Device-associated infection rates and mortality in intensive care units of Peruvian hospitals: findings of the International Nosocomial Infection Control Consortium

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ABSTRACT

Objectives. *To measure device-associated infection (DAI) rates, microbiological profiles, bacterial resistance, and attributable mortality in intensive care units (ICUs) in hospitals in Peru that are members of the International Nosocomial Infection Control Consortium (INICC).*

Methods. *Prospective cohort surveillance of DAIs was conducted in ICUs in four hospitals applying the definitions for nosocomial infections of the U.S. Centers for Disease Control and Prevention National Nosocomial Infections Surveillance System (CDC-NNIS) and National Healthcare Safety Network (NHSN).*

Results. *From September 2003 to October 2007 1 920 patients hospitalized in ICUs for an aggregate of 9 997 days acquired 249 DAIs, accounting for a rate of 13.0% and 24.9 DAIs per 1 000 ICU-days. The ventilator-associated pneumonia (VAP) rate was 31.3 per 1 000 ventilator-days; the central venous catheter-associated bloodstream infections (CVC-BSI) rate was 7.7 cases per 1 000 catheter-days; and the rate for catheter-associated urinary tract infections (CAUTI) was 5.1 cases per 1 000 catheter-days. Extra mortality for VAP was 24.5% (RR 2.07, $P < 0.001$); for CVC-BSI the rate was 15.0% (RR 2.75, $P = 0.028$). Methicillin-resistant strains accounted for 73.5% of all* Staphylococcus aureus *DAIs; 40.5% of the Enterobacteriaceae were resistant to ceftriaxone, 40.8% were resistant to ceftazidime, and 32.0% were resistant to piperacillin-tazobactam. Sixty-five percent of* Pseudomonas aeruginosa *isolates were resistant to ciprofloxacin, 62.0% were resistant to ceftazidime, 29.4% were resistant to piperacillin-tazobactam, and 36.1% were resistant to imipenem.*

Conclusions. *The high rates of DAIs in the Peruvian hospitals in this study indicate the need for active infection control. Programs consisting of surveillance of DAIs and implementation of guidelines for infection prevention can ensure improved patient safety in the ICUs and throughout hospitals.*

Key words Bacterial infections; cross infection/epidemiology; drug resistance, bacterial; hospitals; infection control; intensive care units; length of stay; mortality; Peru.

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In infection control and quality assurance of hospitals in the United States, surveillance of device-associated infections (DAIs) in the intensive care unit (ICU) is considered a determining characteristic of infection control programs (1). The Study on the Efficacy of Healthcare-associated Infection Control (SENIC Project) carried out by the U.S. Centers for Disease Control and Prevention (CDC) concludes that surveillance is an effective means to reduce healthcare-associated infections (2). Similarly, in many other industrialized countries surveillance standards have been devised and form an integral part of their health care policies (3).

An increasing number of research studies indicate that DAIs are a primary cause of patient morbidity and mortality in industrialized countries, and are the most significant threat to safety in the ICU (4–6). The CDC's National Nosocomial Infections Surveillance System (NNIS) has developed standardized criteria for the surveillance of healthcare-associated infections (7). Constant, targeted surveillance along with calculation of DAI rates per 1 000 device-days provide a basis for comparison among health care facilities. This gives health care providers a comprehensive understanding of the institutional problems confronting them, and a way to resolve these problems.

In the context of an expanded framework for DAI control, most relevant studies of ICU-acquired infections have been carried out in industrialized countries (8). In developing countries few published studies use standardized definitions when reporting DAI rates (9–14). The International Nosocomial Infections Control Consortium (INICC) was founded in 1998 to address these issues in developing countries, by determining the incidence of DAIs in tertiary care centers. Initially, certain Latin American hospitals were invited to participate in the INICC project, and today, the INICC comprises a worldwide network of around 400 researchers representing 100 hospitals in 29 countries of Latin America, Asia, Africa, and Europe. INICC member hospitals provide general medical and surgical inpatient services to adults and children.

In the case of Peru, there are no previously published data measuring DAI rates. Peruvian hospitals began INICC participation in September 2003. Each month, selected health care facilities sent data to the INICC research center, which were then entered into an international database. The data were collected using DAI surveillance and standardized protocols (7, 15). The findings of this study in Peru are integral to INICC surveillance and reflect data collected from September 2003 to October 2007.

MATERIALS AND METHODS

Setting

The present study was conducted in four ICUs at four hospitals in Peru from September 2003 to October 2007. Identity of the participating hospitals remains confidential.

The infection control team in each hospital consists of a physician, an infection control practitioner (ICP), a surveillance nurse, and support personnel. An ICP with at least two years of infection control experience is in charge of DAI surveillance at the hospital and can access electronically recorded data for each patient. These data are encoded to protect patient confidentiality and are identifiable only to the infection control team of the respective hospital. In addition, every hospital has a clinical microbiology laboratory which provides *in vitro* susceptibility testing of clinical isolates using standardized methods (16).

The protocol regulating the study was agreed upon by the Institutional Review Board at each hospital.

The study settings consisted of common wards with patient beds. There were no private patient rooms. Nurse-to-patient staffing ratio was one nurse per three patients.

