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CLINICAL AND EPIDEMIOLOGICAL STUDY

Impact of a multidimensional infection control strategy on catheter-associated urinary tract infection rates in the adult intensive care units of 15 developing countries: findings of the International Nosocomial Infection Control Consortium (INICC)

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Abstract
Purpose We aimed to evaluate the impact of a multidimensional infection control strategy for the reduction of the incidence of catheter-associated urinary tract infection (CAUTI) in patients hospitalized in adult intensive care units (AICUs) of hospitals which are members of the International Nosocomial Infection Control Consortium (INICC), from 40 cities of 15 developing countries: Argentina, Brazil, China, Colombia, Costa Rica, Cuba, India, Lebanon, Macedonia, Mexico, Morocco, Panama, Peru, Philippines, and Turkey.
Methods We conducted a prospective before–after surveillance study of CAUTI rates on 56,429 patients hospitalized in 57 AICUs, during 360,667 bed-days. The study was divided into the baseline period (Phase 1) and

Members of the INICC are given in the "Appendix".

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the intervention period (Phase 2). In Phase 1, active surveillance was performed. In Phase 2, we implemented a multidimensional infection control approach that included: (1) a bundle of preventive measures, (2) education, (3) outcome surveillance, (4) process surveillance, (5) feedback of CAUTI rates, and (6) feedback of performance. The rates of CAUTI obtained in Phase 1 were compared with the rates obtained in Phase 2, after interventions were implemented.

Results We recorded 253,122 urinary catheter (UC)-days: 30,390 in Phase 1 and 222,732 in Phase 2. In Phase 1, before the intervention, the CAUTI rate was 7.86 per 1,000 UC-days, and in Phase 2, after intervention, the rate of CAUTI decreased to 4.95 per 1,000 UC-days [relative risk (RR) 0.63 (95 % confidence interval [CI] 0.55–0.72)], showing a 37 % rate reduction.

Conclusions Our study showed that the implementation of a multidimensional infection control strategy is associated with a significant reduction in the CAUTI rate in AICUs from developing countries.

Keywords Health care-acquired infection · Device-associated infection · Catheter-associated urinary tract infection · Developing countries · Intensive care unit · Hand hygiene

Introduction

Catheter-associated urinary tract infections (CAUTIs) have been described in numerous studies as being among the most common device-associated health care-associated infections (DA-HAIs) occurring in the intensive care unit (ICU), and have been related to prolonged hospital length of stay, bacterial resistance, morbidity, and increased health care costs [1]. Recent studies have shown divergence regarding its association with extra mortality, and in many of them, such association results from confounding by unmeasured variables [2].

Different prevention programs, which include the accurate measure of infection risks and surveillance of DA-HAI rates and of infection control practices, have been implemented in the ICUs of high-income countries to reduce CAUTI rates [3]. By contrast, such infection control approaches have only occasionally been assessed in the ICUs of the developing world [4].

In 2002, the International Nosocomial Infection Control Consortium (INICC) designed an integral outcome and process surveillance program for ICUs in developing countries [5]. The INICC multidimensional program for CAUTI prevention is based on the guidelines published by the Society for Healthcare Epidemiology of America (SHEA) and the Infectious Diseases Society of America

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(IDSA), as modified by Lo et al. [6]. The recommendations set forth for CAUTI prevention in these guidelines are classified into categories according to scientific evidence, their applicability, and their economic effects [6].

The data reported from INICC hospitals revealed that DA-HAI rates in the ICUs of limited-resource countries are 3–5 times higher than rates in the ICUs of high-income countries [7–9]. To countervail the burden posed by the high CAUTI rates in our adult intensive care units (AICUs), we implemented a multidimensional infection control strategy in 57 AICUs of 15 developing countries from April 1999 to February 2011. Our approach included a bundle of interventions for CAUTI prevention, education, outcome surveillance, process surveillance, feedback of CAUTI rates, and performance feedback of infection control practices.

