BMC Nursing

RESEARCH Open Access

Intensive and critical care nurses' compliance, barriers, and challenges with ventilator-associated pneumonia prevention: a cross-sectional study

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Abstract

Background Ventilator-associated pneumonia (VAP) poses a significant challenge in critical care settings, impacting patient outcomes and healthcare costs. In Saudi Arabia, several studies have reported concerns regarding VAP, including variable VAP rates, inconsistent compliance with and knowledge of VAP prevention practices, and inadequate national data.

Objectives To investigate the intensive and critical care nurses' (ICCNs) self-reported perceived compliance with VAP prevention guidelines, barriers and challenges in caring for mechanically ventilated patients, the demographic variables that associate compliance and factors affecting VAP prevention, and the association between perceived compliance and the barriers affecting the care of mechanically ventilated patients.

Methods A descriptive, correlational, and cross-sectional design was used. ICCNs ($n = 152$) were conveniently recruited from two tertiary government-owned hospitals. Data were collected using self-report scales from April to June 2024. Descriptive and inferential statistics were used for data analyses.

Results Findings showed that 43% of ICCNs had high compliance with VAP prevention guidelines. The use of protective gloves at every approach to a patient (96.70%) was the VAP guideline that received the highest perceived compliance among ICCNs. Meanwhile, those with 11 to 15 years of experience were more compliant ($p = 0.023$) than other groups and demographics. Major barriers to compliance included nursing staffing shortages (94.10%) and limited resources (75.00%). Only ICCNs with 11 to 15 years of experience showed greater awareness of VAP prevention guidelines ($p = 0.023$). Nurses' nationality, i.e., non-Saudi nurses ($p = 0.024$) and higher educational levels ($p = 0.005$), demonstrated greater awareness of barriers to managing and caring for mechanically ventilated patients. ICCNs

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perceived barriers negatively influenced their perceived compliance with VAP prevention ($p = 0.002$), indicating that increased barriers are associated with lower compliance. Finally, the considerable challenges in VAP prevention were time constraints and the need for more communication among the health team.

Conclusion Staffing shortages and resource limitations impacted ICCNs' compliance with VAP prevention guidelines. Furthermore, they became less compliant with higher VAP barrier perceptions. Time constraints and team communication were considerable challenges in VAP prevention. As a result, nurse managers could create comprehensive programs like long-term VAP prevention training and interdisciplinary collaboration in the ICU. Healthcare organization administrators should enhance resource allocation and policy formulation to foster compliance.

Clinical trial number Not applicable.

Keywords Critical care nursing, Compliance, Healthcare barriers, Intensive care units, VAP prevention, Ventilator-associated pneumonia

Introduction

Ventilator-associated pneumonia (VAP) affects patient outcomes and healthcare systems worldwide [1]. VAP is a common consequence of mechanical ventilation in intensive and critical care units (ICCUs), usually appearing 48 h after intubation and perhaps lasting beyond ventilator removal [2, 3]. VAP increases mortality, hospital stays, and healthcare expenses [1, 4]. A narrative review reported that VAP occurrences in ICCUs are between 5 and 40% depending on clinical settings and diagnostic criteria [3]. A recent review of VAP in 2024 found that it affects 0–36% of critically ill patients [5], with incidence rates ranging from 2 to 16 episodes per 1000 ventilator days and impacted by factors such as diagnostic criteria, preventive treatments, and patient condition and geographical location [5, 6]. VAP mortality rates range from 24 to 76%, depending on severity of medical conditions and diagnostic heterogeneity of ICU patients [5]. Meanwhile, an analysis of different Saudi hospitals found a broad range of unit-specific VAP rates, highlighting the need for systematic data collection to compare with regional and worldwide standards [7, 8].

The International Society for Infectious Diseases (ISID) updated the VAP prevention practice guidelines in 2024 [9]. First, addressing the crucial prerequisites such as creating a VAP surveillance and prevention team, education and training, adequate staff, a dedicated laboratory, and an updated epidemiological bulletin for the healthcare team. Second, implementing VAP prevention strategies involves a multidimensional and multidisciplinary process [9]. Globally, a multifaceted approach including six core components was reported to be effective: bundle, education, surveillance, compliance monitoring, VAP rates, internal reporting, and performance feedback [9]. VAP prevention guidelines involve the 'bundle method.' This method combines numerous strategies such as head of bed elevation, hand and oral hygiene, and daily assessment of extubating preparedness of ICU patients [10, 11]. In Saudi Arabia, VAP rates from 2013 to 2017 across 22 hospitals and 37 ICUs were reduced using the multidimensional approach of VAP prevention guidelines [12]. Saudi nurse's compliance with the VAP bundle resulted in shortened hospital stays, fewer mechanical ventilation days, and reduced hospital costs [13].