Surveillance

Each day, data were collected prospectively from all the patients admitted to the ICUs by means of specifically designed forms. The data were gathered according to the definitions provided by the CDC National Nosocomial Infections Surveillance System (NNIS) (7, 15).

Definitions

The following definitions are adapted from the CDC National Nosocomial Infections Surveillance System (NNIS) as reported in Garner et al. (7).

Ventilator-associated pneumonia (VAP). 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 meet at least one of the following criteria: new onset of purulent sputum or change in character of sputum; organisms 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 central venous catheter-associated bloodstream infection (CVC-BSI). Central venous catheter-associated bloodstream infection is laboratory-confirmed when a patient with a CVC has a recognized pathogen that is isolated from one or more percutaneous blood cultures after 48 hours of vascular catheterization and which is not related to an infection at another site. The patient also has at least one 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 two or more blood cultures.

Clinically suspected central venous catheter-associated bloodstream infection (CVC-BSI). Central venous catheter-associated bloodstream infection is clinically suspected when a patient with a CVC has at least one of the

following clinical signs with no other recognized cause: fever (temperature ≥ 38 °C), hypotension (systolic blood pressure ≤ 90 mmHg), or oliguria (≤ 20 mL/h).

Catheter-associated urinary tract infection (CAUTI). For the diagnosis of catheter-associated urinary tract infection, the patient must meet one of two criteria. The first criterion is satisfied when a patient with a urinary catheter has one or more of the following symptoms with no other recognized cause: fever (temperature ≥ 38 °C), urgency, or suprapubic tenderness. The urine culture is positive for 10^5 colony-forming units (CFU) per mL or more, with no more than two microorganisms isolated. The second criterion is satisfied when a patient with a urinary catheter has at least two of the following criteria with no other recognized cause: positive dipstick analysis for leukocyte esterase or nitrate and pyuria (≥ 10 leukocytes/mL).

Culture techniques

In all cases, standard laboratory methods were used to identify microorganisms, and a standardized susceptibility test was performed (16). The following are culture techniques for VAP, CVC-BSI, and CAUTI.

Ventilator-associated pneumonia (VAP). In most cases, a deep tracheal aspirate from the endotracheal tube was cultured aerobically and gram-stained.

Central venous catheter-associated bloodstream infection (CVC-BSI). Central venous catheters were removed aseptically and the distal 5 cm of the catheter was amputated and cultured using a standardized, semiquantitative method (17). Concomitant blood cultures were drawn percutaneously in nearly all cases.

Catheter-associated urinary tract infection (CAUTI). A urine sample was aseptically aspirated from the sampling port of the urinary catheter and cultured quantitatively.

Forms, training, adjudication, and data feedback

Data relating to patient demographics, age, gender, severity-of-illness score, and hospital location were gathered at admission to the ICU. Additionally, data on mechanical ventilation, placement of CVC and urinary catheters, fever, blood pressure, antibiotic use, and the results of cultures for each patient hospitalized at the ICU were collected daily. Once hospitalization ended, the ICP recorded the date of onset, site of infection, infecting microorganisms, and antimicrobial susceptibilities of the patients who had acquired a DAI.

The average severity-of-illness score (ASIS) was recorded by applying the CDC Nosocomial Infections Surveillance System criteria. Points were ascribed to patients as follows: 1 point for postoperative patients requiring routine postoperative observation; 2 points for physiologically stable patients requiring prophylactic overnight observation; 3 points for nursing and monitoring; 4 points for physiologically unstable patients requiring intensive nursing and medical care with the need for frequent reassessment and adjustment of therapy; and 5 points for physiologically unstable patients in coma or shock, who require cardiopulmonary resuscitation, or who need intensive medical and nursing care with frequent reassessment (15).

Researchers from each participating hospital in Peru received comprehensive training in active, prospective surveillance procedures. They had ongoing assistance from a support team at the INICC headquarters in Buenos Aires who answered relevant queries—further checked by the INICC Chairman—within 24 hours of reception.

Every month, the participating hospitals sent completed surveillance forms to the INICC office in Buenos Aires where the validity of each case was checked against recorded symptoms (fever, blood pressure) and cultures. This process ensured that the criteria for DAI as provided by the CDC NNIS had been met (7, 15).

Each DAI reported by a hospital was adjudicated to be certain that sufficient criteria were fulfilled to justify recording it as a DAI. The adjudication process also included routine scrutiny of the reported data for purportedly uninfected patients to detect unreported, true DAIs. When discrepancies were encountered in surveillance forms, the hospital team was contacted by e-mail to resolve the difference; the judgment of the principal investigator and ICP of the participating hospital was final. Adjudication is a unique feature of INICC outcome surveillance and is considered essential not only for maximizing the accuracy of surveillance data, but also, for assessing on an ongoing basis the capacity of the ICP and principal investigator at each hospital to accurately identify DAIs.

On a monthly basis, the INICC Headquarters team prepared and sent to each participating hospital a report on their institutional rates of device-associated infection, bacterial profile, bacterial resistance, length of stay, and mortality in their ICU or ICUs. The report also included rates of compliance with hand hygiene, CVC and urinary catheter care, and measures to prevent pneumonia.

