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ORIGINAL ARTICLE

Multicenter prospective study on device-associated infection rates and bacterial resistance in intensive care units of Venezuela: International Nosocomial Infection Control Consortium (INICC) findings

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Background: Device-associated healthcare-acquired infections (DA-HAI) pose a threat to patient safety in the intensive care unit (ICU).

Methods: A DA-HAI surveillance study was conducted by the International Nosocomial Infection Control Consortium (INICC) in two adult medical/surgical ICUs at two hospitals in Caracas, Venezuela, in different periods from March 2008 to April 2015, using the US Centers for Disease Control and Prevention's National Healthcare Safety Network (CDC/NHSN) definitions and criteria, and INICC methods.

Results: We followed 1041 ICU patients for 4632 bed days. Central line-associated bloodstream infection (CLABSI) rate was 5.1 per 1000 central line days, ventilator-associated pneumonia (VAP) rate was 7.2 per 1000 mechanical ventilator days, and catheter-associated urinary tract infection (CAUTI) rate was 3.9 per 1000 urinary catheter days, all similar to or lower than INICC rates (4.9 [CLABSI]; 16.5 [VAP]; 5.3 [CAUTI]), and higher than CDC/NHSN rates (0.8 [CLABSI]; 1.1 [VAP]; and 1.3 [CAUTI]). Device utilization ratios were higher than INICC and CDC/NHSN rates, except for urinary catheter, which was similar to INICC. Extra length of stay was 8 days for patients with CLABSI, 9.6 for VAP and 5.7 days for CAUTI. Additional crude mortality was 3.0% for CLABSI, 4.4% for VAP, and 16.9% for CAUTI.

Conclusions: DA-HAI rates in our ICUs are higher than CDC/NSHN's and similar to or lower than INICC international rates.

Keywords: Antibiotic resistance, Catheter-associated urinary tract infection, Central line-associated bloodstream infections, Healthcare-associated infection, Hospital infection, Ventilator-associated pneumonia

Introduction

Device-associated healthcare-acquired infections (DA-HAIs) are among the main causes of patient morbidity and mortality, and are responsible for prolonging the length of stay in the intensive care unit (ICU) and excess hospital costs, particularly in developing countries, where rates have been shown to be much higher than in high-income countries.[1,2]

Implementing an integrated infection control program focused on DA-HAI surveillance was shown to be effective in different studies conducted in the US, suggesting that the incidence of DA-HAI can be reduced by as much as 30%.[3]

Similarly, it is essential to address the burden of antimicrobial-resistant infections and report susceptibility to antimicrobials of DA-HAI-associated pathogens, so that informed decisions can be made to effectively prevent transmission of resistant strains and their determinants.[4]

For more than 40 years, the US Centers for Disease Control and Prevention's National Healthcare Safety Network (CDC/NHSN)[5] has provided invaluable benchmarking data on DA-HAIs, which served as an inspiration to the International Nosocomial Infection Control Consortium (INICC).[6]

The INICC is an international non-profit, open, multi-centre, collaborative healthcare-associated infection control network

with a surveillance system based on that of the CDC/NHSN.[7] Founded in Argentina in 1998, INICC is the first multinational surveillance and research network established to measure, control and reduce DA-HAI, and surgical site infections through the analysis of data collected on a voluntary basis by a pool of hospitals worldwide.[6,8,9]

Prospective surveillance is conducted by infection control professionals through an online platform called INICC Surveillance Online System (ISOS), whose effective impact in DA-HAI rates reduction has been shown in several studies.[10–30] The ISOS allows the classification of prospective, active, cohort surveillance data into specific module protocols that apply CDC/NHSN's definitions published in January 2016.[7,8]

This is the first DA-HAI prospective, active surveillance, cohort study to be conducted in Venezuela, which reports a summary of data collected between March 2008 and April 2015 in two ICUs in two hospitals that participate in INICC.[6]

Methods

Background on INICC

INICC is comprised of more than 2000 hospitals in 500 cities of 66 countries in six WHO regions, such as Africa, the Americas, Eastern Mediterranean, Europe, South East Asia, and Western Pacific and has become the only source of aggregate standardized international data on the epidemiology of healthcare-associated infections (HAIs).[6] The INICC is focused on the surveillance and prevention of DA-HAI in adult, pediatric and neonatal ICUs, step down units, inpatient wards, and of surgical site infections in surgical procedures.

