

Intensive Care Nurses Knowledge, Compliance and Barriers to the Implementation of Ventilators-Associated Pneumonia Care Bundle: A Systematic Review and Meta-Analysis

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ABSTRACT

Background: Ventilator-associated pneumonia (VAP) is the most common hospital-acquired pneumonia that develops within days of patient intubation in the critical care unit. Evidence has demonstrated that implementing the VAP care bundle is effective in preventing this condition. **Objective:** This review aims to determine intensive care nurses' knowledge, compliance, and barriers to implementing Ventilator-Associated Pneumonia (VAP) care bundles. **Methods:** Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guided this systematic review. Three online databases (PubMed, Web of Science, and EMBASE) were searched for relevant articles, alongside a grey literature search. A total of 11 articles meeting the inclusion criteria were included in the study. Articles providing adequate information for meta-analysis were analyzed using Comprehensive Meta-Analysis software version three. **Result:** The study results revealed that intensive care nurses' knowledge of the VAP care bundle was 0.516 or 51.6% (CI: 0.357–0.671), indicating an average knowledge level. Regarding nurses' compliance with the VAP bundle, a statistically significant (p-value 0.022) high compliance level of 66.7% or 0.667 (CI: 0.525–0.784) was observed. Identified barriers to implementing the VAP bundle included inadequate knowledge, insufficient equipment, and absence of protocols or guidelines for VAP care bundle implementation. **Conclusion:** The study therefore concludes that intensive care nurses require training on VAP care bundle implementation. Furthermore, hospital managers should ensure adequate availability of equipment and guidelines to support effective practice.

Key words: Ventilator-associated Pneumonia; Knowledge; Compliance; Barriers; Intensive care nurses

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Introduction

Patients' admission to the intensive care unit (ICU) has been reported to increase the risk of hospital-acquired infections (HAIs).¹ This, according to Wałaszek *et al.* is linked to the increased requirement for invasive and other diagnostic procedures among patients with compromised immune systems. It is reported that ventilator-acquired pneumonia (VAP) is one of the most frequently reported HAIs among patients in the ICU.^{2,3} Ventilator-acquired pneumonia is defined as an infection of the pulmonary parenchyma diagnosed among patients who have been on mechanical ventilation for at least two days.^{4,5} The Centre for Disease Control and Prevention [CDC] reported that lung infection occurs when pathogenic organisms pass through ventilator tubing and gain entry into the patient's lungs.⁶ Consequently, Kohbodi *et al.*⁴ revealed that the infection develops progressively through upper airway and tracheal colonization to tracheitis, eventually leading to pneumonia. According to evidence, VAP is caused by a broad range of Gram-negative and Gram-positive

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organisms, Gram-negative organisms primarily associated with VAP include *Klebsiella pneumoniae*, *E. coli*, *Acinetobacter* species, and *Pseudomonas aeruginosa*, while *Staphylococcus aureus* is the main Gram-positive organism observed in VAP.³ The occurrence of these organisms is reported to vary depending on factors such as the organism constituting epidemic concern in a specific ICU, length of patient hospitalization, continuous patient exposure to the organism, and duration of ventilator use.⁷ Diagnosis of VAP is based on key clinical indicators such as infiltrates on chest imaging, declining oxygenation, and changes in sputum quality.⁸ Furthermore, evidence reports that when these organisms invade the body, patients exhibit clinical symptoms including fever, hypoxemia, and purulent exudates.⁹ Hence, patients require prompt antibiotic treatment, as evidence indicates that 50% of antibiotic use in the ICU is related to VAP; unfortunately, antibiotic resistance complicates management, resulting in the higher mortality associated with VAP.^{10,11}

In this regard, a collection of evidence-based therapies, referred to as “care bundles,” has been introduced to improve outcomes for patients with VAP.¹² The VAP care bundle, as recommended by the Department of Health in the U.K., includes provision of regular oral hygiene, elevation of the head-end of the bed, administration of prophylaxis for stomach ulcers, and daily sedative interruptions. Other recommendations include subglottic aspiration, tracheal tube cuff pressure monitoring, and antiseptic oral hygiene.¹³ This evidence-based guideline, according to He *et al.*,¹⁴ has increasingly demonstrated effectiveness in reducing not only

