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Device-Associated Nosocomial Infections in 55 Intensive Care Units of 8 Developing Countries

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Background: Health care–associated infections from invasive medical devices in the intensive care unit (ICU) are a major threat to patient safety. Most published studies of ICU-acquired infections have come from industrialized western countries. In a Centers for Disease Control and Prevention (CDC) National Nosocomial Infections Surveillance (NNIS) System report, the U.S. pooled mean rates of central venous catheter (CVC)–related bloodstream infections, ventilator-associated pneumonia, and catheter-associated urinary tract infections were 4.0 per 1000 CVC days, 5.4 per 1000 mechanical ventilator days, and 3.9 per Foley catheter days, respectively.

Objective: To ascertain the incidence of device-associated infections in the ICUs of developing countries.

Design: Multicenter, prospective cohort surveillance of device-associated infection by using the CDC NNIS System definitions.

Setting: 55 ICUs of 46 hospitals in Argentina, Brazil, Colombia, India, Mexico, Morocco, Peru, and Turkey that are members of the International Nosocomial Infection Control Consortium (INICC).

Measurements: Rates of device-associated infection per 100 patients and per 1000 device days.

Results: During 2002–2005, 21 069 patients who were hospitalized in ICUs for an aggregate 137 740 days acquired 3095 device-associated infections for an overall rate of 14.7% or 22.5 infections per 1000 ICU days. Ventilator-associated pneumonia posed the greatest risk (41% of all device-associated infections or 24.1 cases [range, 10.0 to 52.7 cases] per 1000 ventilator days), followed by CVC-related bloodstream infections (30% of all device-associated infections or 12.5 cases [range, 7.8 to 18.5 cases] per 1000 catheter days) and catheter-associated urinary tract infections (29% of all device-associated infections or 8.9 cases [range, 1.7 to 12.8 cases] per 1000 catheter days). Notably, 84% of *Staphylococcus aureus* infections were caused by methicillin-resistant strains, 51% of *Enterobacteriaceae* isolates were resistant to ceftriaxone, and 59% of *Pseudomonas aeruginosa* isolates were resistant to fluoroquinolones. The crude mortality rate for patients with device-associated infections ranged from 35.2% (for CVC-associated bloodstream infection) to 44.9% (for ventilator-associated pneumonia).

Limitations: These initial data are not adequate to represent any entire country, and likely variations in the efficiency of surveillance and institutional resources may have affected the rates that were detected.

Conclusions: Device-associated infections in the ICUs of these developing countries pose greater threats to patient safety than in U.S. ICUs. Active infection control programs that perform surveillance of infection and implement guidelines for prevention can improve patient safety and must become a priority in every country.

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*For a list of members of the International Nosocomial Infection Control Consortium, see the Appendix.

Surveillance of health care–associated infections, especially in high-risk hospital settings, such as the intensive care unit (ICU) (1, 2), has become an integral feature of infection control and quality assurance in all U.S. hospitals. The Centers for Disease Control and Prevention (CDC) Study of the Efficacy of Nosocomial Infection Control (SENIC) Project (3) showed that surveillance can help prevent health care–associated infections. Standards for institutional surveillance have been adopted in the United States (1), the United Kingdom (4), Australia (5), Canada (6), and Germany (7).

A growing body of literature has shown that health care–associated infections are a major cause of patient illness and death in developed countries (8, 9). Device-associated infections, particularly ventilator-associated pneumonia (10–12), central venous catheter (CVC)–associated bloodstream infections (13–15), and catheter-associated urinary tract infections (16, 17), pose the greatest threat to patient safety in the ICU (18). Surveillance of health care–associated infection has been standardized by the CDC's National Nosocomial Infection Surveillance (NNIS) System by providing simple unambiguous definitions, especially for device-associated infections (19–21). Targeted surveillance and calculation of device-associated infection rates per 1000 device days allows benchmarking with similar other hospitals and detection of unique institutional problems that need redress.

Most published studies of ICU-acquired infections have come from hospitals in industrialized western countries (1, 8, 10–19, 22, 23). Relatively few data have been reported from developing countries (9, 24–27), especially rates of device-associated infections by using standardized definitions. We report the initial findings of an International Nosocomial Infection Control Consortium (INICC) surveillance study from January 2002 through December

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2005. The consortium was established by Dr. Rosenthal in 1998 when selected hospitals in Latin America began collecting surveillance data on health care–associated infections for inclusion in a regional database. Consortium hospitals provide general medical and surgical inpatient services to adults and children who require short-term care. All data from the participating hospitals were collected by using standardized NNIS System protocols and definitions (19–21). The consortium has initially focused on surveillance and prevention of device-associated infections in adult and pediatric ICUs and high-risk nurseries.

