodstream infection rates in lower middle-income countries were higher than low-income countries or upper middle-income countries (12.2 vs. 5.5 central line-associated bloodstream infections per 1000 catheter-days [$p < .02$ vs. 7.0; $p < .001$]). Catheter-associated urinary tract infection rates were similar in academic, public and private hospitals: (4.2 vs. 5.2 catheter-associated urinary tract infection per 1000 catheter-days [$p = .41$ vs. 3.0; $p = .195$]). Catheter-associated urinary tract infection rates were higher in lower middle-income countries than low-income countries or upper middle-income countries (5.9 vs. 0.6 catheter-associated urinary tract infection per 1000 catheter-days [$p < .004$ vs. 3.7; $p < .01$]). Ventilator-associated pneumonia rates in academic hospitals were higher than private or public hospitals: (8.3 vs. 3.5 ventilator-associated pneumonias per 1000 ventilator-days [$p < .001$ vs. 4.7; $p < .001$]). Lower middle-income countries had higher ventilator-associated pneumonia rates than low-income countries or upper middle-income countries: (9.0 vs. 0.5 per 1000 ventilator-days [$p < .001$ vs. 5.4; $p < .001$]). Hand hygiene compliance rates were higher in public than academic or private hospitals (65.2% vs. 54.8% [$p < .001$ vs. 13.3%; $p < .01$]).**

Conclusions: **Hospital type and country socioeconomic level influence device-associated infection rates in developing countries and need to be considered when comparing device-associated infections from one country to another. (Pediatr Crit Care Med 2012; 13:000–000)**

Key Words: bacteremia; bloodstream infection; catheter-associated urinary tract infection; central line-associated bloodstream infection; developing countries; economy; emerging countries; health care-acquired infection; hospital-acquired pneumonia; hospital infection; INICC; intensive care unit; International Nosocomial Infection Control Consortium; limited resources countries; low-income countries; nosocomial infection; pediatric critical care; pediatric intensive care unit; ventilator-associated pneumonia

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The International Nosocomial Infection Control Consortium (INICC) is an international nonprofit, multicentered, collaborative health care-associated infection surveillance program based on the U.S. Centers for Disease Control and Prevention's (CDC) National Healthcare Safety Network (NHSN, formerly the National Nosocomial Infections Surveillance system) methods (1–4). Founded in Argentina in 1998, INICC is the first multinational health care-associated infection research network established to control and reduce device-associated health care-associated infections (DA-HAIs) through the analysis and feedback of data collected by hospital collaborators worldwide.

The World Bank classifies countries into four economic strata based on 2007 gross national income per capita. These groups are: low income (≤$935); lower middle income ($936–3,705); upper middle income ($3,706–11,455); and high income (≥$11,456) (5).

Together low-income, lower middle-income, and upper middle-income economies are sometimes referred to as developing economies, developing countries, lower-income countries, low-resource countries, or emerging countries. These economies represent 144 of 209 (68.8%) countries of the world and >75% of the world population.

There are very limited data regarding the association between country socioeconomic level and DA-HAI rates or the association between type of hospital (e.g., public, academic, or private) and DA-HAI rates. The goal of our study was to assess whether the socioeconomic or hospital type influenced DA-HAI rates.

METHODS

Setting

The study was carried out from January 2004 to December 2009 in 33 pediatric intensive care units (PICUs) in 16 limited resources countries. All PICUs have an infection control team with a physician and an infection control practitioner with experience in infection control and a microbiology laboratory to provide *in vitro* susceptibility testing of clinical isolates using standardized methods. The institutional review board of each hospital agreed to the study protocol. Patient confidentiality was protected by codifying the recorded information, making it only identifiable to the infection control team.

Surveillance

On a daily basis, data were collected prospectively from all the patients admitted to the PICUs by means of specifically designed forms. The data were gathered according to the DA-HAI definitions provided by the CDC National Nosocomial Infections Surveillance and CDC NHSN (6, 7) and methodology of INICC (2).

Culture Techniques

Central Line-Associated Bloodstream Infection. Central lines were removed aseptically and the distal 5 cm of the catheter was amputated and cultured using a standardized semiquantitative method (8). Concomitant blood cultures were drawn percutaneously in nearly all cases.

