



## Quality indicators for prevention of device-associated infections in a limited resource setting

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### General Note



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## ABSTRACT

**Background:** In resource-limited countries, device-associated infections (DAIs) pose a real threat to patient safety as one of the most significant causes of morbidity and mortality. Nevertheless, inadequate data from ICUs in the developing world is available. *The study aimed* to assess the compliance with the device care bundle and evaluate the impact of device care bundle implementation on the incidences rate of device-associated infections and the mortality rates. Health care workers' compliance with care bundles was observed. DAIs and mortality rates were calculated. **Results:** The compliance rate was (44/84; 52.4%) to each of ventilator care and central catheter care bundles and (45/84; 53.6%) to urinary catheter insertion care bundle. The incidence rate of total DAI was 35.3/1000 device-days. The overall crude excess mortality rates is 39.2% (relative risk, 5.7; 95% CI, 3.04- 10.68; P <0.001) & 15.9% (relative risk, 2.91; 95% CI, 1.55- 5.40; P <0.001), for DAIs and for non-infected cases respectively. **Conclusion:** A highly recommended practice is continuous monitoring of the device care bundle implementation. For ICU staff members, a pre-employment package of training must be provided.

**Keywords:** Compliance; infection control; middle-income countries; ICU; DAIs rates

## 1. INTRODUCTION

Healthcare-associated infections (HAIs) are a significant cause of illness and mortality among hospitalized patients (Harrison et al., 2006; Vu & Le, 2020). In Africa, It has been reported that up to 50% of patients acquired an HAI, with a high burden of device-associated infections (DAIs) (Nejad et al., 2011). The latter occurs in a patient with a relevant device used within the 48 hours preceding the onset of infection. The term "relevant devices" includes the endotracheal tube, central vascular catheter, and urinary catheter respectively (ECDC, 2010).

DAIs rates were reported up to 13 times higher in low-middle income countries than in the USA studies. For DAIs, the pooled cumulative incidence density rates are: 23.9 (95% CI 20.7–27.1) per 1000 ventilator days for ventilator-associated pneumonia (VAP), incidence density rates was 8.8 (95% CI 7.3–10.4) per 1000 urinary catheter days for catheter-associated urinary tract infections (CAUTI), and 12.2 (95% CI 10.5–13.9) per 1000 central line days for central line-associated bloodstream infection (CLABSI) (WHO, 2011). Implementation of care bundles had been shown to reduce the incidence of DAIs. In addition, it restricts the development of multi-drug resistant (MDR) microbes in the ICU (Gao et al., 2015). The idea of a care bundle was originated earlier. The importance of compliance with each of the individual elements hasn't been recognized until more recently (Cooke & Holmes, 2007). For effective implementation, such measures have to be adapted to the local setting, appropriately followed, and continuously evaluated (Richards et al., 2017, Prakash et al., 2017). The strength of a care bundle is that all items must be administered using the "All-or-None" method for any patient, unless medically contraindicated (Fulbrook & Mooney, 2003). To improve the quality of health care delivered, the implementation of device care bundle was assessed in the current study with the objectives to assess the compliance with device care bundle components (Implementation process indicator) and to evaluate the impact of device care bundle practice on the incidences rate of device-associated infections and the mortality rates (Implementation outcome indicator) at the Emergency ICU, Zagazig university hospitals, Egypt.