In this study, we analyzed of the impact of our multidimensional strategy on CAUTI rates in the AICUs of developing countries.

Methods

Setting and study design

This before–after, prospective cohort study was conducted in 57 AICUs in 43 hospitals which are members of the INICC in the following 15 countries: Argentina, Brazil, China, Colombia, Costa Rica, Cuba, India, Lebanon, Macedonia, Mexico, Morocco, Panama, Peru, Philippines, and Turkey. Each hospital had been actively participating in the INICC Surveillance Program for a minimum of 4 months, with an infection control team (ICT) comprised of at least one medical doctor with formal education and background in internal medicine, infectious diseases, and/or hospital epidemiology, and infection control professionals (ICPs). The study period was from April 1999 to February 2011, and was divided into two phases: Phase 1 (baseline period) and Phase 2 (intervention period). The Institutional Review Board at each hospital approved the study protocol. Other hospital and AICU characteristics are summarized in Table 1.

INICC methodology

The INICC Surveillance Program includes two components: outcome surveillance (DA-HAI rates and their

Table 1 Characteristics of hospitals and intensive care units participating in the study from April 1999 to February 2011

Data	ICUs, *n*	ICU patients, *n*
Country		
Argentina	5	8,427
Brazil	4	2,147
China	4	789
Colombia	6	6,064
Costa Rica	2	280
Cuba	1	1,076
India	12	22,179
Lebanon	1	1,139
Macedonia	1	2,435
Mexico	2	434
Morocco	1	3,107
Panama	1	394
Peru	2	1,351
Philippines	3	2,400
Turkey	12	4,207
Type of ICU, *n*		
Cardiac care	5	5,060
Cardio-surgical ICU	1	2,435
Medical ICU	4	3,135
Medical-surgical ICU	34	34,092
Neuro-surgical ICU	2	2,553
Neurological ICU	1	116
Respiratory ICU	2	383
Surgical ICU	6	4,712
Trauma ICU	1	1,927
Ward	1	2,012
Type of hospital, *n* (%)		
Academic teaching	21 (49 %)	20,521
Public hospital	10 (23 %)	13,613
Private community	12 (28 %)	22,295

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adverse consequences, including mortality rates) and process surveillance (adherence to hand hygiene and other basic preventive infection control practices) [5].

Training, validation, and reporting

The INICC Chairman trained investigators at hospitals from Argentina, Colombia, India, Mexico, and Turkey. In the remaining countries, investigators were self-trained by means of manuals that described how to perform surveillance. Investigators have continuous e-mail and telephone access to a support team at the INICC Central Office in Buenos Aires, Argentina, and the INICC Chairman further reviews all queries and responses.

Each month, investigators submit the completed forms to the INICC Central Office, where the validity of each case is checked and the recorded signs and symptoms of infection and the results of laboratory and radiographic studies and cultures are scrutinized to assure that the Centers for Disease Control and Prevention/National Healthcare Safety Network (CDC/NHSN) criteria for DA-HAIs were fulfilled. The forms for the surveillance of each AICU patient permit both internal and external validation, because they include every clinical and microbiological criterion for each type of DA-HAI. The ICT member who reviews the forms filled in at the AICU can verify that the criteria for infection were fulfilled adequately in each case. Moreover, the original patient data form can be further validated at the INICC Central Office before data on the reported infection are entered into the INICC's database.

Intervention period (Phase 2)

The intervention period was initiated after 4 months of participation in the INICC Surveillance Program. The average length of the intervention period was 22.9 months ± standard deviation (SD) 20.85 (range 4–107). The INICC multidimensional infection control approach includes the following: (1) bundle of infection control interventions, (2) education, (3) outcome surveillance, (4) process surveillance, (5) feedback of CAUTI rates, and (6) performance feedback of infection control practices.