Ventilator-Associated Pneumonia. In most cases, a deep tracheal aspirate from the endotracheal tube was cultured aerobically and Gram-stained.

Catheter-Associated Urinary Tract Infection. A urine sample was aseptically aspirated from the sampling port of urinary catheter and cultured quantitatively.

In all cases, standard laboratory methods were used to identify micro-organisms and a standardized susceptibility test was performed (9).

DA-HAI Rate Calculation

Outcomes measured during the surveillance period included the incidence density rate of CLA-BSI (number of cases per 1000 central venous catheter-days), catheter-associated urinary tract infection (CA-UTI) (number of cases per 1000 urinary catheter-days), and ventilator-associated pneumonia (VAP) (number of cases per 1000 mechanical ventilator days).

Rates of VAP, CLA-BSI, and CA-UTI per 1000 device-days were calculated by dividing the total number of DA-HAI by the total number of specific device-days and multiplying the result by 1000 (10).

Device use ratios were calculated by dividing the total number of device-days by the total number of patient-days. Device-days are the total number of days of exposure to the device (central line, ventilator, or urinary catheter) by all of the patients in the selected population during the selected time period. Patient-days are the total number of days during which patients are hospitalized in the intensive care unit for the selected time period (10).

Compliance With the Hand Hygiene Procedure

Infection control nurses at the participating intensive care units (ICUs) monitored healthcare workers' hand hygiene (HH) practices using the INICC standardized protocol (2). They recorded potential opportunities for HH according to recommended guidelines and the actual number of HH episodes either with water and medicated/nonmedicated soap or alcoholic hand rub. Potential confounders of HH included type of ICU, professional category, gender, work shift, and type of procedure.

Observations were conducted at specific time periods distributed in three work shifts (morning, afternoon, and evening); 60 mins (range, 20–140 mins) each time, three times per wk. Observers were unobtrusive, and healthcare workers were not aware of the schedule of the monitoring period. Performance feedback was given by the INICC headquarters team to the participating ICU starting the first month of participation (2); the exact initiation of the performance feedback process was decided by each individual participating INICC ICU.

Education and training on correct HH practice was part of the regular infection control training of each institution.

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Table 1. Pediatric intensive care unit participation by country, hospital type, and socioeconomic level, International Nosocomial Infection Control Consortium, 2004–2009

	Low Income	Lower Middle Income			Upper Middle Income												
	India	Colombia	Egypt	Jordan	Peru	Philippines	Salvador	Sri Lanka	Tunisia	Argentina	Brazil	Lithuania	Malaysia	Mexico	Thailand	Turkey	Overall
Pediatric intensive care unit	4	5	1	1	1	1	1	1	1	1	4	3	1	2	2	4	33
Hospitals, no.	4	5	1	1	1	1	1	1	1	1	4	3	1	2	2	3	32
Academic teaching	1	2	1	1	0	1	1	1	1	0	0	3	0	0	2	2	16
Public	0	0	0	0	1	0	0	0	0	0	1	0	0	2	0	0	4
Private community	3	3	0	0	0	0	0	0	0	1	3	0	1	0	0	2	12

Table 2. Pediatric intensive care unit device-associated health care-associated infection distribution and rate by infection site, International Nosocomial Infection Control Consortium, January 2004 to December 2009

Infection Site	Device Type	Device-Days	Patient-Days	INICC Device Use Ratio[a]	CDC NHSN Device Use Ratio[a]	INICC DA-HAI (No.)	INICC Distribution of DA-HAIs (%)	CDC NHSN Distribution of DA-HAIs (%)	INICC Rate per 1000 Device-Days[b]	CDC NHSN DA-HAI Rates per 1000 Device-Days[b]
Ventilator-associated pneumonia	Mechanical ventilation	71,885	123,597	0.58	0.42	430	42.8%	19.5%	6.0 (95% CI, 5.4–6.6)	1.8 (95% CI, 1.6–2.1)
Central line-associated bloodstream infection	Central line	57,383	123,597	0.46	0.48	466	46.4%	57.2%	8.1 (95% CI, 7.4–9.4)	3.0 (95% CI, 2.8–3.2)
Catheter-associated urinary tract infection	Urinary catheter	26,896	123,597	0.22	0.29	109	10.8%	23.2%	4.1 (95% CI, 3.3–4.9)	4.2 (95% CI, 3.8–4.7)

INICC, International Nosocomial Infection Control Consortium; CDC, Centers for Disease Control and Prevention; NHSN, National Healthcare Safety Network; DA-HAI, device-associated health care-associated infection; CI, confidence interval.