Statistical analysis

Outcomes measured during the surveillance period included the incidence density rate of CVC-BSI, CAUTI, and VAP. The DAI rates per 1 000 device-days were calculated by dividing the total number of DAIs by the total number of specific device-days and multiplying the result by 1 000 (15).

Device utilization (DU) 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 that patients are in the ICU during the selected time period.

Chi square analyses for dichotomous variables and 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 primary and secondary outcomes.

The crude excess mortality was calculated as the difference between the crude mean case-fatality of patients with a device-associated infection and the crude case-fatality of patients hospitalized in the ICU during the same period who did not acquire a device-associated infection. The extra length of stay (LOS) is the difference between the length of stay of patients with a DAI and the LOS of patients hospitalized in the ICU during the same period who did not acquire a DAI.

EpiInfo® version 6.04b (CDC, Atlanta, Georgia) was used to conduct data analysis.

RESULTS

Features of population studied

During the study period (September 2003 to October 2007) surveillance data were collected prospectively on 1 920 patients hospitalized for an aggregate of 9 997 ICU-days in four ICUs in four hospitals in Peru (Table 1). These patients contracted 249 device-associated infections (DAIs) for a mean rate of 13.0% or 24.9 infections per 1 000 ICU-days (Table 2). VAP represented 63.9%, CVC-associated BSI represented 20.1%, and CAUTI represented 16.1% of all DAIs.

The features of each ICU, the number of patients enrolled, ICU-days, and the mean severity-of-illness score (ASIS) are shown in Table 1 (15). Mean patient ASIS was 2.80.

TABLE 1. Features of four International Nosocomial Infections Control Consortium member hospitals and their intensive care units in Peru for the period September 2003 to October 2007

Variable	Hospital A	Hospital B	Hospital C	Hospital D	Total
Hospitals, *n*	1	1	1	1	4
Academic teaching	0	0	0	0	0
Public	1	0	1	1	3
Private community	0	1	0	0	1
Hospital beds, *n*	363	96	212	170	841
Intensive care units, *n*	1	1	1	1	4
Intensive care unit beds, *n*	7	7	5	4	23
Intensive care unit type	Medical-surgical	Medical-surgical	Medical-surgical	Medical-surgical	Medical-surgical
Surveillance period	9/03 to 1/07	2/04 to 1/06	1/04 to 8/05	8/06 to 10/07	9/03 to 10/07
Experience of infection control practitioner, *y*	8	2	8	20	2–20
Patients studied, *n*	962	492	394	72	1 920
Total intensive care unit days	5 132	2 148	2 248	449	9 977
Male patients, %	48.9	64.2	57.1	54.2	54.7
Mean age of patient, *y*	46.4	61.7	62.3	36.9	53.2
Mean average severity-of-illness score	3.02	2.30	3.02	2.89	2.80
Device utilization[a]					
Ventilator-days	2 809	763	1 406	96	5 074
Ratio of ventilator utilization	0.55	0.36	0.63	0.21	0.51
Central venous catheter-days	3 352	1 480	1 607	75	6 514
Ratio of central venous catheter utilization	0.65	0.69	0.71	0.17	0.65
Urinary catheter-days	4 159	1 247	2 134	236	7 776
Ratio of urinary catheter utilization	0.81	0.58	0.95	0.53	0.78

[a] Device utilization 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 venous catheter, ventilator, or urinary catheter) by all patients in the selected population during the selected time period. Patient-days are the total number of days that patients are in the intensive care unit during the selected time period.

TABLE 2. DAIs per 1 000 device-days in intensive care units of four Peruvian International Nosocomial Infections Control Consortium member hospitals for the period September 2003 to October 2007

Infection	Device type	Device-days, *n*	DAIs,[a] *n*	Distribution of DAIs (%)	Rate per 100 patients (%)	Rate per 1 000 device-days (%)[b]
VAP[a]	MV[a]	5 074	159	63.9	8.3	31.30
CVC-BSI[a]	CVC[a]	6 514	50	20.1	2.6	7.70
CAUTI[a]	UC[a]	7 776	40	16.1	2.1	5.14

[a] DAI: Device-associated infection; VAP: ventilator associated pneumonia; CVC-BSI: central vascular catheter-associated bloodstream infection; CAUTI: catheter-associated urinary tract infection; MV: mechanical ventilator; UC: Urinary catheter.

[b] Rate per 1 000 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 1 000.

TABLE 3. Extra mortality of patients with device-associated infections in the intensive cure units of four Peruvian hospitals for the period September 2003 to October 2007

Patients	Crude mortality (%)	Extra mortality (%)	RR	95% CI	*P*-value
Patients without infection	14.0	—	—	—	—
Patients with VAP[a]	38.5	24.5	2.75	2.00– 3.78	0.0001
Patients with CVC-BSI[a]	29.0	15.0	2.07	1.07– 4.04	0.0280
Patients with CAUTI[a]	18.2	4.2	1.30	0.49– 3.49	0.6028

[a] VAP: ventilator-associated pneumonia; CVC-BSI: central venous catheter-associated bloodstream infection; CAUTI: catheter-associated urinary tract infection.