Setting and study design

This prospective cohort surveillance study was conducted in two medical/surgical ICUs in two hospitals in the city of Caracas, Venezuela, through the implementation of the INICC multidimensional approach, as described below. Over the study period, there were 8–10 beds at each ICU.

In accordance with the INICC's Charter, the identity of all INICC hospitals and cities is kept confidential.

Institutional Review Boards agreed to the study protocol, and patient confidentiality was protected by codifying the recorded information, making it only identifiable to the infection control team.

INICC multidimensional approach

The INICC multidimensional approach includes the implementation of CDC/NSHN's definitions of HAIs and methodology, but adds the collection of other data essential to increase infection control professionals' sensitivity to detect HAIs, and avoid underreporting.[7] According to standard CDC/NSHN methods, numerators are the number of HAIs of each type, and denominators are device days collected from all patients, as pooled data; that is, without determining the number of device days related to a particular patient, and without collecting features or characteristics per specific patient.[7] This aspect differs from the INICC surveillance system, because the design of the cohort study through the INICC methods also includes collecting specific data per patient from all patients, both those with and those without HAI, collecting risk factors of HAIs, such as invasive devices, and surrogates of HAIs, which include, but are not limited to, high temperature, low blood pressure, results of cultures, antibiotic therapy, length of stay and mortality. By collecting data on all patients in the ICU, it is possible to match patients with and without HAI by several characteristics to estimate extra risk factors, length of stay, mortality and cost.

The INICC multidimensional approach comprises the simultaneous implementation of the following six components for HAI control and prevention: a bundle of interventions, education, outcome surveillance, process surveillance, feedback on HAI rates and consequences, and performance feedback.

Outcome and process surveillance are conducted by means of an online platform called ISOS, which comprises 15 modules: 10 for outcome surveillance and five for process surveillance. The modules of the outcome surveillance and process surveillance components may be used singly or simultaneously, but once selected, they must be used for a minimum of 1 calendar month.

This study presents the results of the cohort surveillance of HAIs in the ICU. The results of the remaining outcome surveillance modules (*Clostridium difficile* infections, antimicrobial consumption, surveillance of needlestick injuries, cohort surveillance of HAIs in inpatient wards and step down units, cohort surveillance of surgical procedures, and surgical site infections) and of the modules for process surveillance, feedback on HAI rates and consequences, and performance feedback were not included in this report, because they will be published in another future study.

Outcome surveillance

Outcome surveillance included cohort surveillance of HAIs in the ICU through the implementation of the ISOS, which allows the classification of prospective, active, cohort data into specific module protocols that apply CDC/NHSN's definitions published in January 2016.[7] The site-specific criteria include reporting instructions and provide full explanations integral to their adequate application.[7]

On the one hand, the ISOS enables infection control professionals to conduct online prospective, active, surveillance cohort studies, because it was designed to collect specific data per patient from all patients, both those with and those without HAI; this allows the prospective identification of risk factors of HAIs, such as age, gender, severity illness score, invasive devices utilization and several surrogates of HAIs, and the validation of HAIs, thereby ensuring that the latest published CDC/NHSN criteria are met in each DA-HAI diagnosis, so as to avoid underreporting and inconsistent selections due to oversight. Cohort outcome surveillance through ISOS continuously prompts the infection control professionals to suspect HAIs, because it provides a panoramic view of what is happening each day to every patient in the ICU in terms of their risk factors. This approach is especially useful in cases in which no cultures have been done or culture results are equivocal or negative (such as clinical pneumonia) and that may not be otherwise recognized as a HAI, or when infection control professionals lack enough experience and thus sensitivity to detect HAIs. Furthermore, by collecting data on all patients, it is possible to easily match patients with and without HAI by characteristics such as age, gender, underlying diseases, service, admission diagnosis, severity-of-illness score, time of year, and several

others, in order to calculate attributable extra length of stay, costs, and mortality, as well as risk factors for HAI.

