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CLINICAL AND EPIDEMIOLOGICAL STUDY

Socioeconomic impact on device-associated infections in limited-resource neonatal intensive care units: findings of the INICC

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Abstract
Purpose To evaluate the impact of country socioeconomic status and hospital type on device-associated healthcare-associated infections (DA-HAIs) in neonatal intensive care units (NICUs).

Methods Data were collected on DA-HAIs from September 2003 to February 2010 on 13,251 patients in 30 NICUs in 15 countries. DA-HAIs were defined using criteria formulated by the Centers for Disease Control and Prevention. Country socioeconomic status was defined using World Bank criteria.

Results Central-line-associated bloodstream infection (CLA-BSI) rates in NICU patients were significantly lower

For a list of International Nosocomial Infection Control Consortium (INICC) members, see Appendix.

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in private than academic hospitals (10.8 vs. 14.3 CLA-BSI per 1,000 catheter-days; $p < 0.03$), but not different in public and academic hospitals (14.6 vs. 14.3 CLA-BSI per 1,000 catheter-days; $p = 0.86$). NICU patient CLA-BSI rates were significantly higher in low-income countries than in lower-middle-income countries or upper-middle-income countries [37.0 vs. 11.9 ($p < 0.02$) vs. 17.6 ($p < 0.05$) CLA-BSIs per 1,000 catheter-days, respectively]. Ventilator-associated-pneumonia (VAP) rates in NICU patients were significantly higher in academic hospitals than in private or public hospitals [13.2 vs. 2.4 ($p < 0.001$) vs. 4.9 ($p < 0.001$) VAPs per 1,000 ventilator days, respectively]. Lower-middle-income countries had significantly higher VAP rates than low-income countries (11.8 vs. 3.8 per 1,000 ventilator-days; $p < 0.001$), but VAP rates were not different in low-income countries and upper-middle-income countries (3.8 vs. 6.7 per 1,000 ventilator-days; $p = 0.57$). When examined by hospital type, overall crude mortality for NICU patients without DA-HAIs was significantly higher in academic and public hospitals than in private hospitals (5.8 vs. 12.5%; $p < 0.001$). In contrast, NICU patient mortality among those with DA-HAIs was not different regardless of hospital type or country socioeconomic level.

Conclusions Hospital type and country socioeconomic level influence DA-HAI rates and overall mortality in developing countries.

Keywords Central line associated blood stream infection · Ventilator associated pneumonia · Catheter associated urinary tract infection · Intensive care unit · Health care acquired infection · International nosocomial infection control consortium

Introduction

Every year, >4 million neonates die in their first 28 days of life. In fact, more than one-third of all deaths in children <5 years of age occur during this neonatal period, and most die within their first 5 days of life [1]. Approximately 1.6 million neonates are estimated to die of community or healthcare-acquired infections (HAI) [2–4].

In the developing world, most births occur at home [1], and most pregnant women have no skilled attendant present during labor and delivery. Women with problem pregnancies need access to expert prenatal care. However, often that care exposes the women to unhygienic perinatal practices that increase their and their infant's risk of HAIs.

Intensive care units (ICUs) usually receive better funding and staffing than other hospital wards; consequently, care in the ICU often represents the best care available. Little—if any—data are available on the morbidity and mortality rates among neonatal ICU (NICU) patients due to device-associated-HAIs (DA-HAIs) in developing countries.

Worldwide, the most common DA-HAI in pediatric patients is central line-associated bloodstream infections (CLA-BSIs). In a major review, Zaidi et al. [5] identified only 32 studies that reported incidence data on neonatal sepsis, infection, or CLA-BSI per 1,000 hospital born babies. Sepsis rates ranged from 6.5 to 38 per 1,000 live hospital born babies, and reported CLA-BSIs rates were as high as 68 per 1,000 live births. Most resource-poor hospitals do not have infection prevention programs nor do they conduct HAI or CLA-BSI surveillance; thus, it is difficult to estimate the true magnitude of this problem in developing countries.

The largest health disparities in the world are found in maternal and neonatal mortality rates between the industrialized countries and the poorest sections of the poorest countries [6]. In September 2000, almost all countries worldwide adopted the Millennium Declaration, which focused on global health and poverty improvement [7]. Endorsed by 189 countries, the Millennium Development Goals established eight goals to be reached by 2015, including Millennium Development Goal 4: to reduce by mortality in children <5 years of age by two-thirds [7].