[a]Device use ratio: rates were calculated by dividing the total number of specific device-days by the total number of bed days by all of the patients in the selected population during the selected time period; [b]rate per 1000 device-days: rates were calculated by dividing the total number of DAIs by the total number of specific device-days by all of the patients in the selected population during the selected time period and multiplying the result by 1000.

Statistical Analysis

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

Chi-square analyses for dichotomous variables and *t* test for continuous variables were used to analyze baseline differences among rates. Relative risk ratios, 95% confidence intervals and *p* values were determined for all primary and secondary outcomes. Probability values $< .05$ by two-sided tests were considered significant.

DA-HAI rates were stratified by country socioeconomic level (e.g., low income, lower middle income, and upper middle income using World Bank criteria and by type of hospital (public, academic, and private).

RESULTS

From January 2004 to December 2009 (i.e., study period), data were reported from 33 PICUs (from 32 hospitals) in 16 countries in Latin America, Asia, Africa, and Europe (Table 1). The selected PICUs had participated in the INICC surveillance system for a mean of 28.9 ± 24.7 SD (range, 1–67) months. Twenty of the reporting 33 PICUs (61%) collected and sent prospective, original data to INICC, and 13 PICUs (39%) collected and sent aggregated data to INICC. In all instances, the DA-HAI rates of original and aggregated data were similar.

Sixteen (50%) of the 32 participating hospitals are academic teaching, 12 (38%) are private, and four (13%) are public hospitals. Three (75%) of the four reporting low-income country hospitals are private hospitals.

During the study period, the largest number of device-days was for mechanical ventilation (46%) followed by central line days (36.7%) and urinary catheter days (17.2%).

The mechanical ventilator use was 0.58 in our ICUs and 0.42 in the CDC NHSN Pediatric ICUs. The central line use was 0.46 in our study and 0.48 in the CDC ICUs. The urinary catheter use was 0.22 in our ICUs, which is lower than the 0.29 rate in the CDC NHSN.

Data from the CDC's NHSN and for INICC were similar for PICU patients in that CLA-BSIs accounted for the greatest number of DA-HAIs (INICC 46.4% vs. NHSN 57.2%). However, in NHSN, the second most common DA-HAI is CA-UTI (23.2%), whereas in INICC, the second and third most common DA-HAI site was VAP (42.8%), followed by CA-UTI (10.8%). The CLA-BSI and VAP rates at INICC hospitals were significantly higher than at CDC's NHSN hospitals, but the CA-UTI rate was similar (Table 2).

We found that the overall PICU CLA-BSI rate was 8.1 CLA-BSIs per 1000 catheter-days. The CLA-BSI rate was similar for PICU patients at public, academic, or private hospitals (8.4 vs. 8.2, $p = .83$; 8.4 vs. 7.3, $p = .42$) (Table 3). The overall central line pooled mean device use ratio (DUR) was 0.46, which is similar to the

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Table 3. Distribution of central line-associated bloodstream infection rates and central line use ratios for pediatric intensive care units stratified by hospital type

Type of Hospital	No. of Units	No. of Patients[a]	Central Line-Days	No. of CLA-BSI (Laboratory-Confirmed Bloodstream Infection)	No. of CLA-BSI (Clinical Sepsis Without Laboratory Confirmation)	No. of CLA-BSI (Laboratory-Confirmed Bloodstream Infection + Clinical Sepsis Without Laboratory Confirmation)	Pooled Mean CLA-BSI Rate	95% Confidence Interval	Patient-Days	Central Line-Days	Pooled Mean Device Use Ratio (95% Confidence Interval)	Average Central Line Days per Patient
Academic reaching	16	16,158	26,763	145	74	219	8.2	7.1–9.3	47,715	26,763	0.56 (0.56–0.57)	1.66
Public hospitals	4	2,817	22,372	165	22	187	8.4	7.2–9.6	36,971	22,372	0.60 (0.60–0.61)	7.94
Private hospitals	13	4,725	8,248	54	6	60	7.3	5.6–9.4	38,911	8,248	0.21 (0.21–0.22)	1.75
Low income	4	1,247	1,464	8	0	8	5.5	2.4–10.8	6,279	1,464	0.23 (0.22–0.24)	1.17
Lower middle income	12	2,889	12,565	80	73	153	12.4	10.5–14.3	25,097	12,565	0.50 (0.49–0.51)	4.35
Upper middle income	17	19,564	43,354	276	29	305	7.0	6.3–7.9	92,221	43,354	0.47 (0.47–0.47)	2.22
Overall	33	23,700	57,383	364	102	466	8.1	7.4–8.9	123,597	57,383	0.46 (0.46–0.47)	2.42

