

# The effectiveness of a Comprehensive Device Associated Healthcare-Associated Infections Prevention and Control Program: results of a 3-year program in the Republic of Cyprus

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## Research article

**Keywords:** Healthcare-associated infection, Device associated infection, Intensive care unit, Ventilator associated pneumonia, Central line-associated blood stream infection, Catheter-associated urinary tract infection

**Posted Date:** May 9th, 2019

**DOI:** <https://doi.org/10.21203/rs.2.9530/v1>

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# Abstract

**Background:** Device-associated health care-associated infections (DA-HAIs) are a major threat to patient safety, particularly in the Intensive Care Unit (ICU). The aim of this study was to evaluate the effectiveness of a bundle of infection control measures to reduce DA-HAIs in the ICU of a General Hospital in the Republic of Cyprus, over a three-year period. **Methods:** We studied 599 ICU patients with length of stay (LOS) for at least 48 hours. Our prospective cohort study was divided into three surveillance phases. VAP, CLABSI, and CAUTI incidence rates, LOS and mortality were calculated before, during and after the infection prevention and control program. **Results:** There was a statistically significant reduction in the number of DA-HAI events during the surveillance periods, associated with DA-HAIs prevention efforts. In 2015 (prior to program implementation), the baseline DA-HAIs instances were 43: 16 VAP (10.1/1000 Device Days), 21 (15.9/1000DD) CLABSIs and 6 (2.66/1000DD) CAUTIs, (n=198). During the second phase (2016), CLABSIs prevention measures were implemented and the number of infections were 24: 14 VAP (12.21/1000DD), 4 (4.2/1000DD) CLABSIs & 6 (3.22/1000DD) CAUTIs, (n=184). During the third phase (2017), VAP and CAUTI prevention measure were again implemented and the rates were 6: (3 VAP: 12.21/1000DD), 2 (1.95/1000DD) CLABSIs & 1 (0.41/1000DD) CAUTIs, (n=217). There was an overall reduction of 87% in the total number of DA-HAIs instances for the period 01/01/15 to 31/12/17. **Conclusions:** The significant overall reduction in DA-HAI rates, indicates that a comprehensive infection control program can affect DA-HAI rates.

## Introduction

Device-associated-healthcare associated infections (DA-HAIs) constitute a severe threat to Intensive Care Unit (ICU) patients, impacting health care quality in terms of increased morbidity, mortality and attributed costs for the provision of patient care. According to the published international literature, the most common DA-HAIs are central line-associated blood stream infection (CLABSI), ventilator associated pneumonia (VAP) and catheter-associated urinary tract infection (CAUTI) [1]. Incidence rates among European Union (EU) countries vary. Median VAP incidence rates, reported by the ECDC in their 2014 annual epidemiological report [2] including eleven EU countries were 8.4/1000 device days (DD) (Interquartile range/IQR, 3.9-14.3), CLABSIs 1.5/1000DD (IQR, 0.93-3.27) and CAUTIs 1.3/1000DD (IQR, 1.2-1.5). Yet DA-HAIs are preventable. The implementation of evidence based recommendations leading to the utilization of a variety of measures can result in a significant decrease of DA-HAI rates, as several studies have shown [3–7].

Published rates from the Republic of Cyprus are limited, due to the lack of a national active surveillance and reporting system. In the published literature, one report is available by Gikas et al. in 2010 (using data from 2007) [8] showing that the DA-HAI rates were 18.6 for CLABSI, 6.4 for VAP & 2.8 for CAUTI per 1000DD, far higher than the EU reported figures for DA-HAIs at that time.

The current study evaluated the incidence of DA-HAIs, mortality and crude excess mortality in an ICU of a major public General Referral Hospital in the Republic of Cyprus, with 28.000 hospital admissions yearly.

The unit is a closed type, open plan, case mixed, adult ICU with eight beds. Primarily it serves the southern area of the island; however, patients may be admitted from private and other public hospitals across the Republic of Cyprus. The study was conducted over a three-year period, divided in three surveillance phases: specifically 2015, 2016 and 2017. We report on the results of an active DA-HAI surveillance system as a part of a comprehensive prevention program; as well as the reduction in infection rates, device utilization, device days, after the implementation of DA-HAIs prevention strategies. With a view to implementing changes in a more effective way, all interventions were guided by the Kotter's "8-Steps in Leading Change" [9] model. According to the published literature, Kotter's model can additively enhance change in clinical practice [10,11] by reducing barriers and the resistance of staff to the change process.

