Effect of applying Care Bundle Educational Program on reducing Ventilator-Associated Pneumonia in Intensive Care Units at Benha University Hospitals (A Quasi-Intervention Study)

Abstract

Background: One of the most serious illnesses linked to healthcare in intensive care units is ventilator-associated pneumonia (VAP), which can lead to poor patient outcomes, higher expenses, and longer hospital stays. The burden of VAP in Egypt is made worse by a lack of resources and uneven compliance with infection control protocols. ICU nurses play a crucial role in applying evidence-based practices to prevent VAP; however, gaps in knowledge and training hinder optimal care. **Objectives:** This study aimed to evaluate the effectiveness of a Care Bundle Educational Program (CBEP) on improving ICU nurses' knowledge of ventilator care practices and its impact on VAP incidence rates in Benha University Hospitals. **Method**: A quasi-experimental pre/post-intervention design was conducted over nine months in the central and intermediate ICUs at Benha University Hospitals. The intervention targeted all 262 ICU nurses through structured training sessions combining lectures, visual materials, and bedside demonstrations. Data were collected using a validated questionnaire assessing VAP prevention knowledge, alongside surveillance of VAP rates among mechanically ventilated patients. **Results**: The program significantly enhanced nurses' knowledge scores, with the mean score increasing from 5.29 ± 2.38 pre-intervention to 7.99 ± 1.49 post-intervention ($p < 0.001$). Correspondingly, the incidence of VAP among ICU patients decreased notably during the post-intervention phase, reflecting improved clinical practices and integration of training into daily care. **Conclusions:** The Care Bundle Educational Program effectively elevated ICU nurses' knowledge and contributed to a measurable reduction in VAP incidence, underscoring the value of structured, nurse-focused education in critical care settings.

Keywords: Ventilator-associated pneumonia; ICU nurses; Infection prevention; Care bundle; Educational intervention.

Introduction:

One of the biggest causes of morbidity and mortality, device-associated infections (DAIs) pose a major risk to patient safety and include ventilator-associated pneumonia (VAP), central line-associated bloodstream infection (CLABSI), and catheter-associated urinary tract infection (CAUTI) [1].

Between 25 and 42 percent of all infections that occur in intensive care units (ICUs) are caused by VAP, the second most common health care-associated infection (HAI). Patients with VAP had a 46% death rate among those who need mechanical breathing. The length of hospital stays and, consequently, healthcare expenses have increased dramatically for patients with VAP. However, if actions are taken to enhance the care given to the ventilated patient, this could be decreased [2].

A mean VAP density of 3.6 cases/1000 ventilator days was observed by the Centers for Disease Control and Prevention of the National Healthcare Safety Network Hospitals in medical-surgical intensive care units (ICUs) in the United States, while it ranged from 10 to 41.7 cases/1000 ventilator days in developing nations [3].

The VAP care bundle has been shown to be effective in numerous studies conducted globally. According to after using this bundle in surgical intensive care units (SICUs) for two years, the mean VAP density dropped from 9.3 cases/1000 ventilator days to 2.2 cases/1000 ventilator days [3].

The care bundle approach is a set of evidence-based practices recommended by CDC that was proven to improve the patient outcome when performed collectively and reliably [4].

The goal of the Care Bundle Educational Program (CBEP) is to enhance the outcomes of ventilator-associated pneumonia (VAP) and other DAIs by addressing a variety of patient

care topics. The program covers infection control procedures in intensive care units as well as DAI preventive care bundles [1].

So this study aimed to raise the level of knowledge of ventilator-associated pneumonia preventive measures among nurses and reduce the incidence of ventilator-associated pneumonia (VAP) at intensive care units in Benha University hospitals.

Subjects and Methods:

1. **Study design:** This is a quasi-intervention study.
2. **Study setting:** This study was conducted in the Central and Intermediate Intensive Care Units (ICUs) at Benha University Hospitals.
3. **Study period:** The field work of this study was carried out from the first of May 2024 to the end of January 2025.
4. **Target population of the study:** all currently working nurses at central and intermediate ICUs, as well as all cases that were admitted to the ICUs in both the pre- and post-intervention phases and fulfilled the inclusion criteria.

Inclusion criteria: For nurses: all nurses currently working at central and intermediate ICUs at Benha University Hospital during the study period, 147 of whom were in the central ICU and 115 in the intermediate ICU.