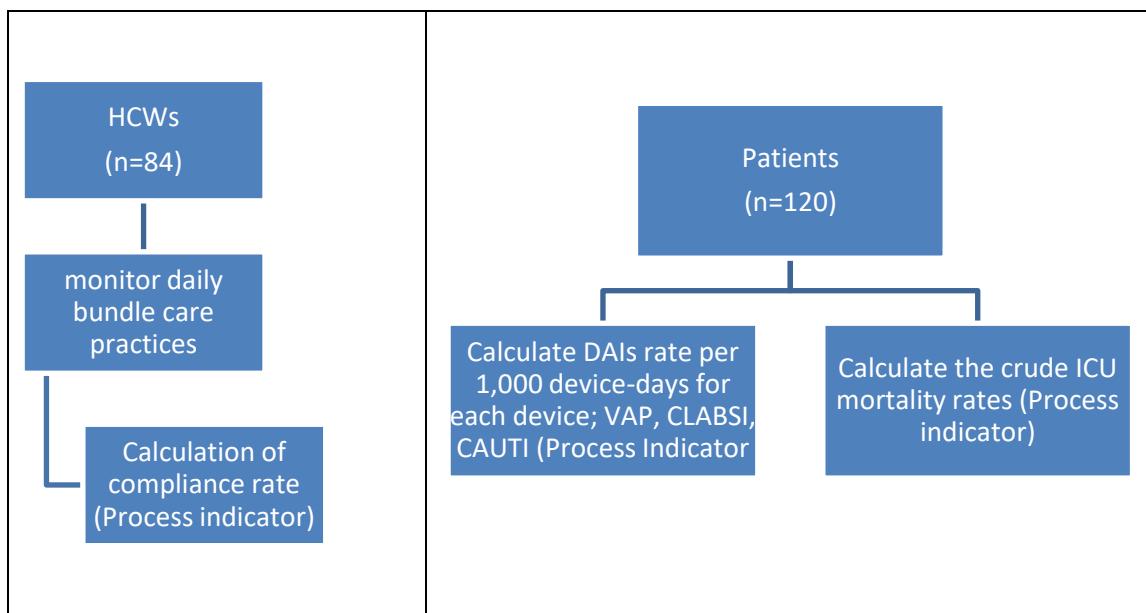
## 2. METHODOLOGY

A prospective cohort study concerning DAIs was conducted in the Emergency ICU of Zagazig University Hospitals from May 1<sup>st</sup>, 2017 to October 1<sup>st</sup>, 2018. The investigated ICU provides medical services for patients from the Eastern region of Egypt, in Africa. This includes Delta, Sinai, and Suez Canal governorates. The investigated unit has 15 beds; the distance between beds 1 meter with physical separation between beds. For hand hygiene, sinks were allocated for hand washing and alcohol dispensers were distributed. There was one isolation room and the nurse-patient ratio was ranged from 1:2 to 1:3.

**Study population and sampling technique**

The study enrolled all cases (120 patients) admitted during the study period that met the inclusion criteria; had invasive devices (endotracheal tube, central vascular catheter, and urinary catheter) inserted in the investigated ICU and lasted more than 48 hrs. On the other hand, intubated patients, patients with an inserted central venous catheter or urinary catheter before ICU admission, previously hospitalized patients in the preceding three months, immune-compromised patients/patients on immunosuppressive drugs, and patients with chronic diseases were excluded.

All health care workers (n=84), on duty, during the study period were also observed for their compliance to implementation of device care bundles (process indicator). All enrolled patients were investigated for DAIs rates and mortality rates (Outcome indicator) (Fig 1).



**Figure 1** Methodology flow chart

#### Data collection tools

For compliance monitoring, a semi-tailored survey was designed after review of earlier studies (Gao et al., 2015; NHSN, 2016; CDC, 2016). Patient's related data was collected by semi-tailored survey to collect the demographic characteristics, clinical and surveillance data.

#### Assessment of bundle compliance (process indicator)

The implementation of all measures of device care bundle components for the prevention of VAP, CAUTI, and CLABSI was monitored and documented during daily rounds by the infection control nurses using a standardized checklist (Gao et al., 2015). The overall performance compliance for each device was calculated using the "All or None" rule: Compliance with device care bundle components was considered if all the elements of the selected care bundle were performed, and if a single element was missed, then it is considered as non-compliance.

#### Calculation of DAIs and mortality rates (Outcome indicator)

Case definition: DAIs in ICU is the infection developed after two calendar days of device insertion and till 48 hours of ICU discharge; with no evidence that infection present or incubating at the time of admission (NHSN, 2016). Besides, the specific diagnosis of VAP, CLABSI, and CAUTI was considered as provided by the CDC / NHSN definitions of healthcare-associated infections (CDC, 2016).