CLA-BSI, central line catheter-associated bloodstream infection.

[a]No. of patients: total of patients admitted to the pediatric intensive care units during the study period.

Table 4. Distribution of urinary-catheter associated infection rates and urinary catheter use ratios for pediatric intensive care units stratified by hospital type

Type of Hospital	No. of Units	No. of Patients[a]	Urinary Catheter-Days	No of Catheter-Associated Urinary Tract Infections	Pooled Mean Catheter-Associated Urinary Tract Infection Rate	95% Confidence Interval	Patient-Days	Urinary Catheter-Days	Pooled Mean Device Use Ratio (95% Confidence Interval)	Average Urinary Catheter Days per Patient
Academic teaching	16	16,158	17,193	72	4.2	3.3–5.3	47,715	17,193	0.36 (0.36–0.36)	1.06
Public hospitals	4	2,817	3,664	19	5.2	3.1–8.1	36,971	3,664	0.10 (0.96–1.02)	1.30
Private hospitals	13	4,725	6,039	18	3.0	1.8–4.7	38,911	6,039	0.16 (0.15–0.16)	1.28
Low income	4	1,247	1,784	1	0.6	0.01–3.1	6,279	1,784	0.27 (0.27–0.30)	1.43
Lower middle income	12	2,889	7,095	42	5.9	4.3–8.0	25,097	7,095	0.28 (0.27–0.29)	2.46
Upper middle income	17	19,564	18,017	66	3.7	2.8–4.7	92,221	18,017	0.20 (0.19–0.20)	0.92
Overall	33	23,700	26,896	109	4.1	3.3–4.9	123,597	26,896	0.22 (0.22–0.22)	1.13

[a]No. of patients: total of patients admitted to the pediatric intensive care units during the study period.

CDC's NHSN for PICU patients. The central line DUR was higher at public hospitals than at either academic or private hospitals (0.60 vs. 0.56, $p < .001$; or 0.60 vs. 0.21, $p < .001$) and the average of central line days was higher in the public hospitals as well (Table 3). When we examined the CLA-BSI rate by socioeconomic level, we found that the CLA-BSI rate was significantly higher at lower-middle income countries than at upper middle-income or low-income countries (12.2 vs. 7.0, $p < .001$ or 12.2 vs. 5.5, $p < .023$). Central line DUR was lower at low-income hospitals and significantly higher at lower middle or upper middle-income countries (0.23 vs. 0.50, $p < .001$, or 0.23 vs. 0.47 $p < .001$) (Table 3).

Next, we evaluated urinary catheter use and CA-UTI rates. CA-UTI rates were similar at public, academic, and private hospitals (5.2 vs. 4.2 CA-UTIs per 1000 catheter-days, $p = .41$, or 5.2 vs. 3.0 CA-UTIs per 1000 catheter-days, $p = .19$, respectively; Table 4), although urinary catheter DUR was higher at academic hospitals than at private or public hospitals (0.36 vs. 0.16, $p < .001$ or 0.36 vs. 0.10, $p < .001$). The average length of urinary catheter use was slightly higher in public hospitals. Urinary catheter DUR was similar at all hospitals at all socioeconomic levels (range, 0.2–0.3), but the average of days per patient was higher in the low middle-income countries (Table 4). However, CA-UTI rates were significantly higher at lower middle-income country hospitals than at either upper middle-income or low-income countries (5.9 vs. 3.7, $p < .01$, or 5.9 vs. 0.6, $p < .004$) (Table 4).