Controlling VAP rates requires regular observation and using international preventative guidelines (e.g., ISID guidelines) and strategies (e.g., multidimensional approach) [4, 9, 12]. Moreover, understanding risk factors such oropharyngeal and stomach colonization and medicinal therapies may help reduce VAP [14]. However, healthcare professionals (e.g., doctors, intensive and critical care nurses [ICCNs]) discrepancies in compliance with VAP prevention guidelines further complicate the positive patient outcomes [11]. These discrepancies hamper preventative actions due to staffing shortages, economic limits, and clinical guideline complexity [7, 15]. Debates about the effectiveness and safety of certain preventative strategies, such as chlorhexidine oral care, demonstrate the dynamic nature of VAP prevention best practices [11]. However, VAP has the greatest influence on low- and middle-income healthcare systems [12].

Notwithstanding being a high-income country, Saudi Arabia's healthcare system faces rapid population growth, high costs, a growing burden of chronic diseases, a less-than-effective electronic health system, staffing shortages, and poor communication and coordination between other care sectors [16]. The Saudi Vision 2030, which commenced in 2016, features a comprehensive healthcare system transformation plan. The strategy seeks to improve patient-centered, innovative, and universal healthcare. It stresses preventative care and health education [17]. The Saudi government invested heavily in healthcare, increased university healthcare programs to boost student admission and graduation rates, and paid expatriate healthcare professionals competitively [16]. Thus creating sustainable healthcare with adequate personnel in all settings [16, 17].

Despite the clear guidelines and established preventive measures, compliance with VAP prevention protocols varies significantly, impacting patient outcomes and resource utilization in critical care settings [8, 9, 18]. The problem is compounded by ICCNs challenges, who are at the forefront of implementing these measures [7]. Research indicates that barriers such as inadequate staffing, forgetfulness, and institutional policies affect compliance levels [7, 8, 19]. These challenges are exacerbated by the barriers to implementing VAP preventive practices (e.g., inadequate supplies and equipment, nursing staff shortage, lack of competence, and breakdown in staff communication), which may deter compliance with best practices [8, 19, 20].

The paucity of nationally representative data in Saudi Arabia makes it difficult to assess VAP and healthcare system interventions [7, 8]. Variable VAP rates in the various regions indicate considerable practice and result disparities, requiring targeted interventions and consistent reporting [7, 8]. Given the impact of VAP on patient mortality, length of hospital stay, and healthcare costs, ICCNs' compliance with VAP prevention guidelines and the multifactorial challenges that affect mechanically ventilated patients' care must be assessed. These elements must be understood to improve ICU compliance and patient outcomes.

Donabedian's [21] theoretical framework illuminated this study by exploring ICCNs' compliance with VAP prevention guidelines and the barriers and challenges they face. Three critical elements compose Donabedian's framework for evaluating healthcare quality [21, 22]. Firstly, structural components represented by the VAP prevention guidelines may impact ICCNs' compliance behaviors. Secondly, the process element includes the implementation of the VAP prevention guidelines. This element ascertains the barriers and challenges experienced by nurses in complying with the VAP guidelines. Lastly, the outcomes element involves VAP and mortality rates, hospital stay, costs, and patient and nurse satisfaction. ICCNs' compliance with VAP prevention guidelines is the foundation of providing safe and quality care while recognizing and addressing barriers and challenges, which offers the opportunity to improve practice. Thus, it provides evidence to improve VAP prevention policies and enhance patient outcomes and nursing practice.