Data collection and analysis

The infection control professionals at each hospital were responsible for extracting patients' data from medical records, charts, patient inspection, and laboratory results, including radiographs, other imaging tests, and all cultures done.

The infection control professionals collected daily data on DA-HAIs, and denominator data—that is, patient-days and specific device days in the ICUs—from all patients whose stay in the hospital exceeds 24 hours. These data were uploaded to the ISOS and were used to calculate DA-HAI rates per 1000 device days, according to the following formulas: device days consisted in the total number of device days; device utilization ratio (DUR) equals the total number of device days divided by the total number of bed days.

Training

The INICC team trained and provided infection control professionals with manuals, training tools and tutorial movies, which described in detail how to perform surveillance and upload surveillance data through the ISOS. Although there is not a formal competency assessment, the training sessions included assessments to ensure surveillance was conducted appropriately through ISOS. On the other hand, ISOS was designed to prompt the infection control professional in case of inconsistent data or if omissions were detected by the application. In addition, investigators attended webinars, and had continuous access to a support team at the INICC headquarters in Buenos Aires, Argentina.

Statistical analysis

ISOS version 2.0 (Buenos Aires, Argentina), was used to calculate HAI rates, DURs, length of stay and mortality. EpiInfo version 6.04 b (CDC, Atlanta, GA, USA), SPSS 16.0 (SPSS Inc., Chicago, IL, USA), and ISOS version 2.0 (Buenos Aires, Argentina), were used to conduct data analysis. Relative risk (RR) ratios, 95% CIs and p-values were determined for primary and secondary outcomes.

Results

During the study period from 1 March 2008 to 30 April 2015, 1041 adult patients were hospitalized in the two participating medical/surgical ICUs, amounting to 4632 bed days. As each ICU joined the INICC program at different times, the ICUs had different lengths of participation over the whole study period.

The pooled means of the DA-HAI rates were 5.1 (n, 18) CLABSIs per 1000 central line days, during 3563 central line days with a DUR of 0.77 (95% CI, 0.76–0.78); 7.2 (n, 14) VAPs per 1000 mechanical ventilator days, during 1933 mechanical ventilator days, with a DUR of 0.42 (95% CI, 0.40–0.43); and 3.9 (n, 11) CAUTIs per 1000 urinary catheter days, during 2846 urinary catheter days, with a DUR of 0.61 (95% CI, 0.60–0.63.) The most frequent DA-HAI was VAP and the highest DUR was for central line.

Table 1 provides data on crude ICU mortality and length of stay in patients hospitalized in each type of unit during the surveillance period, with and without DA-HAI. The DA-HAI associated with the highest mortality was CAUTI. The DA-HAI associated with the longest length of stay was VAP.

Table 2 compares the results of this report from Venezuela with the INICC international report for the period 2007–2012 and with the US CDC/NHSN report of 2013 and against the US CDC/NHSN report (2009–2010)[4–6] In our ICUs, the rate of VAP was lower than in INICC's report, but higher than CDC/NHSN's report.[5,6] The CLABSI and CAUTI rates in this study were higher than CDC/NHSN's and similar to INICC's rates.[5,6] All DURs in this study were higher than CDC/NHSN's. Similarly, DURs for central line and mechanical ventilator were higher in this study than in the INICC Report, although urinary catheter DUR was similar to INICC's.[5,6] Benchmarking of antimicrobial resistance of *Staphylococcus aureus* to oxacillin was similar to INICC's international report,[6] and higher than in the CDC/NHSN's report.[4]

Table 3 provides data on bacterial resistance of pathogens isolated from patients with DA-HAI in adult ICUs. We found a high resistance of *Staphylococcus aureus* and coagulase-negative staphylococci to oxacillin.