When we examined VAP rates and mechanical ventilation use, we found that mechanical ventilator DUR was lower at private hospitals than public and academic teaching hospitals (0.43 vs. 0.63. $p < .001$, or 0.43 vs. 0.67, $p < .001$), but the average length of ventilator use was higher in public hospitals (Table 5). VAP rates were higher in academic teaching hospitals and public hospitals than at private hospitals (8.3 vs. 4.7 VAPs per 1000 ventilator-days, $p < .001$, or 8.3 vs. 3.5 VAPs per 1000 ventilator-days, $p < .001$). When we examined VAP by socioeconomic level, we found that DUR and average of days of use was the highest for lower middle and upper middle-income countries in comparison with low-income countries (0.59 vs. 0.60, $p < .001$, or 0.59 vs. 0.31, $p < .001$) (Table 5). Similarly, the VAP rate was higher in lower middle-income countries compared with upper middle- and low-income countries (9.0 vs. 5.4 VAP per 1000 ventilator-days, $p < .001$, or 9.0 vs. 0.5 VAPs per 1000 ventilator-days, $p < .001$) (Table 5). The extremely low VAP rate in low-income countries—and the overall low rates of CLA-BSI and CA-UTI as well—is related to the fact that three of the four PICUs from low-income countries are private hospitals with a developed DA-HAI prevention program.

The overall crude mortality rate for patients without DA-HAI was 9.3%. DA-HAI-related mortality ranged from 32.3% for VAPs to 26.1% for CLA-BSIs to 25.0% for CA-UTIs (Table 6). Excess crude mortality ranged from 23.0% for VAPs to 16.9% for CLA-BSI to 15.7% for CA-UTIs. When examined by hospital type, overall crude mortality for PICU patients without DA-HAIs ranged from 7.9% (private or pub-

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Table 5. Distribution of ventilator-associated pneumonia and ventilator use ratios for pediatric intensive care units stratified by type of hospital

Type of Hospital	No. of Units	No. of Patients[a]	Ventilator-Days	No. of Ventilator-Associated Pneumonia	Pooled Mean Ventilator-Associated Pneumonia Rate	95% Confidence Interval	Patient-Days	Ventilator-Days	Pooled Mean Device Use Ratio (95% Confidence Interval)	Average Ventilator Days per Patient
Academic teaching	16	16,158	31,476	262	8.3	7.3–9.3	47,715	31,746	0.67 (0.66–0.67)	1.96
Public	4	2,817	23,353	110	4.7	3.9–5.7	36,971	23,353	0.63 (0.63–0.64)	8.29
Private	13	4,725	16,786	58	3.5	2.6–4.5	38,911	16,786	0.43 (0.43–0.44)	3.55
Low income	4	1,247	1,963	1	0.5	0.0–2.8	6,279	1,963	0.31 (0.30–0.32)	1.57
Lower middle income	12	2,812	14,403	129	9.0	7.5–10.6	24,438	14,403	0.59 (0.58–0.60)	5.12
Upper middle income	17	19,564	55,249	300	5.4	4.8–6.1	92,221	55,249	0.60 (0.60–0.60)	2.82
Overall	33	23,623	71,615	430	6.0	5.5–6.6	122,938	71,615	0.58 (0.58–0.59)	3.03

[a]No. of patients: total of patients admitted to the pediatric intensive care units during the study period.

Table 6. Pediatric intensive care unit patient mortality by site of device-associated health care-associated infection, International Nosocomial Infection Control Consortium Members, January 2004 to December 2009

Crude Mortality of Patients by Type of Infection	No. of Deaths	Total	Pooled Crude Mortality, %[a]	95% Confidence Interval Lower Limit	95% Confidence Interval Upper Limit
Crude mortality of patients without device-associated health care-associated infection	328	3,285	10.0	9.0	11.1
Crude mortality of patients with central line catheter-associated bloodstream infection	25	95	26.3	17.8	36.4
Crude excess mortality of patients with central line catheter-associated bloodstream infection	25	95	16.3	8.8	25.3
Crude mortality rate of patients with catheter-associated urinary tract infection	5	16	31.3	10.9	58.7
Crude excess mortality of patients with catheter-associated urinary tract infection	5	16	21.3	1.9	47.7
Crude mortality rate of patients with ventilator-associated pneumonia	57	79	72.2	60.9	81.7
Crude excess mortality of patients with ventilator-associated pneumonia	57	79	62.2	51.9	70.6

[a]Crude excess mortality of patients with device-associated health care-associated infection = crude mortality of patients with device-associated health care-associated infection − crude mortality of patients without device-associated health care-associated infection.

lic hospitals) to 10.6% (academic hospitals) (Table 7). CLA-BSI crude mortality was similar in academic teaching hospitals compared with public and private hospitals (31.5% vs. 17.6%, $p = .216$). Crude excess mortality of CA-UTI and VAP was higher in public and private hospitals, but it should be taken into account that the number of patients with these infections was lower in these types of hospital (Table 7).