Components of the practice bundle to prevent CAUTI

The bundle consisted of the following interventions:

1. Education and training on insertion, care, maintenance, alternatives to indwelling catheters, procedures for catheter insertion, management, insertion, and removal.
2. Insertion of urinary catheters (UCs) only when needed and removal when not necessary.
3. Use of indwelling UCs for perioperative and for selected surgical procedures; urine output monitoring in critically ill patients; management of acute urinary retention and urinary obstruction; assistance in pressure ulcer healing for incontinent residents.
4. To consider other methods for management, including condom catheters or in-and-out catheterization, when appropriate.
5. Hand hygiene before insertion and manipulation of UCs.
6. To use as small a UC as possible.
7. Use of gloves, a drape, and sponges; a sterile or antiseptic solution for cleaning the urethral meatus; and a single-use packet of sterile lubricant jelly for insertion.
8. Use of aseptic technique and sterile equipment for UC insertion.
9. Appropriate management of indwelling catheters: to properly secure indwelling catheters to prevent movement; to maintain a sterile, continuously closed drainage system; not to disconnect the catheter and drainage tube; to replace the collecting system by use of aseptic technique and after disinfecting the catheter tubing junction when breaks in aseptic technique, disconnection, or leakage occur.
10. To maintain unobstructed urine flow.
11. To keep the collecting bag below the level of the bladder at all times.
12. To empty the collecting bag regularly; and to avoid allowing the draining spigot to touch the collecting container.
13. Cleaning of the meatal area as part of routine hygiene.
14. Surveillance of CAUTI; using standardized criteria to identify patients with CAUTIs; to collect catheter-days as the denominator.

These components were based on the practical recommendations for acute care hospitals published by the SHEA and IDSA, as modified by Lo et al. [6].

Outcome surveillance

For outcome surveillance of DA-HAI, we applied the definitions provided by the CDC/NHSN program [10]. Outcome surveillance included rates of CAUTI per 1,000 UC-days, microorganism profile, bacterial resistance, length of stay, and mortality in their ICUs.

Process surveillance

Process surveillance was designed to assess compliance with easily measurable key infection control practices, hand hygiene compliance, and monitoring of UC care [5].

Hand hygiene compliance

Hand hygiene compliance by HCWs is determined by measuring the frequency of which hand hygiene is performed when clearly indicated by guidelines. Hand hygiene practices are monitored by the ICP during randomly selected 1-h observation periods, three times a week. Although HCWs know that hand hygiene practices are regularly monitored, they are not aware of the precise moment at which observations are taking place [5].

Contacts are monitored through direct observation by the ICPs, who record hand hygiene opportunities and compliance before patient contact on a form specifically designed for the study. INICC direct observation comprises the "Five Moments for Hand Hygiene", as recommended by the World Health Organization (WHO) [11].

Urinary catheter care monitoring

UC care compliance is monitored once a day, every day. The observer supervises and records how infection control procedures were performed by HCWs; that is, UC on thigh without strangulating, and UC with collecting bag hanging, and not allowing urine reflux. The forms include information such as date, number of inserted catheters, number of catheters over thigh, and number of bags hanging. The observer checks if the urine collecting bag is hanging on the side of the patient, on the contaminated floor, or elsewhere allowing the reflux, and if the catheter is placed on or under the patient's thigh. HCWs know that their practices are regularly supervised, but they are not aware of the precise moment at which observations are taking place [5].

Performance feedback

Upon processing hospitals' surveillance data on a monthly basis, the INICC Research Team in Buenos Aires prepares and sends to each ICT a report on the results of outcome surveillance; that is, monthly DA-HAI rates, length of stay, bacterial profile and resistance, and mortality, as well as process surveillance rates, including compliance with hand hygiene and UC care [5].

Performance feedback of hand hygiene shows HCWs the proportion of compliance with hand hygiene for all opportunities of hand hygiene that were observed; performance feedback of UC care shows HCWs the proportion of compliance with the monitored practices, such as position of the collecting bag to avoid obstructions of urine flow, or its reflux or contamination if lying on the floor.