Previous studies explored Saudi ICCN's knowledge and compliance with VAP prevention before [7, 23] and during [13, 24, 25] the COVID-19 pandemic. In the post-pandemic setting, there could be changes in the state of VAP and how ICCNs in Saudi Arabia experience implementing VAP prevention guidelines. This healthcare issue necessitates continuous assessment and reporting to identify effective VAP prevention strategies. Hence, this study may provide current evidence on nurses' VAP prevention experiences in Saudi Arabia, which may also reflect similar situations in other countries. Considering the preceding VAP issues in Saudi Arabia, there is a compelling need to explore perceived compliance with VAP prevention protocols and identify the barriers and challenges to effective implementation among ICCNs in Saudi Arabia. Therefore, we investigated the ICCN's compliance, barriers, and challenges with the VAP prevention guidelines and evaluated the relationship between demographic factors, perceived barriers, and compliance levels.

Study objectives

This investigation addressed the following objectives: (a) to assess ICCNs' perceived compliance with VAP prevention guidelines, (b) to examine the barriers and challenges in caring for mechanically ventilated patients, (c) to determine the demographic variables that associate compliance and factors affecting VAP prevention, and (d) evaluate the association between perceived compliance and the barriers affecting the care of mechanically ventilated patients.

Methods

Study design

We utilized a descriptive, cross-sectional survey design to assess the perceived compliance of ICCNs with VAP prevention guidelines and identify the factors and challenges that affect such compliance. This design allows the examination of practices and perceptions at a specific time, allowing for a broad, quantitative data analysis across multiple settings [26]. We adhered to STROBE checklist in reporting the results in this investigation (Supplementary file S1).

Setting

The research was conducted in the ICUs of two tertiary, government-owned hospitals in Mecca, Saudi Arabia (Al Noor Specialist Hospital [ANSH] and King Abdullah Medical City [KAMC]). ANSH is supervised by the Health Affairs Directorate in Mecca, located in the city center near the holy sites (Muzdalifah) and approximately 3.5 km from the Grand Mosque. This hospital provides specialized healthcare services to citizens, residents, and pilgrims of the Holy City and its surrounding region. KAMC is a tertiary 500-bed hospital complex in Mecca that caters to diverse medical-surgical clientele. These hospitals were selected based on their high volume of critical care cases and the diversity of their patient demographics, which provided a comprehensive setting for understanding VAP prevention practices among ICCNs.

ANSH and KAMC VAP policies were anchored on the ISID and Centers for Disease Control and Prevention guidelines. These hospitals are government-owned and

comply with the hospital infection prevention and control policy the Ministry of Health (MOH) set forth. The MOH policy also explicitly articulates VAP standard prevention guidelines that all hospitals and healthcare facilities in Saudi Arabia should comply with. Nursing staff in these hospitals are trained/retained every 1 to 2 months or when there is an increasing incidence of VAP and evaluated between 4 and 6 months. The hospital infection control team will conduct surveillance and retraining of nursing staff when the ICCUs experience increased VAP rates, and their units' VAP prevention guidelines evaluation scores are moderate to low compliance.

Participants

This study employed a convenience sampling technique to select ICCNs from the study settings. The inclusion criteria included ICCNs working in ICUs for at least one year, where mechanically ventilated patients are cared for. These nurses implement VAP prevention guidelines in their respective ICUs. Non-ICU and ICU nurses with less than one year of experience in the study setting were excluded from participating. ICCNs with at least one year of ICU experience were recruited to ensure they possess sufficient knowledge and expertise in managing mechanically ventilated patients. Participants were selected based on their availability and willingness to participate at the respective hospitals during the data collection period. They were approached to participate via posters on their bulletin board, online invitations via group chats and emails, and referrals from their head nurses and colleagues. The hospital directors and chief nurses granted permission to recruit participants in the study setting. A total of 211 ICCNs were invited and 152 participated in the study (response rate: 72.03%) (Fig. 1). The sample size was computed using a 5% margin of error, 95% confidence level, a population size of 211, and 50% response distribution [27]; the minimum sample size