For patients: Patients who were admitted to the ICUs, on a ventilator, and who had the device inserted for more than 48 hours.

Exclusion criteria: For nurses: nurses who refused to participate in the study or were on vacation. **For patients:** Intubated patients before ICU admission and Immune-compromised patients or patients on immunosuppressive drugs.

5. **Study methods and tools:**
    - A well-prepared, structured, validated questionnaire was used to collect data from the studied participants.
    - The prepared questionnaire was written in English and translated into Arabic by a professional translator from the Faculty of Literature. The translated tool was tested for content validity by a jury of professors from the Faculty of Medicine (Community, Environmental and Occupational Medicine department). A pilot study was done on 20 nurses from the participating ICUs. Pilot testing revealed that the language and formatting were appropriate; therefore, no adjustments were made.
    - Reliability of questionnaire was tested using Cronbach alpha test and showed that all parts of questionnaire were reliable (Cronbach alpha was 0.74).
    - The questionnaire includes data about the following topics:
        - Part 1: Socio-demographic data of nurses (6 Q).
        - Part 2: Knowledge of Evidence-Based Guidelines (EBGs) on VAP prevention (10 Q) [5].
        - Part 3: Calculation of the incidence of infection of VAP based on standardized CDC definitions [6].

Administrative consideration:

After obtaining official permission to conduct the study, the research team visited the selected intensive care units (ICUs) to establish contact with the nursing staff and their supervisors. Introductory group discussions were held with nurses in each ICU to explain the study's aim and objectives, clarify any concerns, and encourage their voluntary participation in completing the questionnaire.

Ethical consideration:

- The study was done after approval from the Ethics Committee of the Faculty of Medicine, Benha university **{approval code: M.S.1.6.2024}**, and after administrative approval from the executive manager of Benha University Hospitals.
- Administrative permissions were secured from hospital and ICU management to access nurse records and conduct training on-site.

– An Informed written consent was obtained from all nurses before data collection after clarification of the objectives of the study, confidentiality of data, voluntary involvement, and withdrawal.

Data management and statistical analysis:

Software developed by SPSS Inc. of Chicago, Illinois, USA, version 27.0 for Windows was used for data analysis. For categorical data, we used percentages and frequencies; for continuous variables, we used means with standard deviations to describe the participants' characteristics. For continuous variables, paired t-tests were utilized, whilst for categorical data, the Chi-square test (χ^2) and Fisher's Exact test were employed. also known as the Z-test, which compares two proportions. Statistical significance was determined by a p-value less than 0.05.

Results:

The socio-demographic and professional profile of the nurses revealed that over half (51.1%) were under 25 years old, while only 11.8% were aged 30 or above. Most were female (70.2%), and the majority (53%) were nursing institute graduates, followed by 40% with university degrees and 6.9% with diplomas. Nearly two-thirds (65.3%) had less than five years of experience, and 57.6% had not attended infection control training. Regarding workplace distribution, 56% were assigned to the central ICU and 43.9% to the intermediate ICU **(Table, 1).**

This study identified statistically highly significant differences in nurses' knowledge about VAP prevention guidelines in all items ($p < 0.01$). With a higher proportion of correct answers after the intervention compared to before the intervention **(Table, 2).**

The multiple bar chart demonstrates that there was a higher proportion of correct answers after the intervention in all items of evidence-based guidelines on VAP prevention among the studied nurses. Most notable are the perfect 100% correct response rate for ventilator circuit changes and the significant gains (30-40 percentage points) in items like endotracheal tube selection (53.8% to 90.5%) and oral intubation route (56.9% to 84.4%) **(Figure, 1).**

The current study found highly significant differences in EBG scores across multiple factors. Nurses over 30 scored highest by age group (7.26 ± 1.83), while postgraduate nurses outperformed diploma holders (7.21 ± 1.90 vs. 3.06 ± 2.16; $p < 0.001$). Greater experience correlated with higher scores (7.27 ± 1.95 for >10 years), and prior training was linked to improved knowledge (7.03 ± 1.76 vs. 4.01 ± 1.93; $p < 0.001$). ICU type also showed a significant effect ($p = 0.019$), with intermediate ICU nurses scoring slightly higher (5.68 ± 2.47) than those in central ICUs (4.99 ± 2.28) **(Table, 3).**

This study found consistent and significant improvements in VAP outcomes following the intervention. During pre-intervention months (May-August), both central and intermediate ICUs showed persistently high VAP incidence rates, with considerable monthly variability. Post-intervention (October-January), these metrics declined to lower percentages, with VAP incidence ranging from 17%-28% across both ICU types **(Table, 4).**

Discussion:

The implemented educational bundle produced a marked improvement in nurses' VAP knowledge. In this study, the **mean knowledge score** increased from 5.29 (±2.38) pre-intervention to 7.99 (±1.49) post-intervention (p<0.001). This gain was **highly significant**, indicating that the training has effectively raised understanding of the VAP guidelines.