Definition of catheter-associated urinary tract infection

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

Statistical methods

Patients' characteristics during baseline and during the last 3 months of the intervention period in each AICU were compared using Fisher's exact test for dichotomous variables and unmatched Student's *t*-test for continuous variables. Relative risk (RR) ratios with 95 % confidence intervals (CIs) were calculated for comparisons of rates of CAUTI using Epi Info V6. *P*-values <0.05 by two-sided tests were considered to be significant.

Results

Over the whole study period, we registered 56,429 patients, hospitalized for 360,667 days in 57 AICUs, for a total of 253,122 UC-days.

The participating hospitals were summarized and classified according to number of AICUs, type of ICU, type of hospital, and country. All participating hospitals are from developing economies (Table 1).

The first AICUs to participate in the study began collecting data in April 1999, and the latest data included in this analysis are from February 2011 (Table 1).

Some patients' characteristics, such underlying diseases and previous infection, were similar during baseline and intervention phases. As regards to gender, in Phase 2, we observed an increase in the proportion of females (from 38 to 41 %). Similarly, we observed an increase in Phase 2 as to the patients' mean age (from 56.1 to 57.2 years, $P = 0.0001$) (Table 2).

In relation to infection prevention and control practices, in Phase 2, we found that hand hygiene compliance improved significantly from 55.3 to 66.6 %. Similarly, the compliance rate with UC care measures—that is, UC on thigh without strangulating, and UC with collecting bag hanging, and not allowing urine reflux—rose to 97 % for both measures. We also observed a reduction in the average duration of UC (from 4.89 $\pm$ 9.16 to 4.44 $\pm$ 9.02, $P = 0.0001$), which is associated to the reduction in the CAUTI rate and reinforces the effectiveness of implemented interventions (Table 2).

Table 2 Characteristics of patients, hand hygiene and urinary catheter care improvement, and catheter-associated urinary tract infection rates in patients hospitalized in adult intensive care units in Phase 1 (baseline period) and Phase 2 (intervention period)

	Phase 1	Phase 2	RR	95 % CI	*P*-value
Patients' characteristics					
No. of patients	6,212	50,217	–	–	–
Study period by hospital in months, mean ± SD (range)	4	22.9 ± 20.85 (range 4–107)	–	–	–
ASIS score mean ± SD	2.97 ± 1.15	2.98 ± 1.1	–	–	0.881
Sex, *n* (%)					
Male	3,864 (62)	29,550 (59)	0.95	0.91–0.98	0.0011
Female	2,312 (38)	20,606 (41)			
Age, mean ± SD	56.1 ± 19.0	57.2 ± 19.9	–	–	0.0001
Stroke, *n* (%)	130 (2)	1,137 (2)	1.08	0.90–1.30	0.3949
Hand hygiene improvement[a]					
No. of hand hygiene observations	9,773	64,163			
Hand hygiene compliance % (*n*)	55.3 % (5,407)	66.6 % (42,755)	1.20	1.17–1.24	0.0001
UC care					
No. of inserted UCs	15,179	128,956			
Average duration of UC ± SD	4.89 ± 9.16	4.44 ± 9.02	–	–	0.0001
No. (%) of UCs on thigh without strangulating	13,372 (88 %)	124,933 (97 %)	1.10	1.08–1.12	0.0001
No. (%) of UCs with collecting bag hanging, not allowing urine reflux	1,356 (90 %)	125,197 (97 %)	1.08	1.06–1.10	0.0001
CAUTI					
No. of CAUTIs	239	1103	–	–	–
No. of UC-days	30,390	222,732	–	–	–
UC use, mean	0.72	0.70	–	–	0.6261
CAUTI rate per 1,000 UC-days	7.86	4.95	0.63	0.55–0.72	0.0001

UC urinary catheter, *CAUTI* catheter-associated urinary tract infection, *RR* relative risk, *CI* confidence interval, *SD* standard deviation