## Methods

### Study design and data collection

This was a prospective cohort, active DA-HAIs surveillance study with additional implementation of interventions, that was conducted in three phases using the ECDC ICU protocol (ECDC, HAI-ICU Protocol, v1.01 standard edition) [12] to assess DA-HAI rates and mortality.

The first phase (January-December, 2015) DA-HAI comprised an assessment of the initial DA-HAIs rates and baseline mortality for all ICU patients in that period. During the first phase (2015), general qualitative upgrades to cleaning procedures were implemented, according to the guidelines for environmental infection control, cleaning and sterilization in health-care facilities [13–16]. Due to the absence of any physical barrier between the patients on the unit under study (open plan ICU), contact precautions were implemented by all staff, and visitors as controlled by a visitors' surveillance nurse. All ICU staff were trained according to the World Health Organization (WHO) five moments of hand hygiene [17] programme.

Assessment of DA-HAIs at the first phase provided insight for the design of adequate interventions against CLABSI, which were implemented during the subsequent period, from January to December 2016 (second phase). During the second phase, in an attempt to reduce the incidence of CLABSI, we implemented the five evidence-based procedures recommended by the CDC [18] as used in the Keystone Michigan ICU cohort study [19]. Difficulties were encountered with regard to the recommendation for the removal of intravascular catheters, or avoiding their placement due to problems with peripheral venous access, a phenomenon that is not unusual according to the literature [20–22]. In order to comply with the recommendation for the removal of unnecessary central vascular catheters, or avoid placement, we implemented the ultrasound-guided peripheral venous cannulation (UGPVC) method [23,24] as a supplementary intervention additional to the CDCs evidence-based procedures to improve peripheral venous cannulation success rates.

During the third phase (January-December 2017), a VAP prevention bundle plus CAUTI prevention recommendations were implemented. At the end of the third phase, active surveillance DA-HAIs rates and results were compared against those of the first phase.

To improve post-insertion care, CDC's central vascular catheter maintenance recommendations were introduced as an adjunct to the CDC's procedures [18,25]. Additionally, a daily chlorhexidine bath during patient care was implemented as a part of the CLABSI reducing strategy since this practice can reduce rates of infection according to CDC recommendations[26]. Unit-based safety check lists were used to remind staff to carry out these functions at the appropriate intervals.

For VAP prevention (third phase - 2017), the Institute for Healthcare Improvement (IHI) ventilator bundle of measures was implemented [27]. Before bundle implementation, a short education program was delivered to the ICU nursing staff. Compliance with the ventilator bundle was encouraged by a unit-based safety check list.

CAUTI prevention efforts were implemented during the third phase (2017) as an approach to reducing incidence rates. These measures were based on the "four pillars" supported by the IHI [28], the CDC [29], the UK National Health Service (NHS) [30] and the American Infectious Disease Society [31]. Since usage of urinary catheter could not be avoided due to the need for accurate measurements of urinary output (critically ill patients with a high underline disease severity and high overall predicted mortality rate)[32], our efforts were targeted at the urinary catheter maintenance bundle provided by IHI [28]. All interventions and implementation dates are listed in table 4.

The study protocol was approved by the Cyprus Bioethics Committee (EEKB/ΕΠ/2015/37) and reviewed by the Republic of Cyprus Personal Data Commissioner.

## **Patients**

All the patients admitted in the ICU and hospitalized for more than 48 hours (n=599) were included in the study for the period 01/01/2015 to 31/12/2017. They were monitored for DA-HAIs, until their discharge from the ICU, or death. Patients' demographics, acute/chronic health evaluation (APACHE II), simplified acute physiology score (SAPS II), date and type of DA-HAI onset, duration of device usage (days), length of patient stay and patient outcome on discharge from ICU were recorded. Data were collected by experienced ICU nurses, who had attended a short-term training session on DA-HAI diagnostic criteria and the ECDC protocol.

## **Sampling and laboratory testing**

Blood samples were collected from patients in case of a suspected blood stream infection. For CLABSIs, the CVC was aseptically removed and the distal 3 to 4 cm of the catheter was cut off and cultured. For CAUTIs, urine samples were collected by aseptically aspirating a sample from the urine sample port. Quantitative culture for aerobic bacteria was performed using samples of lower respiratory tract secretions to detect VAP. Lower respiratory tract secretions were collected using tracheal aspiration or/and bronchoalveolar lavage (BAL).

Standard laboratory methods were used to identify microorganisms including the Phoenix 100 [33] automated identification and susceptibility testing system and the Vitek II [34] system.