VAP-associated mortality but also VAP-related complications.^{14,15}

To address VAP, care bundle was introduced among other measures to reduce prevalence and improve prognosis of VAP in the ICU.¹² Unfortunately, evidence shows that there is widespread inadequate knowledge among nurses regarding implementation of the VAP care bundle.^{10,16-18} Evidence opined that nurses’ knowledge is fundamental to providing evidence-based care to patients to improve outcomes for VAP patients.¹⁹⁻²¹

Although systematic reviews have been conducted on VAP,^{2, 22-24} they fall short of addressing the outcome measures considered in this review. Therefore, this review set out to determine intensive care nurses’ knowledge, compliance, and barriers to the implementation of ventilator-associated pneumonia care bundles to provide insight into improving outcomes for patients with VAP.

The objectives of this systematic review therefore are to determine intensive care nurses’ knowledge and compliance with ventilator-associated pneumonia care bundles. The study also aims to identify barriers encountered by intensive care nurses in implementing VAP care bundles.

Methods

This systematic review and meta-analysis were conducted in line with the recommendation of PRISMA 2020 guideline as obtained at <http://prisma-statement.org/prismastatement/checklist.aspx>

Eligibility criteria

According to Drucker *et al.*,²⁵ eligibility criteria help eliminate inclusion bias. Therefore eligibility criteria used in this study are as in Table 1.



Table 1: Table showing Inclusion and exclusion criteria and rationale

S/No	Study characteristic	Inclusion	Exclusion	Rationale
1	Population	Intensive care nurses	Other categories of healthcare workers and nurses not working in ICU	To meet the objective of the study
2	Exposure	VAP care bundle	Other non-standardised care	To enable standards for comparing outcomes across different studies
3	Outcome	Knowledge, adherence, and barriers	Outcomes other than Knowledge, adherence, and barriers	To meet the objective of the study
4	Study design	Quantitative, Non experimental studies	RCT, clinical trials or quasi-experimental studies, qualitative studies	To meet the objective of the study
5	Date of publication	2008 to 2023	Articles before 2008	To be able to access the current set of evidence
6	Peer review	peer review articles	Non peer review articles such as thesis	To ensure the credibility of the findings

Information Sources

The information sources for this systematic review were three online databases. They are Web of Science, PUBMED, and EMBASE.

Search Strategy

The Boolean operator is regarded as the backbone of an effective literature search in databases, as it enables various databases to identify a wide range of literature for potential review.²⁶ According to Exlibiris²⁷ the Boolean operators used include "OR," "AND," and "NOT." The "OR" Boolean operator is reported to be used to broaden searches; the "AND" operator is used to link groups of search terms to ensure that both terms appear in the search results, while the "NOT" operator is used to restrict search terms and help exclude articles containing such terms. According to Grewal *et al.*²⁸ the use of "NOT" should be applied cautiously, as it removes articles without giving researchers the opportunity to review such articles.

The search for articles for this review was therefore conducted using MeSH terms and relevant keywords in three databases (PUBMED, Web of Science, and EMBASE). The search terms

used therefore were: ("ICU nurses" OR "Nurses" OR "Intensive care nurses" OR "Critical care nurses" OR "critical care nursing") AND ("VAP care bundle" OR "VAP bundle" OR "Ventilator associated care bundle" OR "Ventilator associated bundle" OR "Ventilator acquired pneumonia care bundle" OR "Ventilator associated pneumonia bundle") AND (Knowledge OR Awareness OR Understanding) AND (adherence OR Compliance OR Observance) AND (Barriers OR Obstacles OR Challenges OR Difficulties).

Study Selection and Search Result

Study selection was conducted following the PRISMA template. Selection was performed independently by D.H. and E.J. Where discrepancies occurred between studies, a third reviewer, L.N, served as a tiebreaker. The selected databases were searched, and duplicates were manually removed; thereafter, the reviewer subjected the articles to title and abstract screening, followed by full-text screening based on the inclusion criteria previously established for the study. Limiters such as year of publication and English language were also applied to guide the screening process.



Data Collection Process

For research articles that met the inclusion criteria, the data collection process was conducted by D.H. and R.K.T. using spreadsheets.