Device utilization ratio

The DU ratio for mechanical ventilation was 0.51; for central venous catheters it was 0.65; and for urinary catheters it was 0.78. DAI distribution and device utilization are shown in Table 2.

Device-associated infection rates

Ventilator-associated pneumonia. The mean rate of VAP was 31.3 per 1 000 ventilator-days (Table 2). The crude mortality of patients with VAP was 38.5%, with an extra mortality of 24.5% (RR 2.75, 95% CI 2.00–3.78, $P < 0.0001$) (Table 3). The crude mortality of patients without DAIs was 14.0%, yielding an excess mortality of 24.5%. The LOS of patients without DAIs was 4.0 days; the LOS of patients with VAP was 13.4 days, yielding an extra length of stay of 9.4 days (RR 3.35, 95% CI 3.17–3.54, $P < 0.001$).

Central venous catheter-associated bloodstream infection. The mean rate of CVC-BSI was 7.7 per 1 000 catheter-days (Table 2). The crude mortality of patients with CVC-BSI was 29.0%, with extra mortality for CVC-BSI of 15.0% (RR 2.07, 95% CI 1.07–4.04, $P = 0.028$) (Table 3). The LOS of patients with CVC-BSI was 13.1 days, yielding an extra length of stay of 9.1 days (RR 3.27, 95% CI 2.96–3.61, $P = 0.0001$).

Catheter-associated urinary tract infection. The mean rate of CAUTI was 5.1 per 1 000 catheter-days (Table 2). The crude mortality of patients with CAUTI was 18.2%, with an extra mortality of 4.2% (RR 1.30, 95% CI 0.49–3.49, $P = 0.6028$) (Table 3). The LOS of patients with CAUTI was 10.8 days, yielding an extra LOS of 6.8 days (RR 2.71, 95% CI 2.38–3.08, $P = 0.0001$).

TABLE 4. Microbiological profile of device-associated infections in the intensive care units of four International Nosocomial Infections Control Consortium member hospitals in Peru for the study period September 2003 to October 2007

Pathogen	Proportion of cases (%)
Enterobacteriaceae	25.6
Staphylococcus aureus	22.2
Pseudomonas spp.	17.7
Candida spp.	15.3
Coagulase-negative staphylococci	5.9
Acinetobacter spp.	5.4
Stenotrophomonas spp.	3.0
Streptococcus spp.	2.0
Enterococcus spp.	2.0

TABLE 5. Resistance of pathogens in the intensive care units of four International Nosocomial Infections Control Consortium member hospitals in Peru for the study period September 2003 to October 2007

Bacteria	Antibiotic used	Percentage resistance
Enterobacteriaceae	Ceftazidime	40.8
Enterobacteriaceae	Ceftriaxone	40.5
Enterobacteriaceae	Piperacillin/tazobactam	32.0
Pseudomona aeruginosa	Ciprofloxacin	65.0
Pseudomona aeruginosa	Ceftazidime	62.0
Pseudomona aeruginosa	Imipenem	36.1
Pseudomona aeruginosa	Piperacillin-tazobactam	29.4
Staphylococcus aureus	Methicillin	73.5

Overall bacterial resistance

The most common agents causing DAIs were Enterobacteriaceae (25.6%), *Staphylococcus aureus* (22.2%), *Pseudomonas* spp. (17.7%), and *Candida* spp. (15.3 %). Also significant but to a lesser degree were infections caused by coagulase-negative staphylococci (5.9%) and *Acinetobacter* spp. (5.4%) (see Table 4). The drug resistance of these agents in the study population is shown in Table 5.

DISCUSSION

Although DAIs have long been a primary and serious cause of patient

TABLE 6. Comparison of device utilization and rates of device-associated infections in the intensive care units (ICUs) of four Peruvian International Nosocomial Infections Control Consortium (INICC) member hospitals and U.S. hospitals participating in CDC-National Healthcare Safety Network (CDC-NHSN) survey[a]

Variable	U.S. CDC-NHSN ICUs (2005–2006)	Peruvian INICC ICUs (2003–2007)	RR comparing INICC and NHSN rates
Rate of device utilization			
Mechanical ventilators	0.43 (0.20–0.65)[b]	0.51 (0.21–0.63)[c]	1.19
Central venous catheters	0.58 (0.36–0.74)[b]	0.65 (0.17–0.71)[c]	1.12
Urinary catheters	0.80 (0.62–0.92)[b]	0.78 (0.53–0.95)[c]	0.97
Rate per 1 000 device days			
Ventilator-associated pneumonia	3.6 (1.3–5.1)[b]	31.3 (10.4–36.3)[c]	8.69
Central venous catheter-associated bloodstream infection	2.4 (0.6–3.1)[b]	7.7 (5.9–26.6)[c]	3.20
Catheter-associated urinary tract infection	3.4 (1.9–4.5)[b]	5.1 (1.4–10.4)[c]	1.50
Proportion of device-associated infections with resistance, %[d]			
Methicillin-resistant *Staphylococcus aureus*	52.9	73.5	1.39
Ceftriaxone-resistant Enterobacteriaceae	27.6	40.5	1.47
Ciprofloxacin-resistant *Pseudomona aeruginosa*	34.8	65.0	1.87