UC use ratio: UC use ratios were calculated by dividing the total number of UC-days by the total number of patient-days. UC-days: the total number of days of exposure to UCs by all of the patients in the selected population during the selected time period. Patient-days: the total number of days that patients are in the ICU during the selected time period

[a] For hand hygiene, relative risk rather than rate ratios are calculated

Regarding CAUTI rates, in Phase 1 (baseline period), we recorded 239 CAUTIs, for an overall baseline rate of 7.86 CAUTIs per 1,000 UC-days. During Phase 1, there were 30,390 documented UC-days, for a UC use mean of 0.72.

In Phase 2, there were 222,732 UC-days, for a UC use mean of 0.70. After the implementation of the INICC multidimensional infection control approach, we recorded 1,103 CAUTIs, for an incidence density of 4.95 per 1,000 UC-days.

These results showed a CAUTI rate reduction from baseline of 37 % (7.86–4.95 CAUTIs per 1,000 UC-days; RR 0.63, 95 % CI 0.55–0.72, $P = 0.0001$) (Table 2).

The microorganism profile shows that *Candida* spp. (30 %) was the leading isolated uropathogen, with almost no variation in its frequency in both periods (Phases 1 and 2). It was followed by *Escherichia coli* (21 %) and *Pseudomonas* spp. (13 %), which did not significantly vary over the whole study period (Table 3).

Discussion

The analysis on our baseline data showed a high incidence density of CAUTI in our AICUs, which was reduced by 37 % after adopting the multidimensional strategy.

The participating AICUs are from countries with low and middle–low socio-economic levels. Only 23 % were from public hospitals. It has been reported that high DA-HAI rates are factors implied in public hospitals due to their limited financial resources and insufficient ICU staff when compared with other types of hospitals in developing countries [12]. Therefore, the type of hospital was not considered to be a factor that could explain the high CAUTI incidence in our AICUs.

Some patients' characteristics remained similar during the whole study period; however, we observed that, in Phase 2, the proportion of females rose, and there was an increase in the patients' age mean. This difference in patient

Table 3 Microorganisms related to catheter-associated urinary tract infection in adult intensive care units in Phase 1 (baseline period) and Phase 2 (intervention period)

Isolated microorganisms	Baseline	Intervention
Candida spp.	58 (29 %)	275 (30 %)
Escherichia coli	44 (22 %)	185 (20 %)
Pseudomonas spp.	31 (16 %)	115 (12 %)
Klebsiella spp.	22 (11 %)	104 (11 %)
Acinetobacter spp.	14 (7 %)	55 (6 %)
Enterococcus spp.	10 (5 %)	41 (4 %)
Proteus spp.	4 (2 %)	56 (6 %)
Enterobacter spp.	3 (2 %)	36 (4 %)
Staphylococcus aureus	3 (2 %)	20 (2 %)
Coagulase-negative staphylococci	3 (2 %)	26 (3 %)
Citrobacter spp.	2 (1 %)	4 (0.4 %)
Providencia spp.	2 (1 %)	4 (0.4 %)
Stenotrophomonas spp.	2 (1 %)	1 (0.1 %)
Serratia spp.	1 (1 %)	3 (0.3 %)
Morganella spp.	0 (0 %)	3 (0.3 %)
Streptococcus spp.	0 (0 %)	4 (0.4 %)

characteristics in Phase 2 reinforces the fact that interventions were effective, because female gender and older age have been identified as risk factors for CAUTI [13]. A multivariate analysis reviewed by Salgado et al. reported them as being among the five risk factors associated with the later development of a CAUTI: (1) duration of catheterization, (2) catheter care violations, (3) absence of systemic antibiotics, (4) female gender, and (5) older age [14].