Data Item

According to Tawfik *et al.*²⁹ information extracted from individual studies is essential because systematic reviews rely on such data for analysis and characterization of included studies; therefore, this step should be undertaken meticulously. The information extracted for this review included author, year of publication, country, years of nurses' experience, sample size, components of the VAP care bundle, results on knowledge, adherence, and barriers, and finally, conclusions. Based on the recommendation of Hamina *et al.*³⁰ that more than one individual should perform this stage, data extraction was conducted independently by two reviewers (D.H. and H.H), and discrepancies were resolved through discussion.

Risk of Bias/Critical Appraisal

All 11 studies that met the inclusion criteria for this review were subjected to critical appraisal. According to Young and Solomon³¹, critical appraisal is a scientific methodological process through which the trustworthiness and rigor of a research article are assessed against a standard benchmark. In this regard, Harrison *et al.*³² recommended the use of a protocol or checklist appropriate to the methodology of the included studies. Based on this recommendation, the appraisal tool for cross-sectional studies (AXIS) was adopted for this review. AXIS is a 20-item

tool divided into five sections: introduction, methods, results, discussion, and other components. The 20 questions address different aspects of these sections. According to Downes *et al.*,³³ the AXIS tool is uniquely developed, flexible for use across disciplines, particularly in health research, and easy to use even for beginners; hence, it is preferred over other appraisal tools. Two researchers (JEM and IAB) independently appraised the studies. Studies were graded as very low risk of bias if they scored 19–20 points, low risk for scores of 17–18, moderate risk for scores of 15–16, and high risk of bias for scores of 14 or less.³⁴ The appraisal of the included studies are as shown on Table 2

Data Analysis

Regarding analytical methods, studies that provided sufficient information for inclusion in a meta-analysis were pooled to determine pooled effect size statistics. Comprehensive Meta-Analysis software (CMA) version three was used. Additionally, a random-effects model with event rate and p-value was applied. A p-value of >0.05 was used to determine statistical significance. The random-effects model was applied due to anticipated heterogeneity among studies. The I² value was used to assess study heterogeneity. Lastly, narrative synthesis using themes and subthemes was applied for non-homogeneous outcomes to identify barriers to implementing the VAP care bundle



Table 2: Table showing the summary of critical appraisal using Axis

		Alou sh <i>et</i> <i>al.</i> ³⁵	Dumbre ³⁶	Abad, Formalejo and Mantaring ³⁷	Aloush and Al- Rawajfa ³⁸	Alkhazali, Bayraktar and Al- Mugheed ³⁹	Al- Sayaghi ⁴⁰	Bankanie <i>et al.</i> ⁴¹	Jansso n <i>et</i> <i>al.</i> ⁴²	Jansson <i>et</i> <i>al.</i> ⁴³	Ali <i>et al.</i> ⁴⁴	Yeganeh <i>et</i> <i>al.</i> ⁴⁵
1	Clear aims and objectives for the study	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
2	Is the design appropriate for the stated aim	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
3	Is the sample size justified?	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No	Yes
4	Clearly defined population	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
5	Appropriate sample size	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
6	Representativeness of the population	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
7	Measures put in place to address and categorize non-respondents	No	No	Yes	No	No	No	No	No	No	No	No
8	Appropriateness of the outcome to the aims of the study	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
9	The validity and reliability of the instrument reported	Yes	Yes	yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
10	Statistics of the instrument tested	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
11	Were the methods of the study sufficiently described	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
12	Were the basic data sufficiently described	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
13	Response rate reported	Yes	Yes	No	Yes	Yes	Yes	Yes	Yes	Yes	No	Yes
14	Information about non-respondents described?	No	No	No	No	No	No	No	No	No	No	No
15	Were results internally consistent	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
16	Were all results presented for all analysis	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
17	Were the discussion and conclusion justified by the results	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
18	Were the limitations of the study discussed	Yes	No	No	Yes	Yes	Yes	Yes	Yes	No	Yes	Yes
19	No conflict of interest identified?	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
20	Were ethical approval and consent obtained?	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
TOTAL		18/20	17/20	17/20	18/20	18/20	18/20	18/20	18/20	17/20	16/20	18/20
INTERPRETATION		Low Risk	Low Risk	Low Risk	Low Risk	Low Risk	Low Risk	Low Risk	Mode rate Risk	Low Risk	Moderate Risk	Low Risk
DECISION		Accepted	Accepted	Accepted	Accepted	Accepted	Accepted	Accepted	Accepted	Accepted	Accepted	Accepted