## DA-HAI Rate Calculations

For estimating DA-HAI incidence density rates, confirmed VAP events were divided by the total number of ventilator days and multiplied by 1,000. For CLABSI, the confirmed CLABSI events were divided by the total number of CVC days multiplied by 1,000. For CAUTI, confirmed CAUTI events were divided by total urine catheter (UC) days multiplied by 1,000. Device utilization ratios were calculated by dividing the total number of device-days by the total number of patient-days, where device-days are the total number of days of exposure to each device (ET, CVC, or UC) for all patients during the selected time period, and patient-days are the total number of days that patients were in the ICU during the selected time period.

The DA-HAIs were confirmed by multidisciplinary team (intensivist, microbiologist and specialized nurse),

## Statistical analysis

Medians and interquartile ranges (IQR) were used to describe the distribution of continuous variables and frequencies, and percentages for categorical variables. Comparisons between groups were performed by the Mann-Whitney U test for continuous variables, and the Fisher exact test or the chi-square test for categorical variables. Relative risk was calculated for the comparison of mortality rates of patients with DA-HAI against the mortality rate of patients admitted without an HAI and who did not acquire a DA-HAI subsequently. Relative Risks (RRs) were calculated using a binomial regression with a log link function adjusted by age. Both unadjusted and adjusted RRs are reported. To adjust for the number of patients in the cohort and for the device utilisation ratio, Adjusted Incident Rate Ratios are also reported for the number of patients under study and the total number of days using the device hence the device utilisation rate. The adjustment has been made by using a Poisson regression model. Descriptive statistics, correlation tests and relative risks were calculated using IBM-SPSS software, version 24 [35]. Further, 95% confidence intervals of the incident rates and excess mortality were calculated in R version 3.1.3 using the packages exactci for incident rates, and PropCIs for excess mortality.

## Results

### First Phase Surveillance Results

During the initial phase (Jan–Dec, 2015), surveillance data were collected for 198 patients (73 females, 36.9% & 125 males, 63.1%) hospitalized in the ICU for a total of 2,269 ICU days. The results of the first phase are reported elsewhere [36]

### Second Phase Surveillance Results

During the second phase of this study (Jan-Dec 2016), surveillance data were collected for 184 patients (71 females/38.6% & 113 males) hospitalized in the ICU for a total of 2,029 days. Median age was 59.5 years (IQR, 59.5-78).

A total of 24 instances of DA-HAIs were detected in 16 of the 184 patients, indicating an overall infection rate of 8.15% or an overall incidence of 11.83 DA-HAIs per 1000 ICU-days (95%CI: 7.6-17.6). The most commonly encountered type of infection was VAP (58.3%, 12.2/1000DD), followed by CAUTI (25%, 3.26/1000DD) and CLABSI (25%, 3.26/1000DD).

Infection-free on admission patients who did not acquire any infection during their ICU stay totalled 126. As shown in Table 1, there was no statistically significant difference between the infection free and the infected patients regarding their demographic characteristics, SAPS II, Apache II scores, type of admission, as well as patients' origin or impaired immunity.

For patients who remained infection-free, the observed ICU mortality rate was 14.29%, whereas, for patients who developed VAP, or CLABSI or CAUTI, mortality rates were 30%, 66.67% and 33.33%, respectively. The crude excess ICU mortality for VAP was found to be 15.71% (RR=2.1; 95%CI: 0.74–5.92), for CLABSI 52.38% (RR=4.37; 95%CI: 1.88–11.63) and for CAUTI 19.05 (RR=2.33; 95%CI: 0.7–7.812).

The median severity score of all patients admitted during the observation period was 60 (IQR, 42,5-73) and 29 (IQR, 20,5-36) and the predicted mortality rate 75% and 70% for SAPS II and APACHE II respectively.

## Third Phase Surveillance Results

During the final study period, surveillance data were collected for 217 (91 females/41.9% & 126 males) patients hospitalized in the ICU for a total of 2,490 ICU days.

The overall ICU DA-HAI infection rate of 2.76% or an overall incidence of 2.41 DA-HAIs per 1000 ICU-days (95%CI: 0.9-5.2). The more prevalent type of infection was CLABSI (50%, 1.95/1000DD/3 instances), followed by VAP (30%, 1.79/1000DD/2 instances) and CAUTI (20%, 0.41/1000DD/1 incidence). The proportion of patients with invasive mechanical ventilation was 67%, those with central vascular catheters were 41% and urinary catheters 97% (device utilization 0.67, 0.41 and 0.97 for endotracheal tube, central vascular catheters and urinary catheters respectively) (Table 2).

One patient of those with infection on admission (16.7%) developed a DA-HAI, as did five (83.3%) of the infection negative patients. Patients who remained infection-free during their ICU stay were 137. Of these 137 patients, 44 (44/137, 20.27%) died in the ICU, accounting for a mortality rate 32.12%. Due to the low DA-HAI incidence rates during the post intervention period, mortality and crude mortality of the patients who remained infection-free during their stay could not be estimated.