These results are consistent with other Egyptian reports. A study done by **Thabet et al** found that most ICU nurses had **unsatisfactory** VAP knowledge at baseline (87.5% unsatisfactory) but showed highly significant post-training gains (p<0.001) [7]. Similarly, another study done by **Khalifa, E. M.** delivered a bundle-based education to Cairo-area ICU nurses and observed **highly significant improvements** in all knowledge domains in the intervention group (no change in controls). Findings in this study echo these: unsatisfactory baseline knowledge became satisfactory (84–100% correct in most categories) after training in Egyptian studies [8].

In the wider Arab region, comparable interventions have had similar effects. A recent Saudi study done by **Alreshidi et al** used a one-group pre–post design and reported **dramatic post-test gains**. Supporting this, general VAP knowledge correct responses increased from only 27.6% to 95.2%, and knowledge of prevention guidelines from 20.8% to 73.6% (both $p<0.001$). Likewise, a Gulf survey found self-reported bundle adherence varied widely (38–100%), with perfect compliance for head-of-bed elevation but poor extubation readiness adherence, highlighting the need for targeted training[9]**.** These Arab examples reinforce that bundled education significantly boosts guideline knowledge, matching our Benha results.

Internationally, multiple studies confirm that structured education significantly improves VAP knowledge. In India, a study conducted by **Roy, D.** found nurses' mean knowledge scores rose from 21.44±3.06 pre-intervention to 30.26±2.46 post-intervention ($p<0.001$)[10]. Likewise, another study done by **Mogyoródi et al** reported that a single-session training significantly enhanced nurses' VAP knowledge (and translated into higher bundle compliance) [11].

A systematic review of Eastern Mediterranean ICUs conducted by **Al-Mugheed et al** also noted that most nurses initially have **low VAP knowledge**, underlining the need for interventions. Our data – showing large, statistically significant knowledge gains – are fully consistent with these international findings, indicating that education can successfully overcome baseline deficiencies in VAP guideline awareness [12].

Importantly, baseline knowledge varied systematically with nurse characteristics: older nurses (≥30 years), those with higher education (university/postgraduate degrees), more years of ICU experience, and prior infection control training all had significantly higher scores at baseline (all $p<0.01$). Supporting this, nurses >30 years averaged 7.26±1.83 vs. 4.59±2.20 in the 20–24 year group ($p<0.001$), and those with postgraduate degrees scored 7.21±1.90 vs. 3.06±2.16 for diploma holders ($p<0.001$). Nurses who had attended an infection control course scored on average 7.03±1.76 vs. 4.01±1.93 for those without such training ($p<0.001$). Nurses in intermediate ICUs also scored higher than those in central ICUs (5.68±2.47 vs. 4.99±2.28, $p=0.019$).

These findings show that nurses' infection control knowledge was strongly influenced by their education and professional experience. Older nurses and those with more ICU exposure had higher baseline scores, likely due to repeated protocol reinforcement and informal mentorship. University and postgraduate-trained nurses had better theoretical foundations than diploma holders. Prior infection control training also proved to be a strong predictor, highlighting the lasting value of structured courses even before targeted interventions.

Interestingly, nurses in intermediate ICUs scored slightly higher than those in central ICUs, possibly due to lighter workloads allowing better adherence to protocols. In contrast, central ICUs may face higher patient acuity, limiting routine preventive measures. These findings highlight the variability in baseline knowledge and emphasize the need for tailored education, especially for less experienced or less qualified nurses to ensure consistent readiness across staff.

Implementation of the VAP care-bundle education program at Benha University Hospitals led to a significant decline in VAP incidence. Post-intervention, overall monthly VAP incidence across both ICUs stabilized between 17–28%, compared to peaks of up to 39% before the program. These improvements were highly significant and indicate that the bundle education program had a large clinical impact on patient outcomes.