Very low risk (VLR) = 19-20 points; low risk (L.R.) for bias = 17-18; moderate risk (M.R.) = 15-16; high risk (H.R.) for bias= 14 or less. 34



Characteristics of Included Studies

Eleven studies that met the inclusion criteria and passed the critical appraisal were included in this study. Overall, 1839 critical care nurses across eight countries participated in the various studies included in this review. There were more female than male participants in the studies. The study of Aloush *et al.*³⁵ had more research participants with a sample size of 471. However, the study cut across three countries, i.e., Jordan, Egypt, and Saudi Arabia, while the study of Ali *et al.*⁴⁴ had the smallest sample size of 45 participants. With regards to the classification of the countries based on the World Bank classification of the countries based on income⁴⁶, seven studies^{36-39, 41,44,45} were conducted in lower-

middle-income countries, while only three studies^{40,42,43} were conducted in high-income countries. On the other hand, only the study of Aloush *et al.*³⁵ was conducted across three countries; two of the countries were lower-middle-income countries, while one (Saudi Arabia) was a high-income country. About the study design, all the 11 research articles included were survey designs.

Findings from Meta-Analysis

Nurses Knowledge of VAP care bundle

The Figure 1 shows the result of six studies that were used for the meta-analysis to determine the knowledge of nurses with regards to VAP care bundle.

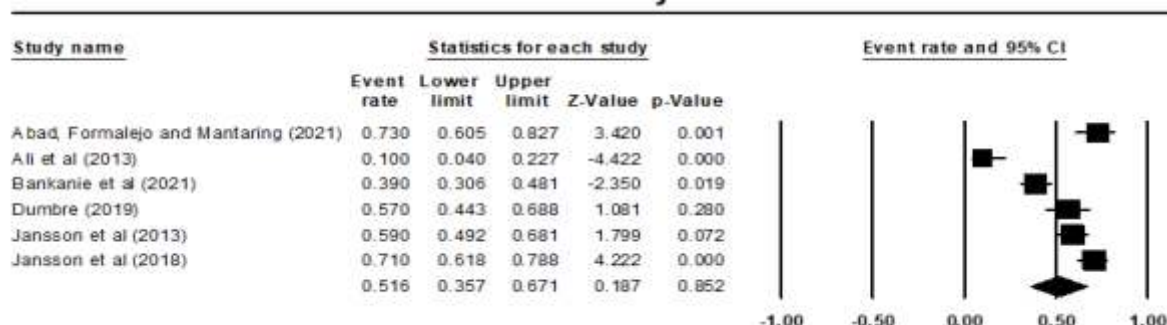


Figure 1: Nurses' Knowledge of VAP care bundle

Heterogeneity Q value=53.753, df=5, I²=90.698, p value=0.000

Figure 1 shows the knowledge of nurses to VAP care bundle; six studies provide sufficient information and were therefore included for meta-analysis. The pool effect results of nurses knowledge with VAP care bundle reveals an event rate of 51.6% or 0.516 (CI: 0.357-0.671) with the p value of 0.852. The heterogeneity I² was found

to be 90.698 indicating a large level of heterogeneity exists bases on the rule of thumbs.

Nurses' compliance with VAP care bundle

Of the eleven studies included for this review, Figure 2 shows nine reported compliances of nurses to VAP care bundle and provided sufficient information for meta-analysis.