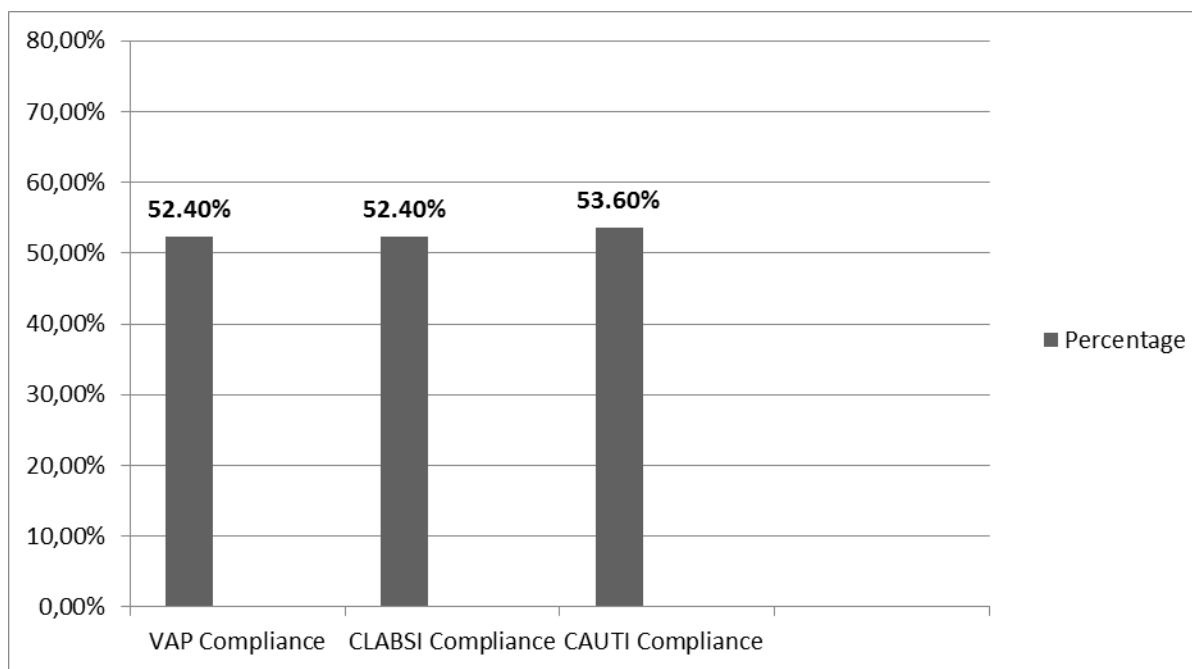
The DAIs rate per 1,000 device-days was calculated as follows: "[Total No. of DAIs / No. of device days) ×1000]" (Emori et al., 1991). The rates for each form of DAIs; VAP, CAUTI, and CLABSI per 1,000 device-days, were calculated as: "[No. of DAIs for each device / No. of device days×1000]" (Edwards et al., 2007). N.B., Device-days are the total number of days of exposure to the device (ventilator, urinary catheter, or central line) by all of the patients in the selected population during the selected period. DAIs crude excess mortality equalled crude mortality of patients with DAI hospitalized in the ICU minus crude mortality of ICU patients who had not acquired a DAIs during the same period.

#### Data analysis

Analysis of data was done using the Statistical Package for Social Science (SPSS) version 21.0 (SPSS, Chicago, IL, USA). Descriptive analysis for quantitative data was represented as a mean and standard deviation and for qualitative data as frequencies and percentages. To determine variations in the categorical variables, the chi-squared test was used. Significant results were considered when p-value < 0.05 (Figure 1).

### 3. RESULTS

The mean physicians' age was  $28.5 \pm 3.1$ ; most of them had less than 12 months of experience in ICU. Nurses' mean age was  $29 \pm 4.2$ ; most of them had less than 5 years' experience in ICU. The majority of physicians and nurses didn't have infection control courses (Table 1). The compliance rate was as follows: (44/84; 52.4%) to each of ventilator care and central catheter care bundles and (45/84; 53.6%) to urinary catheter insertion care bundle (Figure 2). The total DAIs' incidence rate was 35.3/1000 device-days. The highest incidence was of VAP 68.2/ 1000 ventilator-days; followed by CAUTI 24.9/1000 catheter-days, and the least incidence was for CLABSI 18.5/1000 Central-venous days (Table 2).



**Figure 2** VAP, CLABSI, and CAUTI bundle components compliance in the emergency intensive care unit

**Table 1** Socio-demographic and occupational characteristics of the HCWs in the Emergency Intensive Care Unit (n=84).

Characteristics	Physicians (N=14)	Nurses (N= 70)
Age: (X ± SD)	28.5±3.1	29±4.2
Job Description:	Resident Assistant	Head nurse
No ( % )	9 (64.3) Lecturer 5 (35.7)	20 (28.6) Nurse 50 (71.4)
Experience in ICU:	<12 months	<5 years
No (%)	9 (64.3) 12 – 24 3 (21.4) >24 2 (14.3)	35 (50.0) 5- 10 25 (35.7) >10 10 (14.3)
Infection control courses:		
Yes	4 (28.6)	18 (25.7)
No	10 (71.4)	52 (74.3)

**Table 2** Incidence rate of device-associated infections in ICU during the study period

Type of infection	No of Device days	No of infections	Rate per device-days <sup>a</sup>
VAP	997	68	68.2/1000 ventilator-days
CLABSI	1190	22	18.5/1000 Central -venous days
CAUTI	1243	31	24.9/1000 catheter-days
Total DAIs	3430	121	35.3/1000 device-days

CAUTI, catheter-associated urinary tract infection; CLABSI, central catheter-associated bloodstream infection; VAP, ventilator-associated pneumonia; <sup>a</sup> Rate per 1000 device-days: rates were calculated by dividing the number of specific DAIs by the number of device-days and multiplying the result by 1000.