[a] Edwards JR, Peterson KD, Andrus ML, Tolson JS, Goulding JS, Dudeck MA, et al. National Healthcare Safety Network (NHSN) Report, data summary for 2006, issued June 2007. Am J Infect Control. 2007;35(5):290–301.
[b] Overall (pooled) and 10th to 90th percentile ranges for the U.S. teaching hospitals in CDC-NHSN survey (see note "a").
[c] Overall (pooled) and range of individual hospitals for the four INICC hospitals.
[d] Overall (pooled) data from NHSN (211 hospitals), 2005–2006, and from INICC (4 hospitals), 2003–2007.

morbidity and attributable mortality in developing countries, this is the first multi-center study to show DAI rates in selected ICUs in Peru. The researchers chose to focus the INICC's initial efforts on surveillance in ICUs because they represent a hospital setting where invasive devices are extensively used and, therefore, patients are exposed to the highest rates of health care-associated infection (3).

DAIs have been a factor in the increase in health care costs (4, 18–20). Research studies about infection control programs that include device-associated surveillance in U.S. hospitals (2) indicate that the incidence of DAI can be lowered by as much as 30%, thereby reducing corresponding health care costs.

In INICC, the surveillance form is designed to collect data from patients with and without DAIs. The CDC's NNIS/NHSN program in U.S. hospitals collect data only from patients with health care acquired infections (1, 21, 22). In contrast, the form used by INICC is designed to continuously prompt the surveillance officer to suspect DAIs because the form provides an overview of what is happening each day to *every* patient in the ICU in terms of vital signs, exposure to invasive devices, the results of cultures, and antibiotic therapy given. 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 DAI (9–14, 23, 24). By collecting data on all patients in the ICU, it is possible to match patients with and without DAI for several features in order to calculate added length of stay, costs of hospitalization, attributable mortality, and risk factors for infection (12, 19, 20, 25).

We consider that the INICC methodology improves the accuracy of surveillance because each reported DAI is externally adjudicated. However, the vast majority of ICU-acquired infections in both the CDC NNIS/NHSN system and INICC are based on positive cultures, and we doubt whether the two surveillance systems differ materially in sensitivity to detect DAIs except, perhaps, for VAP or clinical sepsis.

We compared DAI rates in ICUs in four Peruvian hospitals with pooled rates for DAIs in the ICUs of U.S. hospitals included in the NHSN survey results for 2005–2006 (1) (see Table 6). In the four ICUs in Peruvian hospitals, the mean rate for CVC-BSI was 7.7 per 1 000 CVC-days compared with a rate of 2.4 per 1 000 CVC-days reported in the NHSN study; the mean rate for VAP was 31.3 per 1 000 ventilator-days in the Peruvian study compared with a rate of 3.6 per 1 000 ventilation-days reported by NHSN; the mean rate for CAUTI was 5.1 per 1 000 catheter-days in the Peruvian study compared with the NHSN rate of 3.4 per 1 000 catheter-days (1).

Where compliance with infection control was studied in INICC member hospitals, there was significant variation among the hospitals. Hand hygiene resources and compliance ranged from 20% to 70% in INICC member hospitals (26). The mean compliance rate for hand hygiene reported in a recent study of all INICC participating ICUs was 50% (26). This rate was similar to recent research studies conducted in the United States and Europe (27). Significant variation also was found among INICC member hospitals in the use of sterile dressings on CVC insertion sites. Among the major obstacles remaining to be overcome at these hospitals are: poor hand hygiene compliance, ineffective isolation of patients, protracted use of invasive devices, and incorrect positioning of urine collection bags (28).

There was a high rate of resistance to all major antibiotics commonly used in the ICUs in this study. This may be due to lack of adequate DAI control programs as well as clonal spread of resistance among isolates and patients. Control of antibiotic resistance requires more restrictive use of anti-infective agents, isolation of patients, and more effective DAI control (29).

There are several factors that can explain the DAI rates shown in this study. First, guidelines on specific infection control practices are not adhered to adequately in Peru, national infection control surveillance is not conducted, and hospital accreditation is not mandatory. According to previous studies carried out in hospitals in developing countries, regulations and standards for the implementation of infection control programs are lacking (30, 31). While national infection control guidelines might exist, they are not properly applied. Second, hand hygiene compliance is highly variable in most health care facilities in Peru, reflecting the general situation in other developing countries (30, 31). Third, in Peru, as in most developing countries, administrative and financial support is lacking, which almost inevitably results in limited funds and resource availability to deal with infection control (32). Fourth, there are insufficient supplies and wards are over-crowded. Fifth, it is almost certain that the low nurse-to-patient staffing ratios result in substantially increased health-care associated infection rates. There is an inadequate number of trained staff, which has been highly associated, together with low nurse-to-patient ratios and inexperienced nurse service, with a greatly increased risk of DAIs in a study carried out in U.S. ICUs (33). Finally, another underlying factor of high infection rates in the Peruvian hospitals is the use of antiquated technology.