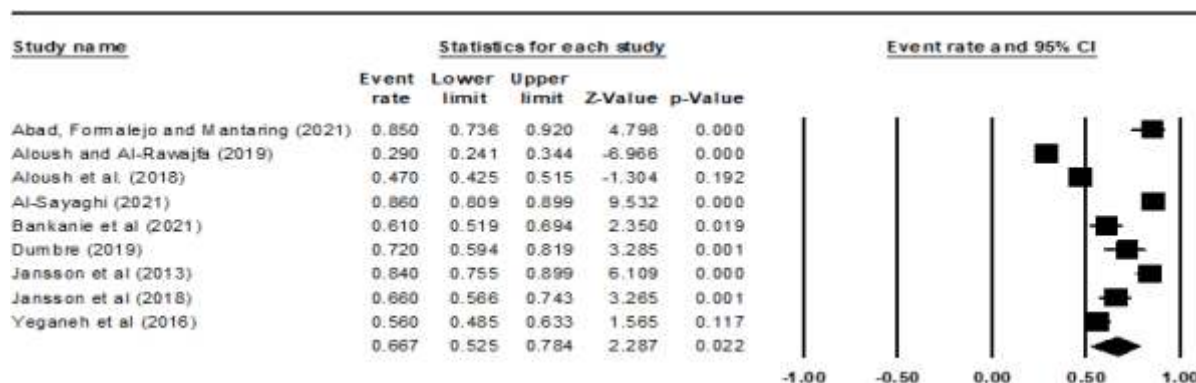


Figure 2: Compliance of nurses to VAP care bundle

Heterogeneity Q value=217.192, I²=96.317, p value=0.000

Nine studies that reported on compliance of nurses to VAP care bundle and provided sufficient information for meta-analysis. The pool effect result of compliance to VAP bundle among nurses reveals an event rate of 0.667 or 66.7% (CI: 0.525-0.784). The p value of the outcome was 0.022 indicating a statistically significant finding with regards to the compliance of nurses to the VAP care bundle among the studies reviewed as shown on Figure 2

Barriers of Nurses to Adhering to VAP Care Bundle

There was no sufficient information for meta-analysis for this outcome measure, and they were, therefore, narratively analyzed. Findings reveal that lack of

knowledge regarding the VAP care bundle was the most commonly reported barrier to the implementation of the bundle. Six of the eleven studies included in this review reported a lack of knowledge.^{35,37,38,41-43} Additionally, four reported inadequate equipment as a barrier to implementing the VAP bundle^{38,39,42,43}, while three studies reported a lack of guidelines and or protocol.^{37,38,43} Other barriers reported were inconsistency of research findings, forgetfulness, shortage of manpower, and lack of skills reported by two studies each. Others reported by one study are lack of mentorship, patient discomfort, inadequate budget, and lastly, role ambiguity. Details of the factors are shown in Table 3.

Table 3: Data extraction table

S/No	Reference	Country	Sample size (n)	VAP Bundle	Research design	Result			Recommendation
						Knowledge	Adherence	Barriers to Compliance	
1	Aloush <i>et al.</i> ³⁵	Jordan (n=185) Egypt (n=200) Saudi Arabia (n=88)	471 Male (233) Female (238)	1. Perform oral hygiene per shift at a minimum 2. Use chlorhexidine for oral hygiene 3. Evaluate suitability for weaning daily 4. perform hand hygiene 5. Use of sterile gloves 6. Positioning the patient on a semi-flower 7. Do not use normal saline for irrigation in suction	Self-reported cross-sectional survey	Not reported	The average compliance of Nurses across all VAP bundles was 47% with a mean score of 12.3 (SD = 3.2)	1. Lack of education 2. lack of mentorship 3. poor use of research findings	Update curriculum of undergraduate nurses to include VAP care bundle
2	Dumbre ³⁶	India	60	Position the head-end sedation breaks	Exploratory survey	Findings reveal that 56.7% had excellent	71.7% of the respondents had good compliance		A positive significant association exists between



				Perform oral wash with chlorohexidine Perform subglottic suction with endotracheal tubes Provide prophylaxis for DVT Provide prophylaxis for peptic ulcer	research design	knowledge regarding to VAP bundle			knowledge and compliance
3	Abad, Formalejo and Mantaring ³⁷	Philippines	60: Nurses 56(Male 17 and Female 26) ICP 4(Male 3 and female 1)	1. elevate the head-end of the bed 2. Subglottic excretion drainage 3. assess daily readiness to extubate 4. offer DVT prophylaxis 5. conduct a closed suctioning system 6. Perform oral hygiene	Cross-sectional survey	73.33% of respondents had good knowledge of the VAP bundle	Self-reported adherence to the VAP care bundle was reported to be 84.6%.	1. Lack of guideline 2. Patient discomfort 3. Lack of education	There is a need for formal training and on-the-job mentorship for practitioners
4	Aloush and Al-Rawajfa ³⁸	Jordan	294 (Male 150, Female 144)	Perform regular hand hygiene Continuous patient education Regular use of gloves	Cross-sectional descriptive	Not Reported	Compliance of nurses with the VAP bundle was 29.6%	1. Lack of education 2. lack of guidelines and protocols 3. Lack of required equipment	On-the-job training and provision of equipment and supplies