METHODS

Setting

Most current participating hospitals and ICUs joined the consortium since 2002 after hearing Dr. Rosenthal (the INICC chairman) speak in their country or after learning about the INICC from its Web site (www.inicc.org), but some hospitals were actively solicited. Study data were collected between 2002 and 2005 in 55 ICUs in 46 hospitals from 8 developing countries: Argentina, Brazil, Colombia, India, Mexico, Morocco, Peru, and Turkey.

The consortium requires each member hospital to have an infection control team, comprising a physician and an infection control practitioner, and a microbiology laboratory that can isolate and identify aerobic pathogens from clinical cultures and perform in vitro susceptibility testing by using standardized methods (28). The person responsible for surveillance in each institution must have had at least 3 years of infection control experience (**Table 1**). In most of the hospitals, the team had access to electronic patient data.

Context

We know little about medical device–associated infections in developing countries.

Contribution

Prospective surveillance of 21 069 patients who were hospitalized in 55 intensive care units in 46 hospitals in Central and South America, India, Morocco, and Turkey showed high rates (22.5 infections per 1000 intensive care unit days) of device-associated infections. Infections included ventilator-associated pneumonia (24.1 cases/1000 ventilator days), central venous catheter–related bloodstream infections (12.5 cases/1000 catheter days), and catheter-associated urinary tract infections (8.9 cases/1000 catheter days). Eighty-four percent of *Staphylococcus aureus* infections were caused by methicillin-resistant strains, 51% of *Enterobacteriaceae* isolates were ceftriaxone-resistant, and 59% of *Pseudomonas aeruginosa* isolates were fluoroquinolone-resistant.

Implications

Medical device–associated infections pose major risks in developing countries.

—The Editors

The institutional review board at each hospital approved the study protocol. Patient confidentiality is protected by coding the recorded information, with patient identities available only to the individual hospital's infection control team.

Table 1. **Features of the International Nosocomial Infection Control Consortium Hospitals and Intensive Care Units***

Variable	Country								Overall
	A	B	C	D	E	F	G	H	
Hospitals, *n (%)*	9	5	9	4	4	1	4	10	46 (100)
Academic teaching	1	2	2	1	1	1	0	9	17 (37)
Public	4	1	3	1	3	0	3	1	16 (35)
Private community	4	2	4	2	0	0	1	0	13 (28)
ICUs, *n*	11	7	10	6	5	1	4	11	55
Range of experience of the infection control practitioner, *y*	3–10	3–6	4–15	3–17	3–7	16	3–8	3–12	3–17
Patients studied, *n*	8867	1029	2172	3413	1514	410	1359	2305	21 069
Total ICU days, *d*	49 109	9971	14 603	18 034	9579	2729	6756	26 959	137 740
Men, %	51.6	54.2	55.0	79.1	39.5	49.5	56.4	60.3	56.9
Mean age, *y*	71	56	52	56	39	42	56	50	60
Mean ASIS	2.70	3.44	2.67	2.58	3.50	3.70	2.67	3.51	2.89
Device use									
Ventilator days, *d*	9442	6376	8593	3401	3754	835	3364	17 222	52 987
Ventilator use, %	0.19	0.64	0.59	0.19	0.39	0.31	0.50	0.64	0.38
CVC days, *d*	11 076	9342	11 110	12 407	9259	593	4477	16 377	74 641
CVC use, %	0.23	0.94	0.76	0.69	0.97	0.22	0.66	0.61	0.54
Urinary catheter days, *d*	31 079	8559	12 433	8695	6827	1910	5376	25 235	100 114
Urinary catheter use, %	0.63	0.86	0.85	0.48	0.71	0.70	0.80	0.94	0.73

* ASIS = average severity of illness score; CVC = central venous catheter; ICU = intensive care unit.