Limitations

The present study has certain limitations, the first being that there are not sufficient data to reflect the situation in all of Peru. For over two years, researchers prospectively collected data from the ICUs in four Peruvian hospitals as part of the implementation of a comprehensive surveillance system. Reported DAI rates could have been affected by the variations among the four hospitals in the efficacy of surveillance and availability of institutional resources. Variations in DAI rates among the different INICC member hospitals result in significantly different severity-of-illness scores or, in most cases, in the different efficacy and accuracy of surveillance of DAIs. Second, the laboratories of INICC member hospitals are relied upon for identifying infecting pathogens and delineating bacterial resistance patterns, and the levels of expertise and resource availability in these facilities vary widely. This, however, is a limitation that is present in the data of any multi-center clinical surveillance. Third, other severity-of-illness scores, such as APACHE, were not applied because there were not enough resources to conduct the more labor-intensive calculation of these other scoring systems. Finally, similar to other cohort studies, hospitals initiated clinical surveillance at different periods and surveillance was suspended at certain times, resulting in the lack of simultaneously collected data from all hospitals enrolled in this study.

Conclusion

The first step toward reducing the risk of DAI in hospitalized patients is the institution of surveillance of nosocomial infections (2). Next, basic, but effective infection control practices need to be adopted to improve the prevention of hospital-acquired infections (34, 35). Needless to say, shared knowledge and accurate information about this serious public health problem can motivate the development of high-quality infection control strategies. In this regard, there is evidence suggesting positive modifications in practices in several of the INICC member hospitals: hand hygiene compliance has substantially increased, performance feedback programs for hand hygiene have been instituted, and CVC and urinary catheter care have shown a significantly reduced incidence of CVC-associated BSI, CAUTI, and VAP (36–42).

The fact that DAIs pose a huge and largely under-recognized threat to patient safety in developing countries is a critical issue. Improvements seen in INICC member hospitals outside of Peru provide health care personnel with examples of simple, effective, and inexpensive DAI preventive strategies (36–42). Evidence of this progress leads to wider acceptance of infection control programs in all INICC member hospitals, and should lead to significant DAI reductions, particularly those occurring in the ICU.

