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Device-associated infection rates in adult and pediatric intensive care units of hospitals in Egypt. International Nosocomial Infection Control Consortium (INICC) findings

Ossama Rasslan[a], Zeinab Salah Seliem[b], Islam Abdullorziz Ghazi[c], Muhamed Abd El Sabour[a], Amani Ali El Kholy[b], Fatma Mohamed Sadeq[c], Mahmoud Kalil[a], Doaa Abdel-Aziz[b], Hosnia Yousif Sharaf[c], Adel Saeed[a], Hala Agha[b], Sally Abd El-Wadood Zein El-Abdeen[c], Maha El Gafarey[a], Amira El Tantawy[b], Lamia Fouad[a], Mona M. Abel-Haleim[b], Tamer Muhamed[a], Hedya Saeed[a], Victor D. Rosenthal[d,*]

[a] *Ain Shams Faculty of Medicine, Cairo, Egypt*
[b] *Children Hospital Cairo University (Abu-el-Reesh), Cairo, Egypt*
[c] *Benha Children's Hospital, Benha, Egypt*
[d] *International Nosocomial Infection Control Consortium (INICC), Buenos Aires, Argentina*

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Summary
Purpose: To determine the rate of device-associated healthcare-associated infections (DA-HAIs) at a respiratory intensive care unit (RICU) and in the pediatric intensive care units (PICUs) of member hospitals of the International Nosocomial Infection Control Consortium (INICC) in Egypt.
Materials and Methods: A prospective cohort DA-HAI surveillance study was conducted from December 2008 to July 2010 by applying the methodology of the INICC and the definitions of the NHSN-CDC.
Results: In the RICU, 473 patients were hospitalized for 2930 d and acquired 155 DA-HAIs, with an overall rate of 32.8%. There were 52.9 DA-HAIs per 1000 ICU-days. In the PICUs, 143 patients were hospitalized for 1535 d and acquired 35 DA-HAIs, with an overall rate of 24.5%. There were 22.8 DA-HAIs per 1000 ICU-days. The central line-associated blood stream infection (CLABSI) rate was 22.5 per 1000 line-days in the RICU and 18.8 in the PICUs; the ventilator-associated pneumonia (VAP) rate was

* Corresponding author at: Av. Corrientes #4580, Piso 12, Dpto. ''D''. Buenos Aires, ZIP 1195, Argentina. Tel.: +54 11 4861 5826.
E-mail address: victor_rosenthal@inicc.org (V.D. Rosenthal).
URL: http://www.inicc.org (V.D. Rosenthal).

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73.4 per 1000 ventilator-days in the RICU and 31.8 in the PICUs; and the catheter-associated urinary tract infection (CAUTI) rate was 34.2 per 1000 catheter-days in the RICU.
Conclusions: DA-HAIs in the ICUs in Egypt pose greater threats to patient safety than in industrialized countries, and infection control programs, including surveillance and guidelines, must become a priority.

Introduction

In an increasingly large amount of scientific literature, DA-HAIs are considered the principal threat to patient safety in the ICU and are among the main causes of patient morbidity and mortality [1,2].

In industrialized countries, device-associated healthcare-associated infection (DA-HAI) surveillance in the intensive care unit (ICU) plays a substantial role in hospital infection control and quality assurance [3] and was reported by the Centers for Disease Control and Prevention (CDC) study of the efficacy of nosocomial infection control (SENIC) as an efficacious tool to reduce DA-HAIs [4].

The CDC's previous National Nosocomial Infection Surveillance System (NNIS) and current National Healthcare Safety Network (NHSN) have established standardized criteria for DA-HAI surveillance [5,6]. This standardized surveillance method allows for the determination of DA-HAI rates per 1000 device-days, which can be used as benchmarks among healthcare centers, and provides infection control practitioners (ICPs) with an in-depth look at the institutional problems they are confronted with so they can design an effective strategy to solve them.

However, in the context of an expanded framework for DA-HAI control, most of the relevant studies of ICU-acquired infections have been carried out in industrialized countries [7]. In developing countries, in contrast, few published studies have reported DA-HAI rates using standardized definitions [8—15].