Table 2. **Ventilator-Associated Pneumonia in the International Nosocomial Infection Control Consortium Intensive Care Units***

Variable	Country								Overall
	A	B	C	D	E	F	G	H	
Ventilator-associated pneumonia, *n*	284	135	86	67	73	44	98	490	1277
Rate per 100 patients (range)†	3.2 (0.0–9.0)	13.1 (0.0–16.5)	4.0 (1.9–7.7)	2.0 (0.2–3.8)	4.8 (0.0–10.5)	10.7‡	7.2 (0.0–8.2)	21.3 (2.6–33.9)	6.1 (2.0–21.3)
Rate per 1000 ventilator days (range)†	30.1 (0.0–51.4)	21.2 (0.0–22.1)	10.0 (3.6–24.1)	19.7 (6.2–18.1)	19.4 (0.0–22.9)	52.7‡	29.1 (0.0–33.5)	28.5 (11.7–46.2)	24.1 (10.0–52.7)
Proportion of cases, %§									
Enterobacteriaceae	44	15	41	53	46	13	35	14	26
Pseudomonas aeruginosa	8	36	21	41	29	32	26	29	26
Acinetobacter spp.	15	28	3	0	3	46	5	28	20
Staphylococcus aureus	32	14	29	2	14	3	21	24	22
Enterococci	1	0	0	2	0	0	2	1	1
Coagulase-negative staphylococci	1	1	5	0	5	0	8	1	2
Candida spp.	0	5	0	0	3	0	11	2	3
Susceptibility of resistant microorganisms, %									
MRSA	83	93	56	100	17	0	80	87	84
Ceftriaxone-resistant *Enterobacteriaceae*	52	94	30	77	44	67	29	52	58
Fluoroquinolone-resistant *P. aeruginosa*	50	67	67	50	65	0	67	59	60
Vancomycin-resistant enterococci	0	0	0	0	0	0	0	0	0

* MRSA = methicillin-resistant *Staphylococcus aureus*.
† Ranges for individual countries are for the individual hospitals; overall ranges are for the individual countries.
‡ Range not given because only 1 participating hospital was from country F.
§ Partial listing of major pathogens; does not total 100%.

Infection Control Practices at the Study Sites

Hand hygiene adherence varies in the different countries and ICUs, ranging from 20% to 70% (29–32). A recent study in all participating ICUs found a 50% overall rate of hand hygiene adherence (32), similar to that of recent studies in the United States and Europe (33). Use of sterile dressings on CVC insertion sites also ranges widely (29, 34, 35). Open infusion systems (rigid or semirigid containers that must admit air to empty) rather than closed systems (fully collapsible containers that do not require any external vent to empty the solution; the container residue after administration does not exceed 5% of the nominal volume) or combinations of open and closed systems are universally used to deliver intravenous fluids and medications in the study hospitals (35).

Surveillance and Case Report Forms

Each center established an augmented infection control program, with the initial major emphasis on active surveillance of health care–associated infections and process surveillance of hand hygiene adherence and invasive device care. During the study, we determined the rates of ventilator-associated pneumonia, CVC-associated bloodstream infection, and catheter-associated urinary tract infection monthly by using current CDC NNIS System definitions (19–21).

Designated surveillance forms were used for all patients in the study ICUs, both patients with and those without health care–associated infection. The following data were to be recorded daily on the forms for each patient: temperature and blood pressure, invasive devices, all cultures done, imaging studies, and antibiotic use. Previous studies have shown that fever, hypotension, cultures, and initiation of antimicrobial therapy are powerful markers for the presence of a health care–associated infection (36).

A mean average severity of illness score was also recorded for each patient at ICU admission by using the CDC NNIS System criteria (19). Points were totaled, with 1 point for surgical patients who require routine postoperative observation only, 2 points for physiologically stable nonsurgical patients who require overnight observation, 3 points for patients who need continuous nursing care and monitoring, 4 points for physiologically unstable patients who require intensive nursing and medical care and need frequent reassessment and adjustment of therapy, and 5 points for physiologically unstable patients who are in a coma or in shock and require cardiopulmonary resuscitation or intensive medical and nursing care with frequent reassessment.

If a patient was determined to have acquired a health care–associated infection, the date of onset, site of infection, infecting microorganisms, and antimicrobial susceptibilities were also recorded.

Definitions

Ventilator-Associated Pneumonia

Ventilator-associated pneumonia is indicated in a mechanically ventilated patient with a chest radiograph that shows new or progressive infiltrates, consolidation, cavitation, or pleural effusion. The patient must also have at least 1 of the following criteria: new onset of purulent sputum or change in character of sputum; organism cultured from blood; or isolation of an etiologic agent from a specimen obtained by tracheal aspirate, bronchial brushing or bronchoalveolar lavage, or biopsy.