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REFERENCES

1. Edwards JR, Peterson KD, Andrus ML, Tolson JS, Goulding JS, Dudeck MA, et al. National Healthcare Safety Network (NHSN) Report, data summary for 2006, issued June 2007. Am J Infect Control. 2007;35(5):290–301.
2. Hughes JM. Study on the efficacy of nosocomial infection control (SENIC Project): results and implications for the future. Chemotherapy.1988;34(6):553–61.
3. National Nosocomial Infections Surveillance (NNIS) System Report, data summary from January 1992 through June 2004, issued October 2004. Am J Infect Control. 2004;32(8): 470–85.
4. Jarvis WR. Selected aspects of the socioeconomic impact of nosocomial infections: morbidity, mortality, cost, and prevention. Infect Control Hosp Epidemiol. 1996;17(8):552–7.
5. Fagon JY, Chastre J, Vuagnat A, Trouillet JL, Novara A, Gibert C. Nosocomial pneumonia and mortality among patients in intensive care units. JAMA. 1996;275(11):866–9.
6. Laupland KB, Zygun DA, Doig CJ, Bagshaw SM, Svenson LW, Fick GH. One-year mortality of bloodstream infection-associated sepsis and septic shock among patients presenting to a regional critical care system. Intensive Care Med. 2005;31(2):213–9.
7. Garner JS, Jarvis WR, Emori TG, Horan TC, Hughes JM. CDC definitions for nosocomial infections, 1988. Am J Infect Control. 1988; 16(3):128–40.
8. Safdar N, Crnich CJ, Maki DG. Nosocomial infections in the intensive care unit associated with invasive medical devices. Curr Infect Dis Rep. 2001;3(6):487–95.
9. Rosenthal VD, Maki DG, Salomao R, Moreno CA, Mehta Y, Higuera F, et al. Device-associated nosocomial infections in 55 intensive care units of 8 developing countries. Ann Intern Med. 2006;145(8):582–91.
10. Rosenthal VD, Guzman S, Crnich C. Device-associated nosocomial infection rates in intensive care units of Argentina. Infect Control Hosp Epidemiol. 2004;25(3):251–5.
11. Ramirez Barba EJ, Rosenthal VD, Higuera F, Oropeza MS, Hernandez HT, Lopez MS, et al. Device-associated nosocomial infection rates in intensive care units in four Mexican public hospitals. Am J Infect Control. 2006;34(4): 244–7.
12. Moreno CA, Rosenthal VD, Olarte N, Gomez WV, Sussmann O, Agudelo JG, et al. Device-associated infection rate and mortality in intensive care units of 9 Colombian hospitals: findings of the International Nosocomial Infection Control Consortium. Infect Control Hosp Epidemiol. 2006;27(4):349–56.
13. Rosenthal VD, Guzman S, Orellano PW. Nosocomial infections in medical-surgical intensive care units in Argentina: attributable mortality and length of stay. Am J Infect Control. 2003;31(5):291–5.
14. Leblebicioglu H, Rosenthal VD, Arikan OA, Ozgultekin A, Yalcin AN, Koksal I, et al. Device-associated hospital-acquired infection rates in Turkish intensive care units. Findings of the International Nosocomial Infection Control Consortium (INICC). J Hosp Infect. 2007; 65(3):251–7.
15. Emori TG, Culver DH, Horan TC, Jarvis WR, White JW, Olson DR, et al. National Nosocomial Infections Surveillance system (NNIS): description of surveillance methods. Am J Infect Control. 1991;19(1):19–35.
16. National Committee for Clinical Laboratory Standards (NCCLS). Approved standard M7–A4: methods for dilution antimicrobial susceptibility tests for bacteria that grow aerobically. 4th ed. Wayne, Pennsylvania: NCCLS; 1997.
17. Maki DG, Weise CE, Sarafin HW. A semiquantitative culture method for identifying intravenous-catheter-related infection. N Engl J Med. 1977;296(23):1305–9.
18. Pittet D, Tarara D, Wenzel RP. Nosocomial bloodstream infection in critically ill patients. Excess length of stay, extra costs, and attributable mortality. JAMA. 1994;271(20):1598–601.
19. Rosenthal VD, Guzman S, Migone O, Safdar N. The attributable cost and length of hospital stay because of nosocomial pneumonia in intensive care units in 3 hospitals in Argentina: a prospective, matched analysis. Am J Infect Control. 2005;33(3):157–61.
20. Rosenthal VD, Guzman S, Migone O, Crnich CJ. The attributable cost, length of hospital stay, and mortality of central line-associated bloodstream infection in intensive care departments in Argentina: a prospective, matched analysis. Am J Infect Control. 2003; 31(8):475–80.
21. Gastmeier P, Geffers C, Brandt C, Zuschneid I, Sohr D, Schwab F, et al. Effectiveness of a nationwide nosocomial infection surveillance system for reducing nosocomial infections. J Hosp Infect. 2006;64(1):16–22.
22. Emori TG, Culver DH, Horan TC, Jarvis WR, White JW, Olson DR, et al. National nosocomial infections surveillance system (NNIS): description of surveillance methods. Am J Infect Control. 1991;19(1):19–35.
23. Mehta A, Rosenthal VD, Mehta Y, Chakravarthy M, Todi SK, Sen N, et al. Device-associated nosocomial infection rates in intensive care units of seven Indian cities. Findings of the International Nosocomial Infection Control Consortium (INICC). J Hosp Infect. 2007;67(2):168–74.
24. Salomao R, Rosenthal VD, Grimberg G, Nouer S, Blecher S, Buchner-Ferreira SI, et al. Device-associated infection rates in intensive care units of three Brazilian hospitals. Rev Panam Salud Publica. Forthcoming 2008.
25. Higuera F, Rangel-Frausto MS, Rosenthal VD, Soto JM, Castanon J, Franco G, et al. Attributable cost and length of stay for patients with central venous catheter-associated bloodstream infection in Mexico City intensive care units: a prospective, matched analysis. Infect Control Hosp Epidemiol. 2007;28(1):31–5.
26. Rosenthal VD, Salomao R, Leblebicioglu H, Akan O, Sobreyra-Oropeza M. Hand hygiene compliance in Argentina, Brazil, Colombia, India, Mexico, Morocco, Peru and Turkey. Findings of the International Nosocomial Infection Control Consortium (INICC). In: Proceedings and Abstracts of the 33rd Annual Scientific Meeting of the Association for Professionals in Infection Control and Epidemiology. 11–15 June 2006; Tampa, Florida, U.S.A.; p. 31.
27. Pittet D. Compliance with hand disinfection and its impact on hospital-acquired infections. J Hosp Infect. 2001;48 (Suppl A):S40–6.
28. Koksal I, Aydin K, Caylan R, Leblebicioglu H, Rosenthal VD. Effect of education and performance feedback on handwashing in a hospital of Trabzon, Turkey. In: Proceedings and Abstracts of the 15th Annual Scientific Meeting of the Society for Healthcare Epidemiology of America; 9–12 April 2005; Los Angeles, California, U.S.A.; p. 90.
29. Safdar N, Maki DG. The commonality of risk factors for nosocomial colonization and infection with antimicrobial-resistant *Staphylococcus aureus*, enterococcus, gram-negative bacilli, *Clostridium difficile*, and *Candida*. Ann Intern Med. 2002;136(11):834–44.
30. Starling CE, Couto BR, Pinheiro SM. Applying the Centers for Disease Control and Prevention and National Nosocomial Surveillance system methods in Brazilian hospitals. Am J Infect Control. 1997;25(4):303–11.
31. Rezende EM, Couto BR, Starling CE, Modena CM. Prevalence of nosocomial infections in general hospitals in Belo Horizonte. Infect Control Hosp Epidemiol. 1998;19(11):872–6.
32. Chandra PN, Milind K. Lapses in measures recommended for preventing hospital-acquired infection. J Hosp Infec. 2001;47(3): 218–22.
33. Hugonnet S, Harbarth S, Sax H, Duncan RA, Pittet D. Nursing resources: a major determinant of nosocomial infection? Curr Opin Infect Dis. 2004;17(4):329–33.
34. O'Grady NP, Alexander M, Dellinger EP, Gerberding JL, Heard SO, Maki DG, et al. Guidelines for the prevention of intravascular catheter-related infections. Am J Infect Control. 2002;30(8):476–89.
35. Boyce JM, Pittet D. Guideline for hand hygiene in health-care settings. Recommendations of the Healthcare Infection Control Practices Advisory Committee and the HICPAC/SHEA/APIC/IDSA Hand Hygiene Task Force. Society for Healthcare Epidemiology of America/Association for Professionals in Infection Control/Infectious Diseases Society of America. MMWR Recomm Rep. 2002;51(RR-16):1–45, quiz CE1–4.
36. Higuera F, Rosenthal VD, Duarte P, Ruiz J, Franco G, Safdar N. The effect of process control on the incidence of central venous catheter-associated bloodstream infections and mortality in intensive care units in Mexico. Crit Care Med. 2005;33(9):2022–7.
37. Rosenthal VD, Guzman S, Safdar N. Reduction in nosocomial infection with improved hand hygiene in intensive care units of a tertiary care hospital in Argentina. Am J Infect Control. 2005;33(7):392–7.
38. Rosenthal VD, Maki DG. Prospective study of the impact of open and closed infusion sys-