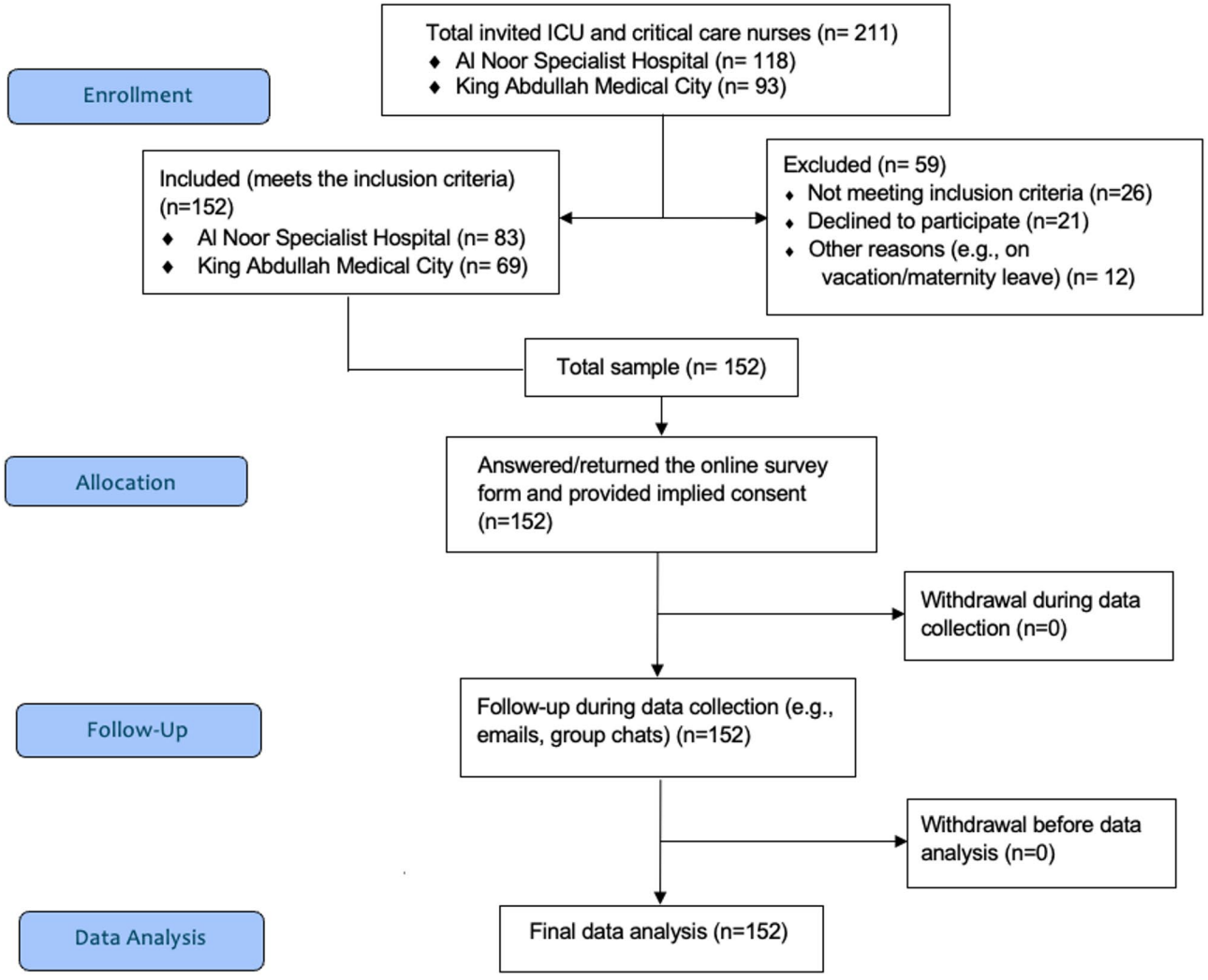

Fig. 1 Flowchart of participant enrolment

was 137. Hence, the number of participants in this study was adequate.

Instruments

Data were collected using a structured questionnaire consisting of four sections. Section "Introduction" included the sociodemographic characteristics of the ICCNs (e.g., nationality, age, gender, highest educational attainment, years of experience as an ICCN, years of employment in the current hospital, and the hospital currently employed).

Section "Methods" included the 17-item compliance with VAP prevention guidelines adopted with permission from Al-Sayaghi [7]. A three 3- point Likert scale (0 = never to 2 = always) was used to rate each item. The total scores of compliance range from 0 to 51 points. Total scores below the 50th percentile (less than 30) indicate unsafe compliance. Scores from the 50th to the 75th percentiles (30–32) denote acceptable compliance. Scores above the 75th percentile (over 32) imply high compliance. The tool's original Cronbach alpha was 0.79 [7] and 0.88 for this study.