Discussion

There are no previous comprehensive studies of DA-HAI in Venezuela. In 1989, Pitteloud et al. published a study that showed

Table 1. Pooled means of the distribution of crude mortality, and length of stay of adult intensive care unit patients with and without device-associated healthcare-acquired infection

Patients	Patients, n	Deaths, n	Pooled crude mortality, %	LOS, total days	Pooled average LOS, days
Without DA-HAI	1,010	82	8.1	3,835	3.8
With CLABSI	9	1	11.1	106	11.8
With CAUTI	4	1	25	38	9.5
With VAP	8	1	12.5	107	13.4

ICU: intensive care units; DA-HAI: device-associated healthcare-acquired infection; CLABSI: central line-associated bloodstream infection; VAP: ventilator-associated pneumonia; CAUTI: catheter-associated urinary tract infection; LOS: length of stay.

Table 2. Benchmarking of device-associated Healthcare-acquired infection rates and device utilization ratio in this report against the report of the International Nosocomial Infection Control Consortium (2007–2012) and the report of the Centers for Disease Control and Prevention's National Healthcare Safety Network Data (2013)

	This report	INICC report (2007–2012)[6]	US CDC/NHSN report (2013)[5]
Medical surgical ICUs			
CL, DUR	0.77 (0.76–0.78)	0.54 (0.54–0.54)	0.37
CLABSI rate (CLABSIs per 1000 CL-days)	5.1 (3.0–8.0)	4.9 (4.8–5.1)	0.8
MV, DUR	0.42 (0.40–0.43)	0.36 (0.36–0.36)	0.24
VAP rate (VAPs per 1000 MV-days)	7.2 (4.0–12.2)	16.5 (16.1–16.8)	1.1
UC, DUR	0.61 (0.60–0.63)	0.62 (0.62–0.62)	0.54
CAUTI rate (CAUTIs per 1000 UC-days)	3.9 (1.9–6.9)	5.3 (5.2–5.8)	1.3

ICU: intensive care unit; CLABSI: central line-associated bloodstream infection; VAP: ventilator-associated pneumonia; CAUTI: catheter-associated urinary tract infection; DUR: device utilization ratio; CL: central line; MV: mechanical ventilator; UC: urinary catheter; CI: confidence interval; INICC: International Nosocomial Infection Control Consortium; CDC/NSHN: Centers for Disease Control and Prevention's National Healthcare Safety Network of the United States of America.

Table 3. Benchmarking of antimicrobial resistance in this report against the report of the International Nosocomial Infection Control Consortium (2007–2012) and the report of the Centers for Disease Control and Prevention's National Healthcare Safety Network Data (2009–2010)

Antimicrobial resistance % (n)	This report	INICC report (2007–2012)[6]	US CDC/NHSN 2009–2010[4]
Pathogen, antimicrobial	Pooled	CLABSI	CLABSI
Staphylococcus aureus			
Oxacillin	60.0% (5)	61.2% (196)	54.6% (3,611)
Enterococcus faecalis			
Vancomycin	0% (2)	12.2%	9.5%

CLABSI: central line-associated bloodstream infection; INICC: International Nosocomial Infection Control Consortium; CDC/NSHN: Centers for Disease Control and Prevention's National Healthcare Safety Network of the United States of America.

that the incidence of nosocomial infections was 74 per 1000 hospital discharges.[31] Our study is the one conducted in Venezuela with a large number of patients (1041) which applies the CDC/NHSN definitions and criteria to calculate DA-HAI rates per 1000 device days. In the ICUs of our study, DA-HAI rates were higher than the rates found in the CDC/NHSN's data,[5] and similar to the international INICC Report (2007–2012) for 43 countries,[6] except for VAP, which was lower in our study. DURs were higher in this study than in CDC/NHSN and INICC's reports, with the exception of urinary catheter DUR, which was similar to INICC's.[5,6] The antimicrobial resistance rates found in our ICUs for *Staphylococcus aureus* to oxacillin was similar to INICC's international report,[6] and higher than in the CDC/NHSN's report,[4] whereas it was lower for *Enterococcus faecalis* to vancomycin than CDC/NHSN[4] and INICC reports' rates[6], although this could be due to the small sample size of isolated microorganisms in this study.