tems on rates of central venous catheter-associated bacteremia. Am J Infect Control. 2004;32(3):135–41.
39. Rosenthal VD, Guzman S, Safdar N. Effect of education and performance feedback on rates of catheter-associated urinary tract infection in intensive care units in Argentina. Infect Control Hosp Epidemiol. 2004;25(1): 47–50.
40. Rosenthal VD, McCormick RD, Guzman S, Villamayor C, Orellano PW. Effect of education and performance feedback on handwashing: the benefit of administrative support in Argentinean hospitals. Am J Infect Control. 2003;31(2):85–92.
41. Rosenthal VD, Guzman S, Pezzotto SM, Crnich CJ. Effect of an infection control program using education and performance feedback on rates of intravascular device-associated bloodstream infections in intensive care units in Argentina. Am J Infect Control. 2003;31(7):405–9.
42. Rosenthal VD, Guzman S, Crnich C. Impact of an infection control program on rates of ventilator-associated pneumonia in intensive care units in 2 Argentinean hospitals. Am J Infect Control. 2006;34(2):58–63.

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RESUMEN

Tasas de infección asociadas a aparatos y mortalidad en unidades de cuidados intensivos de hospitales peruanos: datos del Consorcio Internacional para el Control de las Infecciones Nosocomiales

Objetivos. Determinar las tasas de infecciones asociadas a aparatos (IAA), sus perfiles microbiológicos y la resistencia bacteriana, así como la mortalidad atribuible a estas infecciones en unidades de cuidados intensivos (UCI) de hospitales de Perú, miembros del Consorcio Internacional para el Control de las Infecciones Nosocomiales (INICC).

Métodos. Se hizo un seguimiento retrospectivo de cohorte de las IAA en las UCI de cuatro hospitales, según las definiciones de infección nosocomial del Sistema Nacional de Vigilancia de Infecciones Nosocomiales de los Centros para el Control y la Prevención de Enfermedades (CDC-NNIS) y de la Red Nacional de Seguridad Sanitaria (NHSN), de los Estados Unidos de América.

Resultados. De septiembre de 2003 a octubre de 2007, 1 920 pacientes hospitalizados en las UCI, con un total de 9 997 días, adquirieron 249 IAA, para una tasa de 13,0 por paciente (24,9 IAA por 1 000 días-UCI). La tasa de neumonía asociada a respiradores (NAR) fue de 31,3 casos por 1 000 días-ventilador; la tasa de infecciones circulatorias asociadas con cateterismo venoso central (IC-CVC) fue de 7,7 casos por 1 000 días-catéter; y la tasa de infecciones urinarias asociadas con el uso de catéteres (IUAC) fue de 5,1 casos por días-catéter. La mortalidad adicional por NAR fue de 24,5% (RR = 2,07; $P < 0,001$) y por IC-CVC fue de 15,0% (RR = 2,75; $P = 0,028$). De las IAA por *Staphylococcus aureus*, 73,5% se debían a cepas resistentes a la meticilina; de los aislamientos de Enterobacteriaceae, 40,5% eran resistentes a la ceftriaxona, 40,8% a la ceftazidima y 32,0% a la piperacilina-tazobactam. De los aislamientos de *Pseudomonas aeruginosa*, 65,0% eran resistentes a la ciprofloxacina; 62,0% a la ceftazidima; 36,1% al imipenem; y 29,4% a la piperacilina-tazobactam.

Conclusiones. Las elevadas tasas de IAA encontradas en los hospitales peruanos señalan la necesidad de un control activo de las infecciones. Se puede mejorar la seguridad de los pacientes de las UCI y de los hospitales en general mediante programas que abarquen la vigilancia de las IAA y la implementación de directivas para la prevención de infecciones.

Palabras clave Infecciones bacterianas, infección hospitalaria/epidemiología, farmacorresistencia bacteriana, hospitales, control de infecciones, unidades de terapia intensiva, tiempo de internación, mortalidad, Perú.