Median severity score of all patients admitted during the observation period, was 57 (IQR, 40-70) and 31 (IQR, 22-39) and the predicted mortality rate 75% and 73% for SAPS II and APACHE II, respectively.

As seen in Table 3, for CAUTI the 2017 incident rate (0.41/1000 CVC days) was 87% lower than the incident rate of 2016 (3.22/1000 CVC days, RR=0.13 (95%C.I. 0.003-1.06, p=0.06). The risk adjustment for the number of patients and device utilisation days did not affect the abovementioned reduction. Regarding VAP, the 2017 incident rate (1.79/1000 CVC days) was 86% lower than the incident rate of 2016 (12.1/1000 CVC days; RR=0.14, 95%C.I. 0.03-0.52, p=0.001). In the case of VAP the risk adjustment affected the reduction as it was not statistically significant. For CLABSI, the 2016 incident rate (4.2/1000 CVC days) was 74% lower than the incident rate of 2015 incident rate (15.9/1000 CVC days; RR=0.26, 95%C.I. 0.06-0.77, p=0.07). The risk adjustment affected the significance of the reduction in 2016.

## Discussion

The present study reports on the results of a comprehensive program of DA-HAIs control implemented in an ICU in the Republic of Cyprus, which led to a significant reduction of DA-HAIs rates.

The infection rate of 2016 (8.7%) was lower by 3.9 percentage units than the infection rate of 2015 (-3.9%: 95%C.I.-10.3%-2.4%, p=0.21). On the other hand, that of 2017 (2.8%) was lower by 5.9 percentage units than the infection rate of 2016 (-5.9%: 95% C.I. -11.1-1.5%, p=0.009). The incident rate of 2017 was 80% lower than the incident rate of 2016 (p<0.001) while that of 2016 was 38% lower than the incident rate of 2015 (p=0.07) (phase one - initial baseline) [36]. The total number of DA-HAIs instances in the third phase (2017), were 87% lower compared to the baseline. In fact DA-HAI incidence rates, especially at the third surveillance period (2017), were much lower than the majority of published literature [8,37–40]. After the adjustment for the number of patients, our results confirmed the progressive reduction in both two years that in 2017 was statistically significant. This finding does not undervalue the reduction in 2016 as its significance could be a matter of sample size.

DA-HAI result in extended LOS, as evidenced by the comparison of DA-HAI positive and negative patient. The LOS for patients who developed a DA-HAI during their ICU stay for the 2015 group was found to be higher compared to the LOS for DA-HAI negative patients. The same pattern of results was found for the 2016 group, and the 2017 group. Comparing the LOS of DA-HAI free vs. DA-HAI positive patients a statistically significant difference was observed, as patients who developed DA-HAIs had a longer LOS than the DA-HAI free patients.

The most encountered type of DA-HAI in the first surveillance period (2015) was CLABSI, accounting for 15.9 instances per 1000DD. Our interventions resulted to a significant decrease in CLABSI rates from 15.9/1000DD (2015), to 4.2/1000DD (2016) and then to 1.95/1000DD during the 2017 surveillance period (phase three). The absolute 2017 rate appears to be lower than the majority of the reported published literature [5,8,36,41–60]. By the beginning of the next period (2016), our efforts resulted to a significant decrease in CLABSI rates from 15.9/1000DD (2015), to 4.2/1000DD (2016) and then to 1.95/1000DD during the 2017 surveillance period (phase three). The absolute 2017 rate appears to be lower than the majority of the reported published literature [5,8,48–57,36,58–60,41–47]. By comparing DA-HAI rates between 2015 and 2016 (phases one and two), a strong correlation was found, but there was no

significant correlation between the 2016 vs. 2017 period. Although this correlation was not statistically significant, it is a very important outcome for this ICU, for healthcare professionals and for the patients. On the contrary, regarding the CLABSI there was a significant reduction in the incidence rates between the baseline (2015) and the last study period (2017) ( $p > 0.001$ , 15.9/1000DD vs. 1.59/1000DD).

The significant reduction in CLABSI rates may be associated with the reduction of device utilization ratio (UR) and the median CVC days used, since UR and avoidable CVC use has been established as an important risk factor for infection [61]. There was a noticeable reduction in patients' exposure to CVCs as well as a reduced median of CVCs for patients admitted to the ICU during the second and third surveillance periods-phases.. This is corroborated by previous evidence, as central venous catheterization of duration of more than five to seven days is associated with an increased risk of catheter-related infection [61–64], and the reduction of the duration of catheterization to less than the cut-off point of five days may explain the significant decrease in the reduced infection rate.