Section "Results" consisted of 15 statements focusing on the factors (i.e., barriers) that affect the ICCNs' compliance with the VAP prevention guidelines adopted with permission from Al-Sayaghi [7]. Each statement is rated on a 3-point Likert scale with agree (1), neither agree nor disagree (2) or disagree (3) responses. The scores range from 15 to 45, with higher scores indicating increased barriers. The previous alpha was 0.79 [7], while in this study, it was 0.87.

Section "Discussion" comprised close-ended questions to determine the challenges encountered in the care of mechanically ventilated patients by ICCNs. These questions provided predefined responses, enabling respondents to select the option that best described their experiences. The use of closed-ended questions facilitated the systematic analysis and comparison of the data collected.

The original author psychometrically tested the instrument among nurses in Saudi Arabia [7]. The instrument underwent content validation by three experts (2 nursing professors and one hospital nursing director). The content validity index of the instrument was 0.87, indicating good internal validity [26]. Afterward, the instrument was pilot-tested among 15 ICU nurses to determine its reliability. The overall Cronbach's alpha was 0.88, indicating good reliability [26]. No items were removed and administered in English since all nurses working in the study settings were English literate.

Data collection

We collected data within three months (April to June 2024). To maintain ethical standards, transparency, and protection of participants, they were thoroughly informed about the study's objectives, the confidentiality of the data, and the voluntary nature of their participation. Each participant provided implied consent after submitted the online survey forms, acknowledging their understanding and agreement to partake in the study. To facilitate the process of data collection and to allow for ease of access for participants, the questionnaires were distributed using Google Forms. This digital method proved efficient for data collection and subsequent analysis, as it streamlined gathering responses and enabled real-time data compilation [26, 28]. The use of an online platform also minimized physical contact and scheduling conflicts [29], which was particularly advantageous given the critical care settings and the busy schedules of the ICCNs. A research assistant helped the researchers in facilitating data collection. The collected data was stored in a password-protected laptop accessible only to the researchers.

To minimize response bias, the survey instruments during data collection were well-structured, simple, short, and straightforward (e.g., no leading questions, 3 = option Likert scale); validated the instruments; 5 to 10 min to answer the survey; and strictly followed the inclusion/exclusion criteria.

Data analysis

We analyzed the data using SPSS software (version 23). Descriptive statistics (e.g., frequency, percentage, mean, standard deviation) were used to summarize the demographic data, compliance, and barriers responses. Inferential statistics, including t-tests (i.e., to determine the difference between the means of two groups [e.g., male vs. female]) and analysis of variance (ANOVA) (i.e., comparing the means of two or more groups [e.g., educational level, years of experience]) were employed to explore differences among the demographic variables in relation to VAP prevention guidelines compliance and perceived barriers. Simple linear regression analysis was used to determine the association between compliance with VAP prevention guidelines and barriers. A p-value of < 0.05 indicates statistically significant.

Ethical considerations

Ethical approval was obtained from the Institutional Review Board (IRB) of the University of Hail (Protocol number: H-2024-091; approved: 04/03/2024). Permission to conduct the study was secured from the involved hospitals after providing the intent letter, ethics approval, and accomplishment of documentary files (e.g., application letter, permit to conduct study forms). An online survey form was used for data collection. The first part of the form contains the description of the study (e.g., study purpose/objectives, participants' rights) and the

informed consent forms. Implied consent was secured when participants completed and submitted the survey form [26]. This process ensured that voluntary participation was maintained during the study. Participant anonymity (i.e., no collection of personal information) and data confidentiality (i.e., data was stored in a password-protected laptop accessible only to the researchers who were directly involved in data collection) were observed throughout the study. Finally, all authors adhered to the Declaration of Helsinki when conducting research involving human participants.

Results

Demographic profile of the participants

Supplementary Table S1 shows the socio-demographic profile of the participant ICNNs from the two largest government-owned hospitals in Mecca Region, Saudi Arabia. The majority of the ICCNs were male (67.10%), 31 to 40 years old (65.80%), and Saudi nationals (69.00%). Most of them were married (68.40%), earned a Bachelor's degree (69.10%), had 6–10 years of work experience (49.30%), and were employed in ANSH (54.60%).

Level of self-reported perceived compliance with VAP prevention guidelines

Table 1 shows the level of self-reported perceived compliance of ICCNs regarding VAP prevention guidelines. The highest self-reported perceived compliance was observed in the "*use of protective gloves at every approach to a patient*" (96.