Laboratory-Confirmed CVC-Associated Bloodstream Infection

Central venous catheter–associated bloodstream infection is laboratory-confirmed when a patient with a CVC has a recognized pathogen that is isolated from 1 or more percutaneous blood cultures after 48 hours of vascular catheterization and is not related to an infection at another site. The patient also has at least 1 of the following signs or symptoms: fever (temperature ≥38 °C), chills, or hypotension. With skin commensals (for example, diphtheroids, *Bacillus* spp., *Propionibacterium* spp., coagulase-negative staphylococci, or micrococci), the organism is cultured from 2 or more blood cultures.

Clinically Suspected CVC-Associated Bloodstream Infection

Central venous catheter–associated bloodstream infection is clinically suspected when a patient with a CVC has at least 1 of the following clinical signs with no other identified cause: fever (temperature ≥38 °C), hypotension (systolic blood pressure ≤90 mm Hg), or oliguria (urine output ≤20 mL/h) with blood cultures not obtained or no organisms recovered from blood cultures, infections not apparent at another site, and antimicrobial therapy instituted by the physician.

Catheter-Associated Urinary Tract Infection

For the diagnosis of catheter-associated urinary tract infection, the patient must meet 1 of 2 criteria. The first criterion is when a patient with a urinary catheter has 1 or more of the following symptoms with no other recognized cause: fever (temperature ≥38 °C), urgency, or suprapubic tenderness when the urine culture is positive for 10^5 colony-forming units per mL or more, with no more than 2 microorganisms isolated. The second criterion is when a patient with a urinary catheter has at least 2 of the following criteria with no other recognized cause: positive dipstick analysis for leukocyte esterase or nitrate, pyuria (≥10 leukocytes per mL of urine), organisms seen on Gram stain, physician diagnosis of urinary tract infection, or physician-initiated therapy for a urinary tract infection.

Crude Excess Mortality

The crude excess mortality is the difference between the crude overall case-fatality of patients with a device-

Table 3. **Central Venous Catheter–Associated Bloodstream Infections in the International Nosocomial Infection Control Consortium Intensive Care Units***

Variable	Country								Overall
	A	B	C	D	E	F	G	H	
CVC-associated bloodstream infections, *n*	119	86	126	109	151	11	35	293	930
Rate per 100 patients (range)†	1.3 (0.0–13.0)	8.4 (0.0–11.3)	5.8 (0.0–9.0)	3.2 (0.0–5.2)	10.0 (1.0–15.2)	2.7‡	2.6 (0.0–3.3)	12.7 (1.0–47.6)	4.4 (1.3–12.7)
Rate per 1000 CVC days (range)†	10.7 (0.0–18.9)	9.2 (0.0–25.8)	11.3 (0.0–20.3)	8.8 (0.0–15.4)	16.3 (4.2–23.3)	18.5‡	7.8 (0.0–10.7)	17.9 (6.0–41.5)	12.5 (7.8–18.5)
Proportion of cases, %§									
Enterobacteriaceae	31	26	31	42	29	33	19	22	27
Pseudomonas aeruginosa	10	5	5	13	15	18	10	9	9
Acinetobacter spp.	4	8	7	10	5	9	5	22	13
Staphylococcus aureus	34	20	37	8	8	18	38	26	25
Enterococci	1	5	1	5	0	0	0	4	3
Coagulase-negative staphylococci	20	30	14	8	38	9	5	13	18
Candida spp.	1	7	2	10	6	9	24	4	5
Susceptibility of resistant microorganisms, %									
MRSA	64	100	70.6	100	0	31	80	92	85
Ceftriaxone-resistant *Enterobacteriaceae*	31	100	33.3	71	50	95	50	100	57
Fluoroquinolone-resistant *P. aeruginosa*	56	70	0.0	0	100	0	100	51	49
Vancomycin-resistant enterococci	9	0	0.0	0	0	0	0	0	3

* CVC = central venous catheter; MRSA = methicillin-resistant *Staphylococcus aureus*.
† Ranges for individual countries are for the individual hospitals; overall ranges are for the individual countries.
‡ Range not given because only 1 participating hospital was from country F.
§ Partial listing of major pathogens; does not total 100%.