There are many reasons that can explain these higher DA-HAI rates in Venezuela compared to those in CDC/NHSN's.[5] As it also occurs in other developing countries, adherence to infection control bundles in Venezuela is irregular, nurse-to-patient staffing ratios is low—which has proved to be highly connected to high DA-HAI rates in ICUs—as well as hospital over-crowding, and an insufficient number of experienced nurses or trained healthcare workers.[32]

In order to reduce the hospitalized patients' risk of infection, DA-HAI surveillance is primary and essential, because it effectively describes and addresses the importance and characteristics (risk factors) of DA-HAIs. This must be followed by the implementation of practices aimed at DA-HAI prevention and control. Additionally, participation in INICC has played a fundamental role, not only in increasing the awareness of DA-HAI risks in the ICU, but also providing an exemplary basis for the institution of infection control practices through the use of an online process surveillance tool.

The INICC program is focused on surveillance of DA-HAIs in the ICUs, step down units and general wards, and surveillance of surgical site infections hospital wide. In this particular study, we focused just on the ICUs; that is, healthcare settings with the highest healthcare-acquired rates, in which patients' safety is most seriously threatened, due to their critical condition and

exposure to invasive devices.[32] Through the last 17 years, INICC has undertaken a global effort in America, Asia, Africa, Middle East and Europe to respond to the burden of DA-HAIs, and has achieved extremely successful results, by increasing hand hygiene compliance, improving compliance with other infection control bundles and interventions as described in several INICC publications, and consequently reducing the rates of DA-HAI and mortality.[10–29]

To compare a hospital's DA-HAI rates with the rates identified in this report, it is required that the hospital team concerned collect their data by applying the methods and methodology described for CDC/NHSN and INICC, and then calculate infection rates and DURs for the DA-HAI Module.

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

Study limitations

The first limitation of this study is that its findings did not consider the difference in time periods for the different data sources in the comparisons made with INICC and CDC/NHSN.

Secondly, the calculation of excess length of stay may have been affected by the time-dependent bias. An uncontrolled factor for assessing relative frequencies was the lack of information on competing incidences, which include absolute patient risk. In this study, due to budget constraints, we only show crude length of stay with and without DA-HAI.

Thirdly, there is missing information on competing incidences for assessing relative frequencies, and so the calculation of absolute patient risk was affected. Due to budget constraints, in his study DA-HAI incidence density was just measured by following CDC/NHSN criteria and definitions, where denominators were device days, and numerators were number of DA-HAIs, multiplied by 1000.

Finally, the DA-HAI rates generated must be interpreted with caution when making major inferences, because confidence intervals were relatively wide due to the small sample size in our ICUs.

Conclusions

In conclusion, the data presented in this report support the fact that DA-HAIs in Venezuela are a challenge for patient safety. It is INICC's main goal to enhance infection control practices, by facilitating elemental, feasible and inexpensive tools and resources to tackle this problem effectively and systematically, leading to greater and stricter adherence to infection control programs and guidelines. This should result in a correlated reduction in DA-HAI and its adverse effects, in the hospitals participating in INICC, as well as at any other healthcare facility worldwide.

Authors' contributions: All authors were involved in drafting of the manuscript, provision of study patients, collection of data, critical revision of the manuscript for important intellectual content, and final approval of the manuscript. VDR was responsible for study conception and design; software development; data assembly, analysis, and interpretation; epidemiologic analysis; statistical analysis; administrative, technical, and logistical support. VDR is guarantor of the paper.

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Competing interests: None declared.

Ethical approval: All procedures contributing to this work comply with the ethical standards of the relevant national and institutional committees on human experimentation and with the Helsinki Declaration of 1975, as revised in 2008. The design of the work has been approved by ethical committees of the participating hospitals. Institutional Review Boards agreed to the study protocol, and patient confidentiality was protected by codifying the recorded information, making it only identifiable to the infection control team.

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