				Subglottic suctioning of secretion Elevate the head-end of the bed Conduct regular oral hygiene				nt and supplies	
5	Alkhazali, Bayraktar and Al-Mugheed ³⁹	Jordan	185 (Male 77 and female 108)	Perform regular hand hygiene Continuous patient education Regular use of gloves Subglottic suctioning of secretion Elevate the head-end of the bed Conduct regular oral hygiene	Cross-sectional survey	The mean knowledge of the VAP bundle was 19.6 6 (3.43) which is 65.3%	Not reported	1. Lack of equipment (65.9%) 2. Forgetfulness to practice the sterile techniques (54.1%), 3. Lack of time to practice IPC measures (53.0%)	Education of nurses on VAP prevention is critical for the implementation of the VAP bundle
6	Al-Sayaghi ⁴⁰	Kingdom of Saudi Arabia	229 (Male 15 and female 214)	Perform Hand hygiene Use sterile gloves Consistent oral hygiene using chlorhexidine Monitor endotracheal tube pressure frequently Suction subglottic secretion Positioning of patients	Cross-sectional descriptive survey	Not reported	Compliance score was 85.9%	1. Shortage of nursing staff 2. Forgetfulness 3. Lack of adequate financial budget	Continuous professional development for nurses with regards to VAP as well as recruitment of staff



7	Bankanie <i>et al.</i> ⁴¹	Tanzania	116	Elevate the head-end of the bed Sedation Breaks Assess patients' readiness to extubate Perform oral hygiene with chlorhexidine Offer peptic ulcer prophylaxis Offer dvt prophylaxis	Cross-sectional survey	Knowledge of nurses was reported to be 38.6%	Self-reported compliance was 60.8%	1. Lack of skills (96.6%) 2. Inadequate staff (95.5%) 3. Lack of knowledge (79.3%)	Recommended continuous professional training of nurses on the VAP care bundle
8	Jansson <i>et al.</i> ⁴²	Finland	108	Patient positioning Perform oral hygiene with chlorhexidine Perform regular hand hygiene Subglottic suctioning of exudates	Cross-sectional survey	Knowledge regarding the VAP bundle was 71.1%	Self-reported adherence to the care bundle was 65.8%	1. role ambiguities 2. lack of education 3. inadequate resources	Recommends on-the-job training and encourages nurses to further studies and obtain higher education to serve as mentors.
9	Jansson <i>et al.</i> ⁴³	Finland	101	1. change the ventilator circuit only on the indication 2. perform hand sanitation 3. offer ongoing training and education for staff 4. Sedation break and adherence to weaning guidelines	Cross-sectional survey	Knowledge of VAP bundle among nurses 59.9%	self-reported adherence was 84.0%.	1. inadequate resources 2. inconsistencies with research 3. lack of time, 4. Lack of skills,	On-going professional education



				5. Use of chlorhexidine for oral hygiene				5. Lack of knowledge 6. Lack of guidelines	
10	Ali <i>et al.</i> ⁴⁴	Egypt	45	Perform hand hygiene Positioning of patients Perform endotracheal Suctioning care Conduct regular ventilator circuit care Perform oral hygiene Testing of enteral feeding and offering prophylaxis for Peptic ulcer Assess readiness for weaning and extubation Offer DVT prophylaxis	Descriptive exploratory design	Only 10% had satisfactory knowledge	Compliance (average mean = 8.62 + 7.9 out of 29)	Not reported	On-the-job training
11	Yeganeh <i>et al.</i> ⁴⁵	Iran	171	Perform Hand hygiene Use of sterile gloves	Cross-sectional survey	Not reported	Mean compliance was 56.32%	Not reported	Develop and implement strategies for improving nurses' knowledge and compliance with the VAP bundle



				Perform oral hygiene using chlorhexidine					
				Monitor endotracheal tube pressure often					
				Suctioning of the subglottic secretion					
				Positioning of patients					

VAP= ventilator Associated Pneumonia, ICP= infection control preventionists, IPC= infection prevention control

Results

Search Results

The systematic literature search was conducted across three electronic databases: PubMed [n=08], Web of Science [n=14], and EMBASE [n=10]. Cumulatively, a total of 34 articles published between 2008 and 2023 were retrieved from the three databases. Three duplicate studies were identified manually and removed, leaving 21 articles for screening. Screening was initially conducted by title review, followed by abstract screening and then full-text review. After the screening process, thirteen articles were excluded based on the previously established eligibility criteria, leaving eight articles for critical appraisal. All eight studies passed appraisal and were included in the review. Reference

lists of the eight included studies were searched to identify grey literature. Four additional articles meeting the inclusion criteria were identified; however, one could not be retrieved despite contacting the author via email and searching for alternative sources. Consequently, only three articles identified through reference lists were critically appraised, all of which met inclusion requirements and were included.