Table 4. **Catheter-Associated Urinary Tract Infections in the International Nosocomial Infection Control Consortium Intensive Care Units***

Variable	Country								Overall
	A	B	C	D	E	F	G	H	
Catheter-associated UTIs, *n*	398	84	54	15	70	22	24	221	888
Rate per 100 patients (range)†	4.5 (0.0–9.6)	8.2 (0.9–10.6)	2.5 (0.0–19.2)	0.4 (0.0–0.9)	4.6 (0.7–11.9)	5.4‡	1.8 (0.0–2.7)	9.6 (1.1–16.4)	4.2 (0.4–9.6)
Rate per 1000 catheter days (range)†	12.8 (0.0–13.9)	9.8 (2.9–11.3)	4.3 (0.0–23.8)	1.7 (0.0–3.1)	10.3 (2.7–17.9)	11.5‡	4.5 (0.0–10.6)	8.8 (0.9–35.2)	8.9 (1.7–12.8)
Proportion of cases, %§									
Enterobacteriaceae	52	32	56	25	41	55	50	22	42
Pseudomonas aeruginosa	10	19	15	53	11	19	4	13	13
Acinetobacter spp.	4	1	2	0	2	14	4	6	4
Staphylococcus aureus	4	0	0	0	5	5	0	5	4
Enterococci	8	4	6	0	5	0	9	4	6
Coagulase-negative staphylococci	3	1	4	0	2	5	0	0	2
Candida spp.	19	40	15	13	37	5	26	51	30
Susceptibility of resistant microorganisms, %									
MRSA	53	0	0	0	0	0	0.0	8	68
Ceftriaxone-resistant *Enterobacteriaceae*	35	96	56	73	42	57	27	44	43
Fluoroquinolone-resistant *P. aeruginosa*	66	80	57	0	100	0	100	49	64
Vancomycin-resistant enterococci	5	0	0	0	0	0	0	7	5

* MRSA = methicillin-resistant *Staphylococcus aureus*; UTI = urinary tract infection.
† Ranges for individual countries are for the individual hospitals; overall ranges are for the individual countries.
‡ Range not given because only 1 participating hospital was from country F.
§ Partial listing of major pathogens; does not total 100%.

associated infection and the crude case-fatality of patients hospitalized in the ICU during that period who did not acquire a device-associated infection.

Training, Validation, and Reporting

In Argentina, Brazil, Colombia, India, Mexico, Peru, and Turkey, the consortium chairman trained the principal and secondary investigators in each member hospital. In Morocco, the institutional investigators were self-trained by a manual that described how to carry out surveillance and complete surveillance forms. Institutional investigators had continuous telephone or e-mail access to a support team at the INICC Central Office in Buenos Aires, Argentina, which responds to all inquiries within 24 hours. The INICC chairman further reviews all queries and responses.

The forms used to collect surveillance data for each ICU patient permit both internal and external validation because they include every clinical and microbiological criterion for each type of health care–associated infection. The hospital epidemiologist or other senior infection control officer who reviews completed data forms in the participating hospital can confirm that adequate criteria for infection were fulfilled in each case. Moreover, the original patient data form can further be validated at the INICC Central Office before data on the reported infection are entered into the consortium database.

Each month, participating hospitals submitted the completed surveillance forms to the INICC Central Office, where the validity of each case was checked and the recorded signs and symptoms of infection and the results of laboratory studies, radiographic studies, and cultures were scrutinized to assure that the NNIS System criteria for device-associated infection were fulfilled. Also, on a monthly basis, the INICC Central Office team prepared and sent a chart report to each participating hospital that detailed their institutional rates of device-associated infection and rates of adherence to hand hygiene and CVC and urinary catheter care.

Culture Techniques

Ventilator-Associated Pneumonia

In approximately 50% of cases, a deep tracheal aspirate from the endotracheal tube was obtained for Gram stain and aerobic culture or a bronchoscopic specimen was obtained.

CVC–Associated Bloodstream Infection

Central venous catheters were removed aseptically and the distal 5 cm of the catheter was amputated and cultured by using a standardized semiquantitative method (37). Concomitant blood cultures were drawn percutaneously in most cases.

Catheter-Associated Urinary Tract Infection

A urine sample was aseptically aspirated from the sampling port of the urinary catheter and was cultured quantitatively. In all hospitals, standard laboratory methods were used to identify microorganisms and standardized susceptibility testing was performed (28).