The International Nosocomial Infection Control Consortium (INICC) was founded in 1998, when selected hospitals from Latin America were invited to participate in the project to measure DA-HAIs using standardized definitions and methodology [16]. Subsequently, other hospitals from different parts of the world joined the INICC. Currently, the INICC comprises a worldwide network of 300 hospitals from 40 countries in Latin America, Asia, Africa and Europe [12].

On a monthly basis, healthcare facilities send data to the INICC, which are then entered into an international database. Member hospitals of the INICC provide general medical and surgical inpatient services to adults and children hospitalized in ICUs.

The findings of this study on Egypt DA-HAI rates form an integral part of the INICC and reflect the outcome and process surveillance data that were systematically collected.

Methods

Setting

The study was carried out in 3 ICUs in three hospitals in two cities in Egypt from December 2008 to July 2010. Each hospital had an infection control team (ICT) with a physician, an infection control practitioner (ICP) with at least one year of experience in infection control (Table 1) and a microbiology laboratory to perform in vitro susceptibility testing of clinical isolates using standardized methods. Every hospital's institutional review board agreed to the study protocol. Patient confidentiality was protected by codifying the recorded information, making it identifiable only to the ICT.

INICC methodology

The INICC surveillance program includes two components: outcome surveillance (DA-HAI rates and their adverse effects) and process surveillance (adherence to hand hygiene and other basic preventive infection control practices) [16].

Investigators were required to complete outcome and process surveillance forms at their hospitals, which were then sent to the INICC headquarters office in Buenos Aires for their monthly analysis.

Table 1 Features of the International Nosocomial Infection Control Consortium hospitals and intensive care units.

Variable	Hospital A	Hospital B	Hospital C	Overall
Hospitals, *n* (%)	1	1	1	3
Academic teaching	1	0	1	2 (66%)
Public	0	1	0	1 (33%)
Private community	0	0	0	0
Hospital number of beds	400	150	1000	400—1000
ICUs, *n*	1	1	1	3
ICU type	PICU	PICU	RICU	PICU & RICU
Surveillance period	04/2009—09/2009	06/2010—07/2010	12/2008—12/2009	12/2008—07/2010
Range of experience of the infection control practitioner, *y*	1	3	2	1—3
Patients studied, *n*	119	24	473	616
Total ICU days, d	1274	261	2930	6000
Device use[a]				
Ventilator days, d	510	57	1077	1644
Ventilator use	0.40	0.22	0.37	0.27
Central line days, d	794	112	1021	1927
Central line use	0.62	0.43	0.35	0.32
Urinary catheter days, d	466	67	1551	2084
Urinary catheter use	0.37	0.26	0.53	0.35

ICU, intensive care unit; RICU, respiratory intensive care unit; PICU, pediatric intensive care unit; d, days.

[a] Device utilization (DU): 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 were in the ICU during the selected time period.

Outcome surveillance

The INICC surveillance program applies methods and definitions for healthcare-associated infections (HAIs) developed by the U.S. Centers for Disease Control and Prevention (CDC) for the NNIS/NHSN program [6,17]; however, the INICC methods have been adapted to the setting of developing countries due to their different socioeconomic status and specific resource limitations [16].

Outcome surveillance includes the rates of CLAB, ventilator-associated pneumonia (VAP) and catheter-associated urinary tract infection (CAUTI) per 1000 device-days, the microorganism profile, and the length of stay and mortality in ICUs.

Process surveillance

The infection control and prevention strategies implemented in INICC member hospitals are based on inexpensive and basic evidence-based measures, including outcome surveillance, process surveillance, education and performance feedback on outcome surveillance and process surveillance [18—21].

Process surveillance was designed to assess compliance with easily measurable key infection control practices, such as surveillance of compliance rates for hand hygiene practices and specific measures for the prevention of CLAB, CAUTI and VAP [16]. Hand hygiene compliance by healthcare workers (HCWs), based on the frequency with which hand hygiene is performed when clearly indicated, is monitored by the ICP during randomly selected 1-h observation periods three times per week. Although HCWs are aware that hand hygiene practices are regularly monitored, they are not informed of the schedule for hand hygiene observations. Central line (CL) care compliance is also monitored and recorded five days per week through the completion of surveillance forms that evaluate whether infection control procedures were correctly carried out by the HCWs [16].