Currently, there are no data on the association between either the type of hospital (e.g., public, academic, or private) or country socioeconomic level and NICU population DA-HAI rates. The goal of our study was to assess whether the socioeconomic level or hospital type influenced DA-HAI rates in NICU patients.

Methods

The International Nosocomial Infection Control Consortium (INICC) is an international, multi-center, collaborative DA-HAI surveillance system based on the U.S. Centers for Disease Control and Prevention's (CDC) National Healthcare Safety Network [NHSN; formerly the National Nosocomial Infections Surveillance (NNIS) system] [8–11]. Founded in Argentina in 1998, INICC is the first multi-national HAI research network established to control and reduce DA-HAIs through the analysis and feedback of data collected by hospital collaborators worldwide.

Data on DA-HAI rates were collected for all NICU patients at participating hospitals from September 2003 through to February 2010 (i.e., study period) using CDC DA-HAI definitions [12, 13]. At each hospital, numerator data (i.e., patients with DA-HAIs), denominator data (i.e., device-days and patient-days) were collected. Data were

prospectively collected during the study period from all patients whose stay in the NICU was ≥24 h, as previously described [8–11]. All patients were followed for 48 h after discharge from the NICUs to detect DA-HAIs acquired in the NICU but manifesting only after transfer out of the NICU. In contrast to the CDC's NHSN, in INICC, data are collected on all NICU patients, with or without a DA-HAI. Data reported to the INICC must conform to the protocol of the selected surveillance component or module before they are entered into the central INICC database. INICC methodology includes a process for the adjudication and validation of reported HAIs, as previously described [8–11].

The device utilization ratio was calculated by dividing the total number of device-days by the total number of bed days.

Participating hospitals can either send aggregated data to INICC headquarters or, if there are personnel limitations, they can send the original data and the data are entered and aggregated for them. After quality control checks are performed, the data are entered into the INICC database. The identity of all INICC hospitals, cities, and countries is confidential, in accordance with the INICC charter.

The World Bank classifies countries into four economic strata based on 2007 gross national income per capita. These groups are: low-income countries (<$935); lower-middle-income countries ($936–3,705); upper-middle-income countries ($3,706–11,455); high-income (HI; ≥$11,456) [14]. Low-income, lower-middle-income, and upper-middle-income countries' economies are sometimes referred to collectively as developing economies, developing countries, lower-income countries, low-resources countries, or emerging countries. These economies represent 144/209 (68.8%) countries of the world and >75% of the world population. In our study, DA-HAI rates were stratified by country socioeconomic level (e.g., low-income countries, lower-middle-income countries, or upper-middle-income countries) and by type of hospital (i.e., public, academic, and private).

Hand hygiene compliance surveillance

Hand hygiene compliance by the healthcare worker (HCW) at the ICU was monitored by the Internal Control Program (ICP) through observations of all HCWs during all working shifts. The observations consisted of 1-h randomly selected time periods and were carried out three times a week according to a specific sequence set forth in the INICC protocol. The ICP records the opportunities for hand hygiene and compliance before contact with each patient on a specific surveillance form designed by the INICC [8].

Statistical analysis

EpiInfo ver. 6.04b (CDC, Atlanta, GA) and SPSS ver. 16.0 (SPSS, Chicago, IL) software were used to conduct 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.

Results

During the study period, data were reported from 30 NICUs (at 30 hospitals) in 15 countries in Latin America, Asia, Africa, and Europe (Table 1). Those reporting had participated in the INICC surveillance system for a mean of 12.9 ± 3.0 (standard deviation; SD) (range 1–70) months. Of the reporting NICUs, 21 (70%) collected and sent original data to INICC and nine (30%) collected and sent aggregated data. In all instances, the DA-HAI rates of original and aggregated data were similar. Of the 30 reporting NICUs, four (13%) are in low-income countries, 14 (47%) are in lower-middle-income countries, and 12 (40%) are in upper-middle-income countries; 14 (47%) are academic teaching hospitals, 11 (37%) are private hospitals, and five (17%) are public hospitals. Of the four reporting hospitals from low-income countries, three (75%) are private hospitals.