Internationally, the evidence is equally compelling. A systematic review done by **Martinez-Reviejo et al** confirmed that care bundles significantly reduce VAP incidence, particularly when supported by structured staff education[13]. Another study conducted by **Mogyoródi et al** reported a VAP reduction from 10.4 to 5.2/1,000 ventilator days after similar training. These findings confirm that the VAP bundle's effectiveness is robust across various healthcare systems [14].

On the other side, not all studies have reported significant reductions. As observed in one study conducted by **Semet, C.** in 2023, there was no difference in incidence after bundle implementation, possibly due to inconsistent adherence or short-term follow-up. Such findings highlight the importance of reinforcement and continuous monitoring to sustain change [15]. In this study, constant supervision and visible reminders likely supported the consistent practice adoption that drove incidence decline.

Conclusion:

This study evaluated the impact of a care bundle educational program on reducing Ventilator-Associated Pneumonia (VAP) in the intensive care units of Benha University Hospitals. The program was designed to strengthen ICU nurses' knowledge related to VAP prevention and to assess its effect on clinical outcomes, including VAP incidence. The findings demonstrated that the program significantly improved nurses' overall knowledge of VAP prevention guidelines. After the intervention, a much higher proportion of nurses reached a high level of knowledge, indicating the program's success in delivering essential information and reinforcing best practices. The program's impact extended beyond knowledge and practice, as VAP incidence declined during the study period. These reductions highlight the value of structured educational initiatives in improving clinical outcomes and reducing the burden of healthcare-associated infections in critical care units.

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Table (1): Frequency distribution of sociodemographic data among the studied nurses (n=262)

Sociodemographic Characteristics		N. (n=262)	% (100.0)
Age (years)	20-	135	51.5
	25-	96	36.6
	≥ 30	31	11.8
Gender	Male	78	29.8
	Female	184	70.2
Level of nursing education	Diploma	18	6.9
	Nursing institute	139	53
	Nursing university	86	32.8
	Postgraduate	19	7.3
Years of experience	Less than 5 years	171	65.3
	5 to 10 years	65	24.8
	More than 10 years	26	9.9
Having a training course on infection control program	yes	111	42.4
	no	151	57.6
Type of ICU	Central	147	56.1
	Intermediate	115	43.9

Table (2): Comparison of nurses' knowledge about Evidence-Based Guidelines for prevention of VAP before and after the intervention (n=262)

Items of Evidence–Based Guidelines		Before intervention (n= 262)	After intervention (n= 262)	Test of significance (Z test)	*P* value
1. Oral vs. nasal route for endotracheal intubation	Correct	149 (56.9%)	221 (84.4%)	-6.9121	0.000**
	Incorrect	113 (43.1%)	41 (15.6%)		
2. Frequency of ventilator circuits changes	Correct	185 (70.6%)	262 (100%)	-9.5028	0.000**
	Incorrect	77 (29.4%)	0 (0%)		
3. Type of airway humidifier	Correct	132 (50.4%)	216 (82.4%)	-7.7541	0.000**
	Incorrect	130 (49.6%)	46 (17.6%)		
4. Frequency of humidifier changes	Correct	123 (46.9%)	210 (80.2%)	-7.9191	0.000**
	Incorrect	139 (53.1%)	52 (19.8%)		
5. Open vs. closed suction systems	Correct	126 (48%)	196 (74.8%)	-6.3008	0.001**
	Incorrect	136 (51.9%)	66 (25.2%)		
6. Frequency of change in suction systems	Correct	149 (56.9%)	220 (84%)	-6.7981	0.001**
	Incorrect	113 (43.1%)	42 (16%)		
7. Endotracheal tubes with extra lumen for drainage of subglottic secretions	Correct	141 (53.8%)	237 (90.5%)	-9.3707	0.001**
	Incorrect	121 (46.2%)	25 (9.5%)		
8. Kinetic vs. standard beds	Correct	135 (51.5%)	206 (78.6%)	-.6.5052	0.001**
	Incorrect	127 (48.5%)	56 (21.4%)		
9. Patient positioning	Correct	133 (50.8%)	198 (75.6%)	-5.8858	0.001**
	Incorrect	129 (49.2%)	64 (24.4%)		
10. Use of 0.12% chlorhexidine gluconate antiseptic oral rinse	Correct	141 (53.8%)	213 (81.3%)	-6.7228	0.001**
	Incorrect	121 (46.2%)	49 (18.7%)		

* = significant at $\leq$ 0.05 ** = Highly significant < 0.01 Z= test for two proportion

Table (3): Comparison between sociodemographic and work related factors regarding knowledge score of Evidence-Based Guidelines on VAP Prevention before the intervention.