Definition of device-associated healthcare-associated infections

Ventilator-associated pneumonia (VAP). Ventilator-associated pneumonia is indicated in a mechanically ventilated patient with a chest radiograph showing 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; organism cultured from blood; or isolation of an etiologic agent from a specimen

obtained by tracheal aspirate, bronchial brushing or bronchoalveolar lavage, or biopsy [6].

Central line-associated laboratory-confirmed bloodstream infection (LCBI). A 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 h of vascular catheterization and is not related to an infection at another site. The patient should also have at least one of the following signs or symptoms: fever (temperature $\geq 38\,^{\circ}C$), 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 [6].

Clinical sepsis. A central line-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 $\geq 38\,^{\circ}C$), hypotension (systolic blood pressure ≤ 90 mmHg), or oliguria ($\leq$20 mL/h) [6].

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 $\geq 38\,^{\circ}C$), urgency, or suprapubic tenderness. The urine culture should be positive for 10^5 colony-forming units (CFUs)/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 ($\geq$10 leukocytes/mL) [6].

Culture techniques

Central line-associated bloodstream infection (CLABSI). Central lines were removed aseptically, and the distal 5 cm of the catheter was cut and cultured using a standardized semi-quantitative method [22]. Concomitant blood cultures were drawn percutaneously in all cases.

Ventilator-associated pneumonia (VAP). A deep tracheal aspirate from the endotracheal tube was cultured non-quantitatively and aerobically and gram stained.

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

In all cases, standard laboratory methods were used to identify microorganisms, and a standardized susceptibility test was performed [23].

Device-associated healthcare-associated infection rate calculation

Outcomes measured during the surveillance period included the incidence density rate of CLABSIs (number of cases per 1000 central line-days), CAUTIs (number of cases per 1000 urinary catheter-days) and VAP (number of cases per 1000 mechanical ventilator-days).

DA-HAI rates of VAP, CLABSIs, and CAUTIs per 1000 device-days were calculated by dividing the total number of DA-HAIs by the total number of specific device-days and multiplying the result by 1000 [17].

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 were in the ICU during the selected time period [17].

Statistical analysis

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

Baseline differences among rates were analyzed using the chi-square test for dichotomous variables and a *t*-test for continuous variables. Relative risk (RR) ratios, 95% confidence intervals (CIs) and *P*-values were determined for all outcomes.

Results

Features of the population studied

We recorded 473 patients hospitalized for 2930 days in the RICU. These patients acquired 155 DA-HAIs, with an overall rate of 32.8% (95% CI 28.5—37.2), and 52.9 (95% CI 45.1—61.7) DA-HAIs per 1000 ICU-days. In the PICUs, we recorded 143 patients hospitalized for 1533 days. These patients acquired 35 DA-HAIs, with an overall rate of 24.5% (95% CI 17.7—32.4), and 22.8 (95% CI 15.9—31.6) DA-HAIs per 1000 ICU-days.

CLABSIs represented 20% of all HAIs, VAP represented 52%, and CAUTIs represented 28%. The

Table 2 Device-associated healthcare-associated infections per 1000 device-days: ventilator-associated pneumonia, central line-associated blood stream infection, and catheter-associated urinary tract infection in the pediatric and respiratory intensive care unit.

Type of ICU	Infection site	Device type	Device-days	DA-HAI	Distribution of DA-HAIs (%)	Rate per 100 patients (%)	Rate per 1000 device-days
PICU	VAP	MV	567	18	51.4	12.6	31.7 (95% CI 19.9—49.8)
PICU	CLABSI	CL	906	15	48.6	11.9	18.8 (95% CI 10.9—29.9)
PICU	CAUTI	UC	533	0	0.0	0.0	0.0
RICU	VAP	MV	1077	79	51%	16.7	73.4 (95% CI 58.5—90.6)
RICU	CLABSI	CL	1021	23	15%	4.9	22.5 (95% CI 14.3—33.6)
RICU	CAUTI	UC	1551	53	34%	11.2	34.2 (95% CI 25.7—44.5)

VAP, ventilator-associated pneumonia; CLABSI, central line-associated blood stream infection; CAUTI, catheter-associated urinary tract infection; RICU, respiratory intensive care unit; PICU, pediatric intensive care unit; ICU, intensive care unit; DA-HAI, device-associated healthcare-associated infection; MV, mechanical ventilator; UC, urinary catheter; CL, central line.

individual characteristics of each ICU, the number of patients enrolled in the study, and the number of ICU-days are shown in Table 1. PICUs collected and sent original data to INICC headquarters, and the RICU collected and sent aggregated data to the INICC.