Table 3 shows the relationship between the compliance with device care bundle components and device acquired infections: 62.7% of the VAP infection was identified as having a significant association with non-compliance ( $p < 0.001$ ). Also, it was reported that 61.9% and 56.0% of CLABSI and CAUTI infection was highly frequently related to non-compliance but without significant difference.

**Table 3** Relationship between compliance with device care bundle components and device acquired infections

	None VAP		VAP		P value
	No	%	No	%	
VAP bundle items compliance:					
Compliant	25	75.8	19	37.3	0.001*
Non- Compliant	8	24.2	32	62.7	
	None CLABSI		CLABSI		P value
	No	%	No	%	
CLABSI bundle items compliance:					
Compliant	37	58.7	8	38.1	0.10
Non- Compliant	26	41.3	13	61.9	
	None CAUTI		CAUTI		P value
	No	%	No	%	
CAUTI bundle items compliance:					
Compliant	33	55.9	11	44.0	0.31
Non-Compliant	26	44.1	14	56.0	

Significance difference at  $P < 0.01$

Mortality data associated with DAIs are shown in Table 4. For patients with VAP (47.5%) and total DAIs (24.2%), crude ICU mortality rates were substantially higher than the crude ICU mortality rate for patients admitted without HAI who did not acquire ICU DAIs (8.3%), yielding overall crude excess mortality rates of 39.2% (relative risk, 5.7; 95% CI, 3.04- 10.68;  $P < 0.001$ ) and 15.9% (relative risk, 2.91; 95% CI, 1.55- 5.40;  $P < 0.001$ ), respectively.

**Table 4** Mortality rates for device-associated infections in the ICU

Patient Infection	No of patients	No of deaths	Mortality, %		RR	95% CI	P-value
			Crude	Crude excess			
No infection	120	10	8.3	—	—	—	—
VAP	101	48	47.5	39.2	5.7	3.04-10.68	0.00*
CLABSI	114	13	11.4	3.1	1.36	0.62-2.99	0.43
CAUTI	120	20	16.7	8.4	2.01	0.97-4.09	0.05
Total DAIs	335	81	24.2	15.9	2.91	1.55-5.40	0.00*

ICU, intensive care unit- We only considered cases of patients with a single infection to calculate mortality

RR (Relative risk) = incidence in exposed/ incidence in unexposed. \*Significance difference at  $P < 0.001$

## 4. DISCUSSION

DAIs poses a real threat to patient safety being one of the most serious causes of morbidity and mortality in resource-limited countries. However, insufficient data are available from ICUs in the developing world. The role of education and training, as well as practical experience, usually have a great impact on compliance performance (Borgert et al., 2015). This was evident in the reported rates were nearly half of the study participants; 64.3% of the physicians and 50% of the nurses, were recently admitted to the ICU and 71.4% of physicians and 74.3% of the nurses didn't receive device care training courses. Pre-employment training would be of benefit to increase compliance rates.

A variety of measurements was illustrated in the literature to calculate the levels of bundle compliance (Borgert et al., 2015). We hereby selected to use the 'All or None' measurement, which calculates the percentage of all indicated elements the patients have received (Nolan & Berwick, 2006). Thus, the items with which healthcare workers (HCWs) showed inconsistency could be recognized to assist in future planning for training and interventions. Contextualization matters in the design of any performance improvement

intervention. The enrolled HCWs showed the highest level of incompatibility to following individual elements in each care bundle "unpublished data": "Anti DVT administration" in ventilator care bundle, "Evaluate the need of central catheter insertion" in catheter care bundle and "Assess the necessity of indwelling urethral catheter" and "keep the urine drainage device airtight, unobstructed and complete and close the drainage tube during movement" in urinary catheter insertion care bundle.

Higher compliance rates were reported earlier for the central catheter care bundle (Caserta et al., 2012), and urinary catheter care bundle. For VAP compliance rates, comparable results, 53%, were reported from a previous European study (Rello et al., 2002). On the contrary, higher compliance rates than this one was reported by Morris et al. (2011). The key reasons for non-compliance were inadequate supplies, increased cost problems (Rello et al., 2002), a poor ratio of nurses to patients, the seriousness of cases and the shortage of resources (Chenoweth & Saint, 2011).