Sociodemographic data		EBG Score (Mean ± SD)	Test of significance	*P* value
Age	20-	4.59 ± 2.196	F= 19.876	.000**
	25-	5.64 ± 2.415		
	≥30	7.26 ± 1.825		
Sex	Male	5 ± 2.33	t= 1.285	0.200
	Female	5.41 ± 2.401		
Level of nursing education	Diploma	3.06 ± 2.155	F= 17.780	.000**
	Nursing institute	4.80 ± 2.250		
	Nursing university	6.13 ± 2.130		
	Postgraduate	7.21 ± 1.903		
Years of experience	Less than 5 years	4.85 ± 2.309	F= 13.963	.000**
	5 to 10 years	5.66 ± 2.293		
	More than 10 years	7.27 ± 1.951		
Having a training course on infection control	yes	7.03 ± 1.760	t= 12.95	.000**
	no	4.01 ± 1.932		
Type of ICU	Central	4.99 ± 2.275	t= 2.352	0.019*
	Intermediate	5.68 ± 2.469		

F= ANOVA test t= Independent t test * = significant at $\leq$ 0.05 ** = Highly significant < 0.01

Table (4): Distribution of incidence of Ventilator-Associated Pneumonia (VAP) among patients before and after Intervention

	Month	Number of patients on ventilator		Incidence of VAP	
		Central	Intermediate	Central	Intermediate
Before intervention	May	50	14	28%	29.4%
	June	45	17	34.2%	35%
	July	68	10	39%	29.4%
	August	70	16	25.7%	22.5%
After intervention	October	35	5	28%	25%
	November	40	3	24%	22%
	December	30	15	20%	19%
	January	57	10	18%	17%

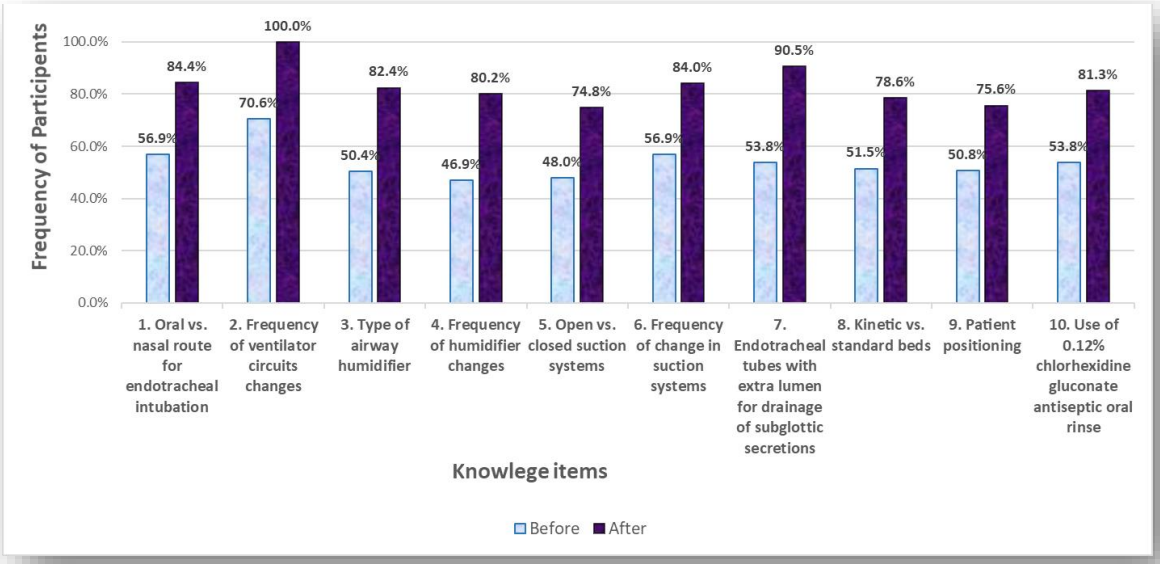

Figure (1): Frequency distribution of the correct answers regarding knowledge of Evidence-Based Guidelines on VAP prevention before and after the intervention.