Device utilization (DU) ratio

In the RICU, the device utilization ratio was 0.37 for mechanical ventilation, 0.35 for CLs, and 0.53 for urinary catheters. In the PICUs, the device utilization ratio was 0.37 for mechanical ventilation, 0.59 for CLs, and 0.35 for urinary catheters. Device utilization is shown in Table 1.

Hand hygiene compliance

The total number of HH opportunities observed in the PICUs was 140. The HH compliance rate was 47.1% (95% CI 38.7—55.8).

Device-associated infection (DAI) rates

VAP

The VAP rate was 31.8 (95% CI 19.9—49.8) per 1000 MV-days in the PICUs and 73.4 (95% CI 58.5—90.6) in the RICU, with an overall rate in the 3 ICUs of 59.0 (95% CI 48.1—71.5) (Table 2).

Cultures were performed for VAP patients, and 87.2% showed growth. *Klebsiella* and methicillin-resistant *Staphylococcus aureus* (MRSA) were the most common microorganisms associated with VAP, followed by *Pseudomonas aeruginosa*.

CLABSI

The CLABSI rate was 18.8 per 1000 CL-days (95% CI 10.9—29.9) in the PICUs and 22.5 (95% CI 14.3—33.6) in the RICU, with an overall rate in the 3 ICUs of 20.8 (95% CI 14.8—28.2) (Table 2).

CAUTI

The CAUTI rate per 1000 UC-days was 0.0 in the PICUs and 34.2 (95% CI 25.7—44.5) in the RICU, with an overall rate in the 3 ICUs of 25.4 (95% CI 19.7—33.2) (Table 2).

Discussion

Although DA-HAIs have been a primary and serious cause of patient morbidity and attributable mortality in developing countries [9—11,13,14,24—27], this is the first multi-center study to show DA-HAI rates in selected ICUs in Egypt. Furthermore, DA-HAIs have also been considered to increase healthcare costs [9,10]. Several research studies conducted in the US have indicated that the incidence of DA-HAIs can be reduced by as much as 30%, which would result in accompanying decreased healthcare costs. It is noteworthy that the studies carried out in the US hospitals consisted of infection control programs that included targeted device-associated surveillance [4].

The CLABSI rate in our PICUs was 18.8 (95% CI 10.9—29.9) per 1000 CL-days, which is higher than the INICC report's rate (7.8 per 1000 CL days [95% CI 7.1—8.5]) and the NHSN rate (3.1, 95% CI 2.5—3.8). The CLABSI rate in the respiratory ICU was 22.5 (95% CI 14.3—33.6), which is higher than the rate of 7.4 in INICC medical-surgical ICUs (95% CI 7.2—7.7) and much higher than the NHSN rate of 1.5 (95% CI 1.4—1.6). In a previous study in a pediatric ICU in Saudi Arabia, the rate was 20.06 per 1000 central line-days, which is similar to our rate of 18.8 [28].

The VAP rate in our PICUs was 31.7 (95% CI 19.9—49.8) per 1000 MV-days, which is higher than the INICC report's rate (5.5 per 1000 MV-days [95% CI 4.9—6.0]) and the NHSN rate (1.8 [95% CI 1.6—2.1]) [3,12]. The VAP rate in the respiratory ICUs was 73.4 (95% CI 58.5—90.6), which is higher than the INICC overall rate of 14.7 (95% CI 14.2—15.2) and the NHSN rate of 1.9 (95% CI 1.8—2.1). In a study performed in an adult ICU in Kuwait, VAP was the most common infection at 9.1 per 1000 ventilator-days, which is lower than the results in this study [29]. The CAUTI rate was 34.2 per 1000 catheter-days (95% CI 25.7—44.5) in the respiratory ICU, which was also higher than the INICC report's rate (6.1 per 1000 catheter-days [95% CI 5.9—6.4]) and the NHSN rate (3.4 [95% CI 3.3—3.6]) [3,12]. However, in another study performed in Egypt, the CAUTI rate was 15.7 per 1000 catheter-days (95% CI 13.4—18.3), which is lower than the results found in this study [30].