A comparison of INICC and CDC's NHSN data revealed that ventilator-associated-pneumonia (VAP) accounted for approximately one-third of the DA-HAIs in the INICC data and for approximately one-fifth of the DA-HAIs in the NHSN; in addition, CLA-BSIs accounted for nearly 70% of the DA-HAIs in the INICC data and nearly 80% of the DA-HAIs in the NHSN. In INICC, the largest number of device-days was for central lines (61%) followed by mechanical ventilation (39.1%). When we compared device utilization ratios (DUR) in INICC versus CDC NHSN NICUs, the central line DURs (CL-DURs) were similar (0.25 vs. 0.24), whereas the mechanical ventilator DURs (MV-DURs) were lower in INICC than NHSN NICUs (0.16 vs. 0.21). Despite similar or lower NICU DURs, both the CLA-BSI and VAP rates at INICC hospitals were significantly higher than those at CDC's NHSN hospitals (p value < 0.001 in both cases) (Table 2).

We next examined NICU CLA-BSI rates and CL-DURs by hospital type and socioeconomic status. CLA-BSIs can be reported as laboratory-confirmed BSI (LC-BI) or clinical sepsis (CSEP) using CDC definitions. Laboratory confirmation (LC-BI) was significantly more commonly reported at academic or private hospitals than at public

Table 1 Distribution of NICUs by country, type, and socioeconomic level

	Low income	Lower-middle income									Upper-middle income					Overall
	India	Colombia	Dominican Republic	Jordan	Morocco	Peru	Philippines	Salvador	Thailand	Tunisia	Argentina	Brazil	Malaysia	Mexico	Turkey	
NICUs (*n*)	4	3	1	1	1	3	2	1	1	1	3	2	1	1	5	30
Academic	1	1	1	1	1	1	1	1	1	1	0	0	0	0	4	14
Public	0	1	0	0	0	2	0	0	0	0	1	0	0	1	0	5
Private	3	1	0	0	0	0	1	0	0	0	2	2	1	0	1	11

Data from the International Nosocomial Infection Control Consortium (INICC) for the period September 2003 to February 2010

NICU Neonatal intensive care unit

Table 2 Device-associated healthcare-associated infection and device utilization ratios

Infection site	Device type	Device-days	Patient days	INICC DUR	CDC NHSN DUR	INICC DA-HAIs (*n*)	Percentage of all DA-HAIs in INICC	Percentage of all DA-HAIs in CDC NHSN	INICC infection rate per 1,000 device-days (95% CI)[a]	CDC NHSN infection rates per 1,000 device-days (95% CI)	INICC vs. NHSN comparison, RR (95% CI)	INICC vs. NHSN comparison (*p* value)
VAP	MV	25,753	157,389	0.16	0.21	251	31.4	21.9	9.7 (8.6–11.0)	1.6 (1.5–1.8)	5.91 (5.06–6.91)	0.0001
CLA-BSI	CL	40,060	157,389	0.25	0.24	549	68.6	78.1	13.7 (12.6–14.9)	2.9 (2.8–3.04)	4.74 (4.30–5.22)	0.0001

Data from INICC and CDC's NHSN for the period September 2003 to February 2010

VAP Ventilator-associated pneumonia, *CLA-BSI* central line catheter-associated blood stream infection, *MV* mechanical ventilator, *CL* central line, *DUR* device utilization ratio, *CDC* Centers for Disease Control and Prevention, *NHSN* National Healthcare Safety Network, *DA-HAI* device associated healthcare associated infection, *RR* relative risk, *CI* confidence interval

[a] Rate per 1,000 device-days: Rates were calculated by dividing the total number of DA-HAIs by the total number of specific device-days for all of the patients in the selected population during the selected time period, and multiplying the result by 1,000

Table 3 Central line-associated bloodstream infection rates and central line device utilization ratios for NICUs stratified by hospital type