Healthcare workers' HH compliance rates were higher at public hospitals than at academic or private hospitals (65.2% vs. 54.8% compliance, $p < .01$, or 65.2% vs. 13.3% compliance, $p < .03$).

DISCUSSION

Since the inception of the CDC's Study of the Efficacy of Nosocomial Infection Control Programs, it has been known that integrated infection surveillance and control programs are cost-effective and can reduce the incidence of DA-HAIs by at least 30%, leading to a correlated decrease in healthcare costs (11). Inspired by the success of CDC's long-standing surveillance systems (National Nosocomial Infections Surveillance/NHSN), which has provided invaluable data on DA-HAIs and antimicrobial resistance in U.S. hospital ICUs for >30 yrs (12–14), we chose to focus INICC's first efforts on surveillance of DA-HAIs in the ICU setting (1–4). We felt this was particularly important because ICU DA-HAI surveillance addresses the healthcare setting with the most vulnerable patient population, the greatest invasive device exposure, and the highest DA-HAI rates and related morbidity and mortality.

Regarding the comparison between DA-HAI rates in the INICC PICUs and the data from the CDC's NHSN, representing the healthcare setting in developing and developed countries, it is noteworthy that the greatest number of DA-HAIs (INICC 46.4% vs. NHSN 57.2%) was found in both cases for CLA-BSIs. Nevertheless, our findings show a difference in relation to the second most common DA-HAI site, which was CA-UTIs (23.2%) in NHSN and VAP (42.8%) followed by CA-UTI (10.8%) in the INICC PICUs.

We found that the CLA-BSI and VAP rates at INICC PICUs were significantly higher than at CDC's NHSN hospitals, but the CA-UTI rate was similar.

These reported higher rates of DA-HAI from PICUs in developing countries (1, 3, 4, 15–28) may have many plausible explanations. First, most developing countries lack any legal framework, laws governing, or mandate requiring the establishment of DA-HAI prevention and control programs (25, 29). In the few instances in which such regulations exist, for example, in the form of national infection control guidelines, compliance is usually highly variable at best. Second, hospital accreditation in most developing countries is not mandatory and many times not even available. Third, HH compliance in most healthcare facilities in the INICC PICUs from developing countries is as low, or lower, than rates reported from U.S. hospitals. Fourth, the majority of hospitals in developing countries receive limited financial or administrative support, which invariably results in very limited funds for infection control personnel or programs (25, 29). Fifth, nurse-to-patient staffing ratios in hospitals in developing countries are typically very low (i.e., more patients for each nurse) compared with hospitals in developed countries; low nurse-to-patient staffing ratios is a powerful determinant of high

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Table 7. Pediatric intensive care unit patient mortality, stratified by hospital type, international nosocomial infection control consortium, january 2004 to december 2009

Type of Hospital	Crude Mortality of Patients by Type of Infection	No. of Deaths	Total	Pooled Crude Mortality. %[a]	95% Confidence Interval	
					Lower Limit	Upper Limit
Academic teaching	Crude mortality of patients without health care-associated infection	188	1780	10.6	9.2	12.1
Academic teaching	Crude mortality of patients with central line catheter-associated bloodstream infection	17	54	31.5	19.5	45.6
Academic teaching	Crude excess mortality of patients with central line catheter-associated bloodstream infection	17	54	20.9	10.3	33.5
Academic teaching	Crude mortality rate of patients with catheter-associated urinary tract infection	2	10	20.0	23.4	55.7
Academic teaching	Crude excess mortality of patients with catheter-associated urinary tract infection	2	10	9.4	14.2	43.6
Academic teaching	Crude mortality rate of patients with ventilator-associated pneumonia	18	60	30.0	18.8	43.2
Academic teaching	Crude excess mortality of patients with ventilator-associated pneumonia	18	60	19.4	9.6	31.1
Public and private hospitals pooled	Crude mortality of patients without health care-associated infection	126	1604	7.9	6.6	9.3
Public and private hospitals pooled	Crude mortality of patients with central line catheter-associated bloodstream infection	6	34	17.6	6.7	34.6
Public and private hospitals pooled	Crude excess mortality of patients with central line catheter-associated bloodstream infection	6	34	9.8	0.1	25.3
Public and private hospitals pooled	Crude mortality rate of patients with catheter-associated urinary tract infection	2	6	33.3	4.3	77.7
Public and private hospitals pooled	Crude excess mortality of patients with catheter-associated urinary tract infection	2	6	25.5	−2.3	68.4
Public and private hospitals pooled	Crude mortality rate of patients with ventilator-associated pneumonia	2	2	100.0	15.8	100.0
Public and private hospitals pooled	Crude excess mortality of patients with ventilator-associated pneumonia	2	2	92.1	9.2	90.7