The overall rate of DAIs in the present study was 35.3 per 1,000 device days, which is higher than that documented in a previous Egyptian study (EL-Kholy et al., 2012) conducted in adult medical, pediatric and neonatal ICUs. The difference could be attributed to: the type of ICU, disease severity, available financial support for the infection control program, and variations in compliance with infection control recommendations among staff. Relative to a previous analysis (Inan et al., 2012), the incidence of VAP was high. This may be due to the heterogeneity between various studies in the underlying health conditions of investigated patients. The patients admitted to our emergency ICU were those with respiratory failure, multiple injuries, multiple organ failure, septic shock, or cardiopulmonary resuscitation in critical circumstances. Almost all patients included were in a coma-like state, with a reduced cough reflex, impeded drainage, or ventilated. Such serious cases constitute a daily challenge for doctors at our hospital, especially when considering the limited resources and overload of work. The same could be noticed with CLABSI rates and CAUTI rates. Published reports showed lower rates, (Inan et al., 2012; Datta et al., 2014; Apostolopoulou et al., 2013).

Although the use of ultrasound has been shown to minimise infection (Karakitsos et al., 2006), the lack of practise in using it by junior workers during central venous catheter insertion with a lack of properly applied aseptic techniques may be the main causes of increased incidence of CLABSI in this research. A number of concerns have been raised regarding the repeated technical failure of the air conditioning system with resultant elevated temperature and humidity, especially during the summer months. Practice variance regarding the insertion of urinary catheters with lack of adherence to aseptic procedures may be the cause of increased CAUTI rates.

A substantial correlation was found between HCW's failure to comply with the ventilator care bundle and the high rates of VAP, and earlier studies reported similar results (Al-thaqafy et al., 2014) in which they strongly suggested adherence to the ventilator bundle as a key patient safety initiative, this figure out the importance of human factors in VAP prevention. Moreover, increased rates of device utilization could be another important factor (Al-thaqafy et al., 2014). For the other two bundles, further studies are needed with regression analysis of all probable risk factors, other than compliance, that may correlate with elevated infection rates. In this study mortality rate was higher than a previous study conducted in Colombia (Moreno et al., 2006). There might be no relation or direct impact between device infection and death, yet the difference may be due to different ICU types with different patients' conditions. The investigated ICU in this study is a referral ICU at which severe cases is admitted. It receives very complicated cases, which in turn may inversely affect the mortality rates.

There are some limitations to the current research. First, the comprehensive clinical characteristics of patients in the emergency ICU or details on the implementation of additional control measures for infection in this unit during the study period were not obtained. Thus, we could not eliminate potential confounding variables that could have influenced the effect of care packages in this analysis. Second, the current research was focused on a single ICU. In the future, therefore, we need to enroll more units with a longer period of follow-up to determine the efficacy of these care packages.

## 5. CONCLUSION

While the challenges facing any improvements process are usually anticipated in resources-limited settings, a suitable solution is always a matter of context. This report's findings could help to resolve the skepticism from doctors of existing evidence and the suspicions from nurses concerning the value of additional work, linked to bundle implementation. The effect of monitoring on the updating of the defects and effective corrective measures is further stressed. Therefore, as part of the pre-employment training course for ICU staff members, we suggest the incorporation of device care bundle training. The continuous monitoring of the care bundle application is a strongly recommended activity that should be endorsed by healthcare facility management.

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### List of abbreviations

DAIs: Device Associated Infections  
 ICU: Intensive Care Unit  
 HAIs: Healthcare-Associated Infections  
 VAP: Ventilator-Associated Pneumonia  
 CAUTI: Catheter-Associated Urinary Tract Infections  
 CLABSI: Central Line-Associated Bloodstream Infection  
 HCWs: Healthcare Workers

### Author Contributions

Howaydah Ahmed Othman: Conceived the study, manuscript design and drafting.  
 Marwa Mohamed Zalat: Data analysis, interpretation, manuscript design and drafting.  
 Essamedin Mamdouh Negm: Data collection, literature search, manuscript drafting.  
 Mohamed Mohamed Tawfeek: Data collection, manuscript design and drafting.  
 Rehab Hosny El-Sokkary: Literature search, manuscript design, drafting, and submission.  
 All the authors revised the manuscript critically and approved it before submission.

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### Conflict of Interest

The authors declare that there are no conflicts of interests.

### Informed consent

Written informed consent was obtained from all participants included in the study. Privacy and confidentiality were assured.

### Ethical approval

The study was approved by the Institutional Review Board Committee of Faculty of Medicine, Zagazig University (ethical approval code: ZU- IRB # 2710-9-3-2017).

### Data and materials availability

All data associated with this study are available upon request to the corresponding author.

### Peer-review

External peer-review was done through double-blind method.

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