The second more encountered DA-HAI observed during phase one (2015) was VAP with a rate which appears to be higher than that reported in other studies [41,42,48,51,55,56,65–68]. In the subsequent year (2016), an increase in the rate was noted since no specific VAP prevention or control measure was implemented in that surveillance period. The ventilator care bundle, as well as staff training, was implemented at the beginning of the third phase (2017) and resulted to a significant decrease in infection rates.

The third more frequently encountered type of DA-HAI for all surveillance periods was CAUTI; however, those rates and instances were lower compared to the several previous reports [37,39,49,50,52–58,66,41,69–75,42–48]. A noticeable reduction was also found in the rates and instances per 1000DD, in the third phase (2017). This can be attributed to the implementation of measures including a CAUTI prevention bundle, and demonstrates the potential to improve acceptable DA-HAI rates even further.

The hierarchical distribution of the rates for the DA-HAIs CLABSI and VAP in our study appears to be either similar [8,32,37,76,77] or different [78,79] with the current study pattern, but overall ICU CAUTI rates are found to be lower in the majority of studies [8,37,76–79].

Despite that APACHE II and SAPS II scores, that reflect the underlying disease severity and provide an estimate of the predicted mortality rate (PMR), were lower in the first phase (2015) compared to the second phase and third phase, DA-HAI rates dropped after the implementation of infection prevention and control practices, which further supports the effectiveness of the program. Accordingly, the increased severity of underlying disease may be associated with an increased use of invasive devices, but not with increased DA-HAIs rates. Even with raised severity scores and increased PMR, DA-HAIs reduction is possible whenever prevention practices are implemented.

## Limitations

The present study has certain limitations. It is a single-centred study, so the results cannot be readily generalized to other public or private hospitals across Cyprus. The estimation of the financial impact of DA-HAIs was not possible due to the lack of financial data. Another limitation is that there were no data on previous infection rates that could have been used as a baseline. Despite the study's limitations, it provides clinicians with valuable data with regard to incidence rates and prevalence of DA-HAIs, as data for the Republic of Cyprus are scarce due to the lack of a national infection surveillance system.

## Conclusions

In our comprehensive DA-HAIs control and prevention program, a significant decrease in overall infections (87%) was observed with incidence rates reported to be among the lowest published in the last ten years.

Universal contact precautions are effective at preventing the spread of pathogens among patients and surrounding environment when used along with ICU grading zones. The use of Ultrasound Guided Peripheral Venous Cannulation in ICU patients resulted in an increased compliance with the prompt removal of CVCs, in line with the CDC's recommendations, therefore reducing CVC utilization ratios and CLABSI rates, by decreasing patient CVC exposure.

A comprehensive infection control program may affect the incidence of DA-HAIs more than the implementation of simple measures or care bundles alone. In order to achieve and sustain DA-HAI surveillance data to support efforts in improving infection control, a national active infection surveillance system should be urgently set up in the Republic of Cyprus.

## List Of Abbreviations

DA-HAI: Device-associated health care-associated infections

ICU: Intensive care unit

VAP: Ventilator Associated Pneumonia

CLABSI: Central Line-associated Blood Stream Infection

CAUTI: Catheter-associated Urinary Tract Infection

CVC: Central Venous Catheter

LOS: Length of stay

## Declarations

## Acknowledgments

We would like to thank all the individuals who participated in this study

## Funding

None

## Authors' contribution

VR and SI conceived of, designed, coordinated the study, reviewed the statistical analysis, prepared and revised the manuscript. SI collected the data and performed the statistical analysis. VR was the main PhD advisor of the first author (SI). NM and EP were members of the PhD advisory committee and were involved in the overall supervision of the study and the revision of the manuscript. All authors have read and approved the final version of the manuscript.

## Availability of data and materials

All data generated or analyzed during this study are included in this published article. The data will be freely available to any scientist wishing to use them for non-commercial purposes. The data can be requested from the first author of the manuscript.

## Competing interests

The authors declare that they have no competing interest.

## Consent for publication

Not applicable.

## Ethics approval and consent to participate

The study protocol was approved by the Cyprus Bioethics Committee (EEKB/EP/2015/37) and reviewed by the Republic of Cyprus Personal Data Commissioner (PDC). The Special Research Committee in the Ministry of Health has given its permission to conduct the study and collect patients' data according to the principles of the Declaration of Helsinki. There is no need for patients' or their legal tutors' consent before the enrolment in the study, since the data were anonymously collected.

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