Overall, 11 articles that met the inclusion criteria and passed critical appraisal were included in this review to determine nurses' knowledge, compliance, and barriers related to ventilator-associated pneumonia. The details of the steps of the screening leading to the inclusion of the studies are presented in Figure 3



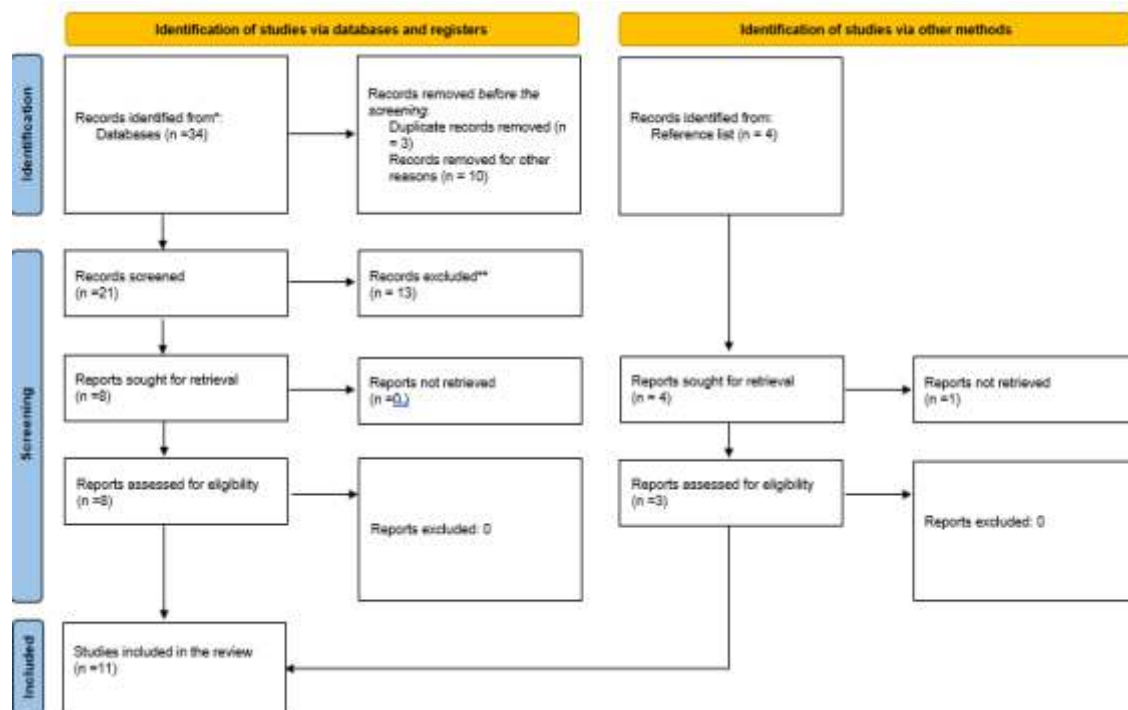


Figure 3: PRISMA Flow Chart

Critical Appraisal/Risk Assessment

Result from the risk assessment shows that studies included were either low risk or moderate as shown on Table 2. Consequently to this, the articles were accepted to inclusion in this review. Refer to Table 2 for details outcome of the appraisal and decision.

Discussion

This review examined critical care nurses' knowledge, compliance, and perceived barriers related to the implementation of VAP care bundles. Eleven studies that met the inclusion criteria and spanned different countries and regions were included. Overall, more studies originated from low- and middle-income countries (LMICs) than from high-income countries (HICs). According to Arabi *et al.*⁴⁷, ventilator-associated pneumonia remains a more significant challenge in developing countries than in developed settings, with substantially higher associated mortality. This disparity may explain the higher volume of research emerging from LMICs and likely reflect a response to the increased burden and challenges of VAP in these regions.