[a]Crude excess mortality of patients with device associated health care-associated infection = crude mortality of patients with device associated health care-associated infection − crude mortality of patients without device associated health care-associated infection.

DA-HAI rates in ICU patients (30). Finally, the mentioned problems are exacerbated further by overcrowding in most hospitals in the developing world, few experienced nurses, and pressing shortages of other trained healthcare personnel and supplies.

Surveillance of DA-HAIs—defining the magnitude and nature of the problem—is the first step toward reducing the risk of DA-HAIs in vulnerable hospitalized patients. The next step is to implement targeted basic infection control interventions that have been repeatedly shown to prevent DA-HAIs. Increased awareness of the risks of DA-HAIs in INICC ICUs, which has been enormously enhanced by this collaborative (1–4), is providing the impetus for instituting a positive change. To date, targeted performance feedback programs for HH compliance and central line, ventilator, and urinary catheter care already have reduced the DA-HAI rates in the ICUs of many consortium hospitals (31–36). Further advances in reducing the risk of DA-HAIs in INICC hospitals will include site-specific targeted evidence-based interventions. In addition, control of antimicrobial resistance will mandate effective nosocomial infection control and more restrictive use of antiinfectives (25).

We found that DA-HAI rates, specifically CLA-BSIs, CA-UTIs, and VAPs, are higher at lower middle-income countries. By type of hospital, VAP was higher in academic hospitals, and CLA-BSI and CA-UTI were similar in all hospital types. We did not always find a high correlation between DURs. For CA-UTIs, urinary catheter DUR was higher for academic hospitals and low-income countries, yet CA-UTI rates were similar by hospital type and were lower in low-income countries.

Our data confirm that DA-HAIs in PICU patients are a huge and largely unrecognized threat to patient safety in the developing world and a far greater threat than in developed countries. We hope our data will be useful in convincing health ministers and hospital directors in developing countries of the critical importance of infection prevention and control programs. Our data complement the activities of the World Health Organization, because they focus the attention on the worldwide problem of DA-HAIs through their patient safety efforts. Only through the recognition of the high rate of DA-HAIs in PICU patients and enhancing implementation of evidence-based prevention interventions can we hope to improve the safety of PICU patients throughout the world.

To conclude, our data suggest that DA-HAI rates are associated with the socioeconomic level of the country and, in the case of VAP, also with the type of hospital. Our findings showed that PICUs from lower middle-income countries have higher DA-HAI rates than those from low-income or upper middle-income countries. This may be partially

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explained by the fact that in the group of low-income countries, 75% are private hospitals, meaning that INICC hospitals representing low-income countries are, in fact, hospitals with more financial and personnel resources compared with the other participants in countries from higher socioeconomic levels. Understanding the factors that change as the socioeconomic status of countries improves (e.g., greater device use, care of more severely ill patients, improved staffing, other enhanced resources, etc.) may be useful in enhancing DA-HAI prevention programs worldwide.

Hospital worldwide may participate for free in the nonprofit INICC network, which was created with an understanding of the paramount need from developing countries to significantly prevent, control, and reduce DA-HAIs and their adverse consequences. In INICC, not only are investigators freely provided with training and methodologic tools to conduct outcome and process surveillance, but through the publication of these confidentially collected data, relevant scientific evidence-based literature is fostered as well.

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