Statistical Analyses

We used EpiInfo, version 6.04b (CDC, Atlanta, Georgia), for data analysis. We calculated the device utilization rates by dividing the total number of device days by the total number of ICU patient days. We also calculated the rates of ventilator-associated pneumonia, CVC-associated bloodstream infection, and catheter-associated urinary tract infection per 1000 device days by dividing the total number of health care–associated infections by the total number of specific device days and multiplying the result by 1000 (19).

Role of the Funding Source

No outside funding was received for the study.

RESULTS

Characteristics of the Study Sample

During the 4 years of the study, 46 hospitals with 55 ICUs in 28 cities of 8 countries provided prospectively collected surveillance data on 21 069 patients who were hospitalized in an ICU for an aggregate of 137 740 ICU days (**Table 1**). Seventeen (37%) of the participating hospitals were municipally supported public hospitals, 16 (35%) were university teaching hospitals, and 13 (28%) were private hospitals. Fifty-eight percent of the study ICUs were medical–surgical units, 12% were coronary care units, 25% were combined medical–surgical and coronary care units, and 10% were other types of adult ICUs. The pooled patient average severity of illness score per country ranged from 2.58 to 3.70 and was 2.89 overall.

Device Use Ratio

Device use ranged widely: mechanical ventilation, 0.19 to 0.64 (overall, 0.38); CVCs, 0.22 to 0.97 (overall, 0.54); and urinary catheters, 0.48 to 0.94 (overall, 0.73).

Ventilator-Associated Pneumonia

Rates of ventilator-associated pneumonia also ranged widely among countries, from 10.0 to 52.7 per 1000 ventilator days with an overall rate of 24.1 per 1000 ventilator days (**Table 2**). The infecting pathogen was an *Enterobacteriaceae* species in 26% of cases (58% of which were resistant to ceftriaxone); *Pseudomonas aeruginosa* in 26% of cases (60% of which were resistant to fluoroquinolones); *Staphylococcus aureus* in 22% of cases (84% of which were methicillin-resistant); and an *Acinetobacter* species in 20%. The crude mortality rate of patients without health care–associated infection was 17.1%, and the crude mortality rate of all patients with ventilator-associated pneumonia was 44.9%, yielding an overall crude excess mortality rate of 27.8%.

CVC–Associated Bloodstream Infection

The rate of CVC-associated bloodstream infection ranged from 7.8 to 18.5 per 1000 CVC days and was 12.5 per 1000 CVC days overall (**Table 3**). The infecting pathogen was an *Enterobacteriaceae* species that was resistant to ceftriaxone in 57% of cases; *S. aureus* in 25% (of which 85% were methicillin-resistant); coagulase-negative staphylococci in 18%; *P. aeruginosa* in 9%; and *Acinetobacter* species in 13%. The crude mortality rate of patients with CVC-associated bloodstream infection was 35.2%, yielding an overall crude excess mortality rate of 18.0%.

Catheter-Associated Urinary Tract Infection

Rates of catheter-associated urinary tract infection ranged from 1.7 to 12.8 per 1000 catheter days; the overall rate was 8.9 per 1000 catheter days (**Table 4**). *Enterobacteriaceae* were implicated in 44% of catheter-associated urinary tract infections (43% of which were resistant to ceftri-

Table 5. **Comparison of Device Use and Rates of Device-Associated Infection in the Intensive Care Units of the International Nosocomial Infection Control Consortium and of the U.S. National Nosocomial Infection Surveillance System***

Variable	U.S. NNIS ICUs: 1992–2004	INICC ICUs: 2002–2005
Rate of device use†		
Mechanical ventilators	0.43 (0.23–0.62)	0.38 (0.19–0.64)
CVCs	0.57 (0.36–0.74)	0.54 (0.22–0.97)
Urinary catheters	0.78 (0.65–0.90)	0.73 (0.48–0.94)
Rate per 1000 device days†		
Ventilator-associated pneumonia	5.4 (1.2–7.2)	24.1 (10.0–52.7)
CVC-associated bloodstream infection	4.0 (1.7–7.6)	12.5 (7.8–18.5)
Catheter-associated UTI	3.9 (1.3–7.5)	8.9 (1.7–12.8)
Proportion of device-associated infections with resistance, %‡		
MRSA	59	84
Ceftriaxone-resistant *Enterobacteriaceae*	19	55
Ciprofloxacin-resistant *Pseudomonas aeruginosa*	29	59
Vancomycin-resistant enterococci	29	5