With respect to study participants, this review focused on intensive care unit (ICU) nurses, as the objective was to assess their knowledge, compliance, and barriers related to the VAP care bundle. In total, 1,839 ICU nurses participated across the 11 included studies. Vincent *et al.*⁴⁸ reported that intensive care nursing consistently faces workforce shortages due to

the specialized nature of the role and the high workload, which often leads to burnout. This may account for the relatively modest sample sizes observed in some of the included studies, particularly given that most employed cross-sectional designs, where larger sample sizes are typically expected.

Regarding nurses' knowledge of the VAP care bundle, the pooled effect from six studies indicated an average level of knowledge. Closer examination revealed that only two of these studies were conducted in high-income settings^{42,48}, both from Finland, while the remaining four were from lower-middle-income countries. Consequently, caution is required when interpreting and generalizing these findings to high-income countries, as contextual differences may influence knowledge levels. The average knowledge level identified in this review contrasts with the findings of Al-Mugheed *et al.*⁴⁹, whose systematic review in the Eastern Mediterranean region reported low levels of nurses' knowledge regarding the VAP care bundle. Evidence suggests that inadequate knowledge among nurses is a major contributor to the

persistence of VAP in ICUs, with adverse implications for patient recovery, length of hospital stay, and healthcare costs.^{10,50} In this regard, evidence emphasized that improving ICU nurses' knowledge is fundamental to enhancing patients' quality of care and outcomes.³⁹ Similarly, evidence highlighted that targeted job training and advanced professional certification are practical strategies that hospital administrators can adopt to improve nurses' knowledge of VAP care bundles.¹⁰

Compliance with evidence-based VAP guidelines by ICU nurses has been shown to significantly reduce the incidence of ventilator-associated pneumonia.^{51,52} The pooled analysis of nine studies in this review demonstrated a statistically significant high level of compliance with VAP care bundles. Notably, this finding was derived from evidence rated as good to excellent quality based on the critical appraisal of the included studies. Of the nine studies assessing compliance, three were conducted in high-income countries and six in lower-middle-income countries. All studies from high-income countries reported high compliance, whereas only half of those from lower-middle-income countries reported similarly high levels. Therefore, although the overall pooled estimate indicates high compliance, interpretation and application of this finding should be approached with caution in light of these contextual differences. The high compliance reported in this review contrasts with the findings of Al-Mugheed *et al.*⁴⁹, who reported inadequate compliance with VAP care bundles, but aligns with the findings of John *et al.*⁵³, who observed high compliance among ICU nurses. These discrepancies may be attributed to geographical and economic differences, as Al-Mugheed *et al.*⁴⁹ focused primarily on the Eastern Mediterranean region, largely comprising LMICs, whereas John *et al.*⁵³, like this review, imposed no geographical restrictions. Furthermore, most studies included in this review relied on self-reported measures of compliance, which introduces the potential for reporting bias and may not accurately reflect actual clinical practice. This further underscores the need for cautious interpretation of the compliance findings.

Finally, the review assessed barriers to the implementation of the VAP care bundle. The most frequently reported barriers were inadequate knowledge of the VAP bundle, insufficient equipment, and the absence or unavailability of VAP protocols and guidelines. Similar barriers related to

knowledge deficits and lack of protocols were also identified in the systematic review by Al-Mugheed *et al.*⁴⁹ The issue of inadequate equipment was predominantly reported in studies conducted in lower-middle-income countries and has likewise been highlighted.⁵⁴ These findings emphasize the need for adequately resourced ICUs, supported not only by well-trained personnel but also by accessible guidelines and sufficient equipment to ensure effective delivery of care.^{53,55}

Summary and Conclusion

This review provides valuable insight into ICU nurses' knowledge, compliance, and barriers related to the implementation of ventilator-associated pneumonia care bundles. The findings indicate an overall average level of knowledge that was not statistically significant, alongside a statistically significant high level of reported compliance. The review also identified lack of knowledge, inadequate equipment, and absence of protocols as the major barriers to effective implementation of the VAP care bundle. Based on these findings, the study recommends that future research employ observational designs to objectively assess compliance and validate the predominantly self-reported compliance documented in existing studies.

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Competing Interest

The authors declare no competing interests.

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