The overall hand hygiene compliance rate was lower in the PICUs included in this study than in the overall INICC PICUs (47.1% [95% CI 38.7—55.8] vs. 58.6% [95% CI 56.3—60.7], respectively) [27].

The DA-HAI rates shown in this study can be explained by several factors. In Egypt, guidelines on specific infection control practices are not adequately adhered to, national infection control surveillance is not conducted, and hospital accreditation is not mandatory. Similarly, in accordance with the explanations suggested in previous studies conducted in hospitals in developing countries, there is an absence of legal regulations regarding the implementation of infection control programs in most of these countries [31]. Administrative and financial support is lacking, which almost inevitably results in limited funds and resource availability to address infection control. Additionally, it is almost certain that the low nurse-to-patient staffing ratios result in substantially high healthcare-associated infection rates. In these hospitals, insufficient supplies, over-crowded wards and antiquated technology are also among the primary factors that can explain high DA-HAI rates.

The institution of DA-HAI surveillance is the first step to reduce and systematically prevent DA-HAI risk in ICU-hospitalized patients [4]. Next, infection control practices need to be adopted to improve the prevention of DA-HAIs. Needless to say, shared knowledge and accurate information on the burden posed by device-associated infections in these hospital ICUs can serve to foster the implementation of effective infection control strategies in developing countries [32]. In this regard, there is evidence suggesting positive results in healthcare worker performances. It has been shown in different studies from member hospitals of the INICC that hand hygiene compliance and CL, urinary catheter and ventilator care have improved considerably through the implementation of the INICC surveillance program, including performance feedback for healthcare practices in the ICU, leading to a substantial reduction in the incidence of CLABSIs [19,24,33,34], CAUTIs [21,35] and VAP [18,36—38].

This study had many limitations. First, the data reported cannot be generalized for the entire population in Egypt. From December 2008 to July 2010, data from three ICUs in Egypt were recorded within the comprehensive surveillance system of the INICC. A major limitation lies in the possibility that the determined rates may have been affected by slight variations in the efficacy of surveillance and resource availability for the three hospitals. Similarly, the laboratories involved may have widely varying levels of expertise and resource availability. In this study, we only had microorganism data from VAP infections. However, this is a common feature that is present in any surveillance study that involves different healthcare facilities. Additionally, the hospitals enrolled in this study initiated the surveillance program at different periods, and therefore, data were not simultaneously collected from the participating ICUs. Finally, severity illness scores, such as APACHE, were not applied because of the lack of resources to calculate more labor-intensive scores.

Conclusions

DA-HAIs present a serious and largely under-recognized threat to patient safety in developing countries, which needs to be faced immediately. The INICC program provides health care personnel with simple but effective and inexpensive preventive strategies, which have proved successful in different studies [18,19,21,24,33—38].

The INICC network was established to address the urgent need of developing countries to significantly prevent, control and reduce DA-HAIs and their adverse consequences. We aim to encourage wider adherence to infection control programs in all INICC member hospitals, which will result in accompanying and significant DA-HAI reductions, particularly in the ICU setting. Similar to these hospitals in Egypt, any hospital worldwide is invited to join the INICC program, through which infection control teams are furnished with training, tools and basic methods to conduct outcome and process surveillance. Moreover, through the publication of

these confidentially collected data, the scientific evidence-based literature is advanced, which also contributes to effectively and systematically tackling this problem.

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Conflict of interest

None declared.

Ethical approval

Every hospital's Institutional Review Board agreed to the study protocol, and patient confidentiality was protected by codifying the recorded information, making it identifiable only to the ICT.

Author contributions

Idea, conception and design: Victor D. Rosenthal; software development: Victor D. Rosenthal; assembly of data: Victor D. Rosenthal; analysis and interpretation of the data: Victor D. Rosenthal; epidemiological analysis: Victor D. Rosenthal; statistical analysis: Victor D. Rosenthal; administrative, technical, and logistic support: Victor D. Rosenthal; drafting of the article: Victor D. Rosenthal; critical revision of the article for important intellectual content: all byline authors; final approval of the article: all byline authors; provision of study patients: all byline authors; collection of data: all byline authors; funding: Victor D. Rosenthal and the Foundation to Fight against Nosocomial Infections, which funds all of the activities at INICC headquarters.

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