After adopting the INICC multidimensional infection control strategy for CAUTI, in Phase 2, we found significant improvements in compliance rates with preventive strategies. We found that the compliance rate with UC care measures, specifically related to the correct management and care of UCs—that is, UC on thigh without strangulating, and UC with collecting bag hanging, and not allowing urine reflux—rose to 97 % [14]. Likewise, we found that hand hygiene compliance rose from 55.3 to 66.6 %. Such improvement was also found in another prospective study performed in Argentina, in which the implementation of a program focused on education and performance feedback led to a sustained improvement with hand hygiene compliance, which was correlated to a reduction in DA-HAI rates in the ICU setting [15].

Additionally, we observed a reduction in the average of UC duration and in the use mean, which is another improvement associated with the reduction in the CAUTI rate [16]. In a prospective study by Crouzet et al., reducing the duration of catheterization by means of daily reminders from nurses to physicians to remove unnecessary UCs 4 days after insertion was described as a key intervention in CAUTI prevention that lead to a decrease in CAUTI from 12.3 to 1.8 per 1,000 catheter-days ($P = 0.03$) [17].

With respect to the microorganism profile, the leading isolated uropathogen was *Candida* spp. (30 %) in both periods (Phases 1 and 2), which was followed by *Escherichia coli* (21 %). In the case of *Escherichia coli*, these findings are relatively consistent with conclusions of other studies, in which the uropathogens reported as the most frequent in AICU patients with CAUTIs were Gram-negative species [18]. However, the most frequent pathogens in our AICUs were *Candida* spp., which have been identified as species predisposing HCWs' hands to DA-HAI transmission. In this respect, in a study performed in Turkey, the high rate of *Candida* spp. carriage on the hands of HCWs was evaluated as an important risk factor for the colonization and infection of *Candida* spp. [19]. In relation to our findings, the improvement found in hand hygiene compliance and UC care in Phase 2 can be plausibly associated with a decrease in the transmission of *Candida* spp. in HCWs' hands, and, therefore, with a subsequent reduction in the incidence of CAUTI in our AICUs. Furthermore, fungi, such as *Candida* spp., have been identified as atypical of the CAUTI etiology; however, *Candida* colonization has been reported as a triggering factor for CAUTI, particularly in immunocompromised patients receiving catheter insertion [20].

Our analysis on the multidimensional infection control program for CAUTI prevention showed that the reduction in the CAUTI rate of our AICUs was associated with the correlative improvement in compliance with hand hygiene adherence and CAUTI prevention measures. The INICC multidimensional strategy for CAUTI prevention implemented in this study included the implementation of a practice bundle (consisting of training on procedures for catheter insertion, management, and removal; inserting UCs only when needed; removing them when not necessary; and maintaining unobstructed urine flow, among other interventions), hand hygiene, education, outcome and process surveillance of CAUTI, feedback of CAUTI rates, and performance feedback [17]. These preventive measures have already been proved effective in several studies performed by INICC member hospitals in limited-resource countries [21–30]. In a study conducted by the INICC in Argentina, it was shown that, after the inception of a strategy that included education, performance feedback, and outcome and process surveillance, CAUTI rates decreased by 42 % (from 21.3 to 12.39 CAUTIs per 1,000 catheter-days; RR, 0.58; 95 % CI, 0.39 to 0.86; $P = 0.006$) [22].

Methodological limitations

First, our findings cannot be generalized to AICU patients from each developing country; nonetheless, they are a clear

indication of the trend in limited-resource settings. Second, we could not quantify all information on the compliance of each bundle component for every AICU.

Conclusions

Improvements in infection control practices, as part of a multidimensional strategy, can reduce the incidence of catheter-associated urinary tract infection (CAUTI) and their adverse effects in adult intensive care units (AICUs) from developing countries. However, there is a constant need to continue fostering improvements in practices, because our rates are still higher than those reported from the developed world [8]. We expect that the International Nosocomial Infection Control Consortium (INICC) multidimensional infection control approach will increasingly be carried out in the developing world to achieve substantial reductions in device-associated health care-associated infections (DA-HAIs).

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