Hospital type	No. of NICUs	No of patients	Central line-days	No. (%) of CLA-BSI (LC-BI)	No. (%) of CLA-BSI (CSEP)	No. of CLA-BSI (LC-BI + CSEP)	Pooled mean CLA-BSI rate[a]	95% CI	Comparisons	RR (95% CI)	*p* value
Academic	14	8,866	29,430	236 (56)	184 (44)	420	14.3	12.9–15.7	Academic vs. public	0.98 (0.73–1.29)	0.8620
Public	5	727	3,690	14 (26)	40 (74)	54	14.6	11.0–19.1	Public vs. private	1.35 (0.95–1.92)	0.0881
Private	11	3,658	6,940	55 (73)	20 (27)	75	10.8	8.5–13.5	Academic vs. private	1.32 (1.03–1.69)	0.0260
Overall	30	13,251	40,060	305 (56)	244 (44)	549	13.7	12.2–15.2	–	–	–
Hospital type	No. of NICUs		Patient-days	Central line-days		Pooled mean CL-DUR	95% CI	Comparisons	RR (95% CI)	*p* value	
Academic	14		104,966	29,430		0.28	0.28–0.28	Academic vs. public	0.57 (0.55–0.59)	0.0001	
Public	5		7,451	3,690		0.50	0.48–0.51	Public vs. private	3.21 (3.08–3.34)	0.0001	
Private	11		44,972	6,940		0.15	0.15–0.16	Academic vs. private	1.82 (1.77–1.87)	0.0001	
Overall	30		157,389	40,060		0.25	0.25–0.25	–	–	–	

Data from the INICC for the period September 2003 to February 2010

LC-BI Laboratory-confirmed BSI, *CSEP* clinical sepsis, without laboratory confirmation *CL-DUR* central line device utilization ratio

[a] CLA-BSI rate per 1,000 central line-days

hospitals (56 vs. 73 vs. 26%, respectively) (Table 3). The CLA-BSI rates were lower in NICUs in private hospitals than in academic ones (10.8 vs. 14.3 CLA-BSI per 1,000 catheter-days; $p < 0.03$), but they did not differ in public and academic hospitals (14.6 vs. 14.3 CLA-BSI per 1,000 catheter-days; $p = 0.86$). The CL-DUR was higher at public hospitals than at either academic or private ones [0.50 vs. 0.28 ($p < 0.001$) and 0.50 vs. 0.15 ($p < 0.001$), respectively] (Table 3). When the NICU CLA-BSI rates were assessed by socio-economic level, CLA-BSI rates in low-income countries were higher than than lower-middle-income and upper-middle-income countries [37.0 vs. 11.9 ($p < 0.01$) vs. 17.6 ($p < 0.05$) CLA-BSIs per 1,000 catheter-days, respectively]. The CL-DUR was lower at hospitals in low-income countries and significantly higher at those in lower-middle-income countries and upper-middle-income countries [0.11 vs. 0.26 ($p < 0.001$) vs. 0.25 ($p < 0.001$), respectively] (Table 4).

Our comparison of VAP rates and MV-DURs by hospital type and country socioeconomic level revealed that the MV-DUR was higher at public hospitals than either private or academic hospitals [0.33 vs. 0.14 ($p < 0.001$) or 0.33 vs. 0.16, $p < 0.001$), respectively] (Table 5). NICU VAP rates were higher in academic hospitals than in private or public ones [13.2 vs. 2.4 ($p < 0.001$) vs. 4.9 ($p < 0.001$) VAPs per 1,000 ventilator days, respectively]. The NICU MV-DUR was higher in upper-middle-income countries than in either low-income or lower-middle-income countries [0.21 vs. 0.14 ($p < 0.001$) or 0.21 vs. 0.14 ($p < 0.001$), respectively] (Table 6). The NICU VAP rate in lower-middle-income countries was higher than that in low-income countries (11.8 vs. 3.8 per 1,000 ventilator-days; $p < 0.001$), while there was no difference in the rates of VAP in low-income and upper-middle-income countries (3.8 vs. 6.7 per 1,000 ventilator-days; p 0.57).

We next assessed the CLA-BSI and VAP rates and DURs stratified by birth-weight category. The CL-DUR was highest in the <750 g birth-weight group, and the CLA-BSI rates were higher in the 750–1,000 vs. >2,500 birth-weight group (17.4 vs. 10.2 per 1,000 CL days; $p < 0.001$) (Table 7). The MV-DUR was higher in the >2,500 g birth-weight group compared with the <750 g group (11.4 vs. 4.9 per CL 1,000 days; $p = 0.0125$ (Table 8).

Healthcare worker hand hygiene compliance rates were higher in private hospitals than in public or academic ones [75.2 vs. 65.0% (p 0.005) vs. 60.8% (p = 0.002), respectively]. The overall rate was 65.7%.

The overall crude mortality rate for patients without a DA-HAI was 9.4%. Mortality rates for NICU patients without DA-HAIs by hospital type ranged from 5.8% (private hospitals) to 12.5% (academic and public hospitals) ($p < 0.001$).

Table 4 Central line-associated BSI rates and central line device utilization ratios for NICUs stratified by country socioeconomic level

Socioeconomic level	No. of NICUs	No of patients	Central line-days	No. (%) of CLA-BSIs (LC-BI)	No. (%) of CLA-BSIs (CSEP)	No. of CLA-BSIs (LC-BI + CSEP)	Pooled mean CLA-BSI rates[a]	95% CI	Comparisons	RR (95% CI)	*p* value
Low income	4	291	216	5 (63)	3 (37)	8	37.0	16.0–71.8	Low income vs. lower middle income	3.12 (1.55–6.28)	0.0008
Lower middle income	14	8,970	28,100	188 (56)	146 (44)	334	11.9	10.7–13.2	Lower middle income vs. upper middle income	0.67 (0.57–0.80)	0.0001
Upper middle income	12	3,990	11,744	112 (54)	95 (46)	207	17.6	15.3–20.2	Low income vs. upper middle income	2.10 (1.04–4.26)	0.0349
Overall	30	13,251	40,060	305 (56)	244 (44)	549	13.7	12.2–15.2	–	–	–

Socioeconomic level	No. of NICUs	Patient-days	Central line-days	Pooled mean CL-DUR	95% CI	Comparisons	RR (95% CI)	*p* value
Low income	4	1,909	216	0.11	0.09–0.13	Low income vs. lower middle income	0.44 (0.38–0.50)	0.0001
Lower middle income	14	108,409	28,100	0.26	0.26–0.26	Lower middle income vs. upper middle income	1.04 (1.02–1.06)	0.0005
Upper middle income	12	47,071	11,744	0.25	0.25–0.25	Low income vs. upper middle income	0.45 (0.40–0.52)	0.0001
Overall	30	157,389	40,060	0.25	0.25–0.25			

Data from the INICC for the period September 2003 to February 2010

[a] CLA-BSI rate per 1,000 central line-days

Table 5 Ventilator-associated pneumonia and mechanical ventilator utilization ratios in NICUs stratified by hospital type

Hospital Type	No. of NICUs	No of patients	Ventilator-days	No. of VAPs	Pooled mean VAP rate[a]	95% CI	Comparisons	RR (95% CI)	*p* value
Academic	14	8,866	16,983	224	13.2	11.5–15.0	Academic vs. public	2.69 (1.50–4.80)	0.0001
Public	5	727	2,445	12	4.9	2.5–8.6	Public vs. private	2.07 (0.97–4.42)	0.0549
Private	11	3,658	6,325	15	2.4	1.3–3.9	Academic vs. private	5.56 (3.30–9.38)	0.0001
Overall	30	13,251	25,753	251	9.7	8.0–11.0	–	–	–

Hospital type	No. of NICUs	No of patient-days	No. of ventilator-days	Pooled mean MV-DUR	95% CI	Comparisons	RR (95% CI)	*p* value
Academic/teaching	14	104,966	16,983	0.16	0.16–0.16	Academic vs. public	0.49 (0.47–0.51)	0.0001
Public	5	7,451	2,445	0.33	0.32–0.34	Public vs. private	2.33 (2.23–2.44)	0.0001
Private	11	44,972	6,325	0.14	0.14–0.14	Academic vs. private	1.15 (1.12–1.18)	0.0001
Overall	30	13,251	25,753	0.16	0.16–0.16	–		

Data from INICC and CDC's NHSN for the period September 2003 to February 2010

MV-DUR mechanical ventilator device utilization ratio

[a] VAP rates per 1,000 ventilator days

Table 6 Ventilator-associated pneumonia rates and mechanical ventilator device utilization ratios in NICUs stratified by socioeconomic level

Socioeconomic level	No. of NICUs	No of patients	No. of ventilator-days	No. of VAPs	Pooled mean VAP rate[a]	95% CI	Comparisons	RR (95% CI)	*p* value
Low income	4	291	262	1	3.8	0.1–21.1	Low income vs. lower middle Income	0.32 (0.05–2.32)	0.2373
Lower middle income	14	8,970	15,655	184	11.8	10.1–13.6	Lower middle income vs. upper middle income	1.75 (1.32–2.32)	0.0001
Upper middle income	12	3,990	9,836	66	6.7	5.2–8.5	Low income vs. upper middle income	0.57 (0.08–4.10)	0.5704
Overall	30	13,251	25,753	251	9.7	8.0–11.0			

Socioeconomic level	No. of NICUs	No. of patient-days	No. of ventilator-days	Pooled mean MV-DUR	95% CI	Comparisons	RR (95% CI)	*p* value
Low income	4	1,909	262	0.14	0.12–0.15	Low income vs. lower middle income	0.95 (0.84–1.07)	0.4141
Lower middle income	14	108,409	15,655	0.14	0.14–0.15	Lower middle income vs. upper middle income	0.69 (0.67–0.71)	0.0001
Upper middle income	12	47,071	9,836	0.21	0.21–0.21	Low income vs. upper middle income	1.52 (1.35–1.72)	0.0001
Overall	30	13,251	25,753	0.16	0.16–0.16			

Data from INICC and CDC's NHSN for the period September 2003 to February 2010

[a] VAP rates per 1,000 ventilator-days

Table 7 Central line-associated bloodstream infection rates and central line device utilization ratios for NICU stratified by birth-weight category

Birth-weight categories (g)	No. of NICUs	No of patients	No. of central line-days	No. (%) of CL-BSIs reported as LC-BI	No. (%) of CLA-BSIs reported as clinical sepsis (CSEP)	No. of CLA-BSIs (LC-BI + CSEP)	Pooled mean CLA-BSI rates[a]	95% CI
<750	14	115	1,585	13 (61.9)	8 (38.1)	21	13.2	7.2–32.6
750–1,000	24	667	6,147	62 (57.9)	45 (42.1)	107	17.4	10.7–19.9
1,001–1,500	26	1,400	9,372	97 (59.9)	65 (40.1)	162	17.3	12.5–19.1
1,501–2,500	28	4,687	12,542	80 (52.3)	73 (47.7)	153	12.2	11.0–16.2
>2,500	28	6,382	10,414	53 (50.0)	53 (50.0)	106	10.2	8.9–14.2
Overall	30	13,251	40,060	305 (55.6)	244 (44.4)	549	13.7	12.6–14.9

Birth-weight categories (g)	No. of NICUs	No. of patient-days	No. of central line-days	Pooled mean CL-DUR	95% CI
<750	14	4,100	1,585	0.39	0.37–0.40
750–1,000	24	14,611	6,147	0.42	0.41–0.43
1,001–1,500	26	35,760	9,372	0.26	0.26–0.27
1,501–2,500	28	54,727	12,542	0.23	0.23–0.23
>2,500	28	48,191	10,414	0.22	0.21–0.22
Overall	30	157,389	40,060	0.25	0.25–0.26

[a] CLA-BSI rate per 1,000 central line-days

Table 8 Ventilator-associated pneumonia rates and mechanical ventilator device utilization ratios in NICUs stratified by birth-weight category

Socioeconomic level (g)	No. of NICUs	No. of patients	No. of ventilator-days	No. of VAPs	Pooled mean VAP rate[a]	95% CI
<750	14	115	1,855	9	4.9	2.2–9.2
750–1,000	24	667	4,959	48	9.7	7.1–12.8
1,001–1,500	26	1,400	5,562	51	9.2	6.8–12.05
1,501–2,500	28	4,687	6,982	70	10.0	7.8–12.66
>2,500	28	6,382	6,395	73	11.4	8.95–14.3
Overall	30	13,251	25,753	251	9.7	8.6–11.03

Socioeconomic level (g)	No. of NICUs	No. of patient-days	No. of ventilator-days	Pooled mean MV-DUR	95% CI
<750	14	4,100	1,855	0.45	0.44–0.47
750–1,000	24	14,611	4,959	0.34	0.33–0.35
1,001–1,500	26	35,760	5,562	0.16	0.15–0.16
1,501–2,500	28	54,727	6,982	0.13	0.12–0.13
>2,500	28	48,191	6,395	0.13	0.13–0.14
Overall	30	157,389	25,753	0.16	0.16–0.16

[a] VAP rate per 1,000 mechanical ventilator-days

Table 9 Overall patient mortality in NICUs by site of device-associated healthcare-associated infection

Patient group	No. of deaths	No. of patients	Pooled crude mortality (%)	95% CI	
				Lower limit	Upper limit
Crude mortality of patients without DA-HAI	414	4,399	9.4	8.6	10.3
Crude mortality of patients with CLA-BSI	63	170	37.1	29.7	44.8
Crude excess mortality of patients with CLA-BSI	63	170	27.7	21.1	34.5
Crude mortality rate of patients with VAP	33	121	27.3	19.6	36.1
Crude excess mortality of patients with VAP	33	121	17.9	11.0	25.8

Data from INICC and CDC's NHSN for the period September 2003 to February 2010

DA-HAI-related mortality was 37.1% for CLA-BSIs (Table 9) and excess crude mortality was 27.7% for CLA-BSI. (Table 10). CLA-BSI crude or excess mortality rates were not different in academic and public hospitals and thus these rates were pooled. Crude excess mortality rates for CLA-BSI were not different at academic and public hospitals compared to private hospitals (25.3 vs. 10.9; $p = 0.1487$).

DA-HAI-related mortality was 27.3% for VAPs (Table 9), and excess crude mortality was 17.9% for VAPs (Table 10). Crude excess mortality rates for VAP were not different at academic and public hospitals compared to private hospitals (15.2 vs. 0, $p = 0.4564$).

The length of stay (LOS) of patients without DA-HAI did not differ in academic and public hospitals compared to private hospitals (11.4 vs. 11.8 days). The excess LOS of patients with CLA-BSI did not differ in academic or public hospitals (29.8 vs. 32.9 days). When compared to academic and public hospitals, private hospitals had a slightly lower CLA-BSI patient excess LOS of 21.1 days (Table 11). The extra LOS of patients with VAP was significantly higher in academic and public hospitals than at private hospitals (25.6 vs. 10.2 days; $p < 0.01$).

Discussion

Since the CDC's Study of the Efficacy of Nosocomial Infection Control (SENIC) 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% and, consequently, healthcare costs [15]. Inspired by the success of CDC's long-standing surveillance systems (NNIS/NHSN), which has provided invaluable data on DA-HAIs and antimicrobial resistance in U.S. hospital ICUs for >30 years [16–18], we chose to focus

Table 10 Patient mortality in NICUs stratified by hospital type

Patient group	No. of deaths	Total	Pooled crude mortality (%)	95% CI	
				Lower limit	Upper limit
Academic or Public hospitals pooled					
Crude mortality of patients without DA-HAI	298	2,391	12.5	11.2	13.9
Crude mortality of patients with CLA-BSI	62	164	37.8	30.3	45.7
Crude excess mortality of patients with CLA-BSI	62	164	25.3	19.1	31.9
Crude mortality rate of patients with VAP	33	119	27.7	19.9	36.7
Crude excess mortality of patients with VAP	33	119	15.2	8.7	22.9
Private hospitals					
Crude mortality of patients without DA-HAI	116	2,008	5.8	4.8	6.9
Crude mortality of patients with CLA-BSI	1	6	16.7	4.2	64.2
Crude excess mortality of patients with CLA-BSI	1	6	10.9	−0.6	57.3
Crude mortality rate of patients with VAP	0	2	–	0.0	84.2
Crude excess mortality of patients with VAP	0	2	–	−4.8	77.3

Data from INICC and CDC's NHSN for the period September 2003 to February 2010

Table 11 Overall length of stay of patients in NICUs by site of device-associated healthcare-associated infection

Patient groups	No. of patients	No. of bed days	Average length of stay	95% CI	
				Lower limit	Upper limit
Academic and public hospitals pooled					
LOS of patients without DA-HAI	2,451	28,006	11.4	11.0	11.9
LOS of patients with CLA-BSI	172	5,120	29.8	25.7	34.7
Extra-LOS of patients with CLA-BSI	172	5,120	18.4	14.7	22.8
LOS of patients with VAP	125	4,619	37.0	31.1	44.3
Extra-LOS of patients with VAP	125	4,619	25.6	20.1	32.4
Private hospitals					
LOS of patients without DA-HAI	2,190	25,793	11.8	11.3	12.3
LOS of patients with CLA-BSI	7	230	32.9	16.2	81.6
Extra-LOS of patients with CLA-BSI	7	230	21.1	4.9	69.3
LOS of patients with VAP	2	44	22.0	6.5	195.3
Extra-LOS of patients with VAP	2	44	10.2	−4.8	183.0

Data from INICC and CDC's NHSN for the period September 2003 to February 2010

LOS Length of stay

INICC's first efforts on the surveillance of DA-HAIs in the ICU (including NICUs) [8–11]. We felt this choice was particularly important because ICU DA-HAI surveillance addresses the healthcare setting with the most vulnerable patient population, those with the greatest invasive device exposure, and those with the highest DA-HAI rates and related morbidity and mortality.

The reported higher rates of DA-HAI from ICUs in developing countries [8, 10, 11, 19–33] may have many plausible explanations. First, most developing countries lack any legal framework, laws, or mandate requiring the establishment of DA-HAI prevention and control programs [29, 34]. In the few cases where such regulations exist—for example, in the form of national infection control guidelines—compliance usually is highly variable at best. Second, hospital accreditation in most developing countries is not required—if available at all. Third, healthcare worker hand hygiene compliance in most healthcare facilities in developing countries is as low as, 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 [29, 34]. 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 DA-HAI rates in ICU

patients [35]. Last, the above 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.

In this evaluation of DA-HAIs in INICC NICUs, we found that DA-HAI rates, specifically CLA-BSIs and VAPs, are relatively higher in NICUs in lower-middle-income countries. Stratified by type of hospital, the VAP rate was higher in academic hospitals, and the CLA-BSI rate was not different between hospital types. The DUR and DA-HAI rates were not always highly correlated. The mortality of patients without DA-HAI was higher in "academic and public hospitals" than in private ones, but the mortality of patients with CLA-BSI and VAP differ not differ according to hospital type. This latter result is probably due to insufficient data on deaths attributable to DA-HAIs in private hospitals to be able to find a statistical difference in the comparison. A limitation of this study is that in our comparison of infection rates between different countries and different types of hospitals, we did not correct the results for other risk factors.

Our data confirm that DA-HAIs in NICU patients are a large and largely unrecognized threat to patient safety in the developing world—and a far greater threat than in developed countries [33]. A previous investigation conducted in seven Brazilian NICUs showed CLA-BSI rates higher than ours: 34.9 CLA-BSI per 1,000 CL days in patients weighing <1,000 g. However, the VAP rate per 1,000 MV days in patients between 1,000 and 1,500 g was 9.2, which is not different to our rate [33]. We hope our data will be useful in convincing Ministers of Health and Directors of hospitals in developing countries of the critical importance of infection prevention and control programs. Our data complement the activities of the World Health Organization as they focus attention on the worldwide problem of DA-HAIs through patient safety efforts. Only through the recognition of the high rate of DA-HAIs in NICU patients and enhanced implementation of evidence-base prevention interventions can the safety of NICU patients throughout the world be improved.

Our data imply that DA-HAI rates are associated with the socioeconomic level of the country, and in the case of VAP, also with type of hospital. Lower-middle-income countries have higher DA-HAI rates than low-income and upper-middle-income countries. This difference may be partially explained by the fact that in the group of hospitals located in low-income countries, 75% are private hospitals; as such, INICC hospitals representing low-income countries are, in fact, hospitals with more financial and personnel resources compared to hospitals in countries with higher socioeconomic levels. Our data illustrate the impact that DA-HAIs in NICUs have on infant mortality rates in developing countries. 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.

Surveillance of DA-HAIs—defining the magnitude and nature of the problem—is the first step towards 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 study [8–11], is providing the impetus for instituting positive change. To date, targeted performance feedback programs for hand hygiene compliance and central-line, ventilator, and urinary-catheter care have already reduced the DA-HAI rates in the ICUs of many consortium hospitals [36–40]. 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 a more restrictive use of anti-infectives [29].

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Conflict of interest None.

Appendix

International Infection Control Consortium, listed by country alphabetically

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6. **India**: Amit Gupta, Narinder Saini (Pushpanjali Crosslay Hospital, Ghaziabad); Arpita Dwivedy, Suvin Shetty, Sheena Binu (Dr. L H Hiranandani Hospital); Vatsal Kothari, Tanu Singhal, Sweta Shah (Kokilaben Dhirubhai Ambani Hospital, Mumbai); Deepak Govil, Namita Jaggi, Shaleen Bhatnagar (Artemis Health Institute, New Delhi).
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