* Data are from an NNIS report (1). CVC = central venous catheter; ICU = intensive care unit; INICC = International Nosocomial Infection Control Consortium; MRSA = methicillin-resistant *Staphylococcus aureus*; NNIS = National Nosocomial Infection Surveillance System; UTI = urinary tract infection.
† Overall (pooled) and 10th to 90th percentile range for U.S. NNIS teaching hospitals; overall (pooled) and range of individual countries for the INICC hospitals.
‡ Overall (pooled) data from NNIS, 1992–2004 (300 hospitals), and from INICC, 2002–2005.

axone), *Candida* spp. in 30%, *P. aeruginosa* in 13% of cases (64% of which were resistant to fluoroquinolones), and *Acinetobacter* in 4%. The crude mortality rate of catheter-associated urinary tract infections was 38.4%, yielding an overall crude excess mortality rate of 21.3%.

Discussion

Health care–acquired infections have been associated with substantial morbidity and attributable mortality (8, 9, 38–44), as well as greatly increased health care costs (6, 13, 17, 39, 42, 45). Studies done in U.S. hospitals 30 years ago showed that an integrated infection control program that includes surveillance of health care–associated infections can reduce the incidence of infection by as much as 30% and can lead to reduced health care costs (3).

In the INICC, the surveillance forms used are designed to collect data from all patients, both those with and those without health care–associated infection. The CDC NNIS System in U.S. hospitals (1) and the surveillance systems used in several other countries (5–7, 46–48) use data forms to collect device days and bed days of the entire ICU population and another form to collect data from patients with infections that are acquired in the ICU. In contrast, our forms are designed to continuously prompt the surveillance officer to suspect health care–associated infection because the form provides a panoramic view of what is happening every day to every patient in the ICU: daily data on the patient's temperature, blood pressure, exposure to invasive devices, cultures done, and antibiotic use. This approach is especially useful in cases in which no cultures have been done or the culture results are equivocal or negative, such as with pneumonia or sepsis, and that may not be otherwise recognized as a nosocomial infection. Moreover, by using these forms, we can match different patient features, such as age, sex, underlying diseases, service (medical or surgical), severity of illness score, time of year, and exposure to invasive devices, to calculate the added length of stay, costs of hospitalization, and attributable mortality rate (29, 40–44) by using the method of Haley (49). Although the INICC method may increase the accuracy of surveillance because each reported infection can be internally and externally validated, the vast majority of device-associated ICU infections in both the NNIS System and the INICC databases are based on positive cultures, and we doubt whether the 2 surveillance systems differ materially in their capacity to detect most device-associated nosocomial infections vis-à-vis their sensitivity for detecting infections.

For our analyses, we have assumed that the NNIS System rates during 1992 to 2004 were constant over the 12-year period because the 2004 NNIS report (1) did not address changing rates over time. Since the rates in 2005 were little changed, we can reasonably conclude that the difference between the INICC and NNIS System represents true differences in risk for ICU-acquired infection in the 2 surveillance populations.

We chose to focus the consortium's first efforts on surveillance of device-associated infections in the ICU because it addresses the health care setting with the most vulnerable patients with the heaviest exposure to invasive devices and the highest rates of health care–associated infection (1–3). Although device use in the consortium ICUs was similar or slightly lower than that reported from U.S. ICUs in the NNIS System (1) (**Table 1**), we found that rates of device-associated infection were far higher (**Table 5**). The overall incidence of CVC-associated bloodstream infection in the consortium medical–surgical ICUs, 12.5 per 1000 CVC days, is nearly 4-fold higher than the 1.7 to 7.6 per 1000 CVC days reported in similar U.S. ICUs in the NNIS System. The overall rates of ventilator-associated pneumonia and catheter-associated urinary tract infection were also far higher than pooled NNIS System rates: 24.1 per 1000 ventilator days versus 1.2 to 9.9 per 1000 ventilator days and 8.9 per 1000 catheter days versus 1.3 to 7.5 per 1000 catheter days, respectively. Most remarkably, infections caused by methicillin-resistant *S. aureus* (84% vs. 48%), ceftriaxone-resistant *Enterobacteriaceae* (51% vs. 17%), and fluoroquinolone-resistant *P. aeruginosa* (59% vs. 29%) were also more common in the consortium ICUs than in the NNIS System ICUs. In contrast, resistance of enterococcal isolates to vancomycin was much lower in the INICC ICUs (5% vs. 29%), which probably reflects the less frequent use of vancomycin in the consortium hospitals.

The consortium rates of health care–associated infection are, however, remarkably similar to those found in limited, smaller, and earlier studies reported from other Latin American countries (48–52). In 1 Brazilian hospital, the bloodstream infection rate was 32 per 1000 CVC days and the rate of ventilator-associated pneumonia was 42 per 1000 ventilator days (50). In a Mexican hospital, rates of nosocomial ventilator-associated pneumonia and bacteremia or sepsis were 28 and 26 cases per 1000 device days, respectively (51). The high rates that we found were in some of the most preeminent medical centers in these countries that had already demonstrated a major commitment to hospital infection control by the established infection control program.

The higher rates of device-associated infection that seem to be representative of ICUs in developing countries have many plausible explanations, some of which have been suggested by previous investigators (52–54). Most developing countries do not have laws mandating health care–associated infection control programs, and hospital accreditation is not required. Hand hygiene also greatly varies in most centers (29–31). Funds and resources for infection control are very limited in most developing countries (55–58), and nurse-to-patient staffing ratios are often much lower on average than those in U.S. ICUs. Studies of device-associated infection in U.S. ICUs have shown a powerful association between low nurse-to-patient ratios

and high proportions of inexperienced nurses and a greatly increased risk for device-associated infections (59–63). Finally, the use of outdated technology may also be a factor. For example, open intravenous infusion systems are used almost universally in developing countries, but closed systems are the standard of care in developed countries. We have shown in a recent prospective trial in consortium ICUs that use of closed infusion systems result in much lower rates of CVC-associated bloodstream infection (35).

Surveillance of health care–associated infections—defining the magnitude and nature of the problem—is the first step toward reducing the risk for infection in vulnerable hospitalized patients. The next step is to implement targeted basic infection control practices that have been shown to prevent health care–associated infections (16, 64–68). We are confident that increased awareness of device-associated infections in the consortium ICUs will continue to provide impetus for instituting change. We have already seen evidence of positive change. Instituting targeted performance feedback programs for hand hygiene and CVC, ventilator, and urinary catheter care has already substantially reduced the incidence of ICU-acquired infections in consortium hospitals (29–31, 34, 35, 69–73).

Similar positive experiences have been reported from other hospitals in developing countries (74, 75). In Guatemala, after 3 months of prospective surveillance and targeted interventions—including an educational program focused on respiratory care—the rate of nosocomial pneumonia decreased from 33% (41 of 123 patients) to 16% (21 of 130 patients) ($P = 0.001$) (75). In a hospital in Argentina, after surveillance of high-risk procedures and implementation of guidelines developed by physician and nurse consensus for hand hygiene, handling of infants, care of intravenous lines, and endotracheal suctioning, the rate of nosocomial bacteremia decreased within a year from 20.0 to 12.4 per 1000 patient days ($P < 0.003$) (74).

Our study has limitations. First, we do not consider our data to be adequate in representing any single entire country. With data collected prospectively during 4 years of comprehensive surveillance in 55 ICUs from 46 hospitals in 8 developing countries, we believe our findings are representative of the developing world, but likely variations in efficiency of surveillance and institutional resources may have affected the detected rates. Second, rates of device-associated infections have widely varied among the member hospitals and between countries, which suggests substantial differences in severity of illness or, more likely, in the efficiency of surveillance and institutional resources for prevention among the member hospitals. Third, we must rely on the member hospitals' laboratories to reliably identify infecting pathogens and delineate bacterial resistance patterns. Different laboratories may have widely varying levels of expertise and resource availability; however, similar concerns can be raised about any multi-institutional clinical surveillance data.

Health care–associated infections clearly are a huge and largely unrecognized threat to patient safety in the developing world, a far greater threat than in the developed countries. We hope that the initial successes of the INICC, combined with our ongoing efforts to more consistently implement simple and inexpensive measures for prevention, will lead to wider acceptance of infection control practices and consistent reductions in device-associated infections not only in the hospitals of the consortium but in their many neighboring hospitals. Control of antibiotic resistance will mandate more effective nosocomial infection control and more restrictive use of anti-infectives (76).

Appendix: Members of the International Nosocomial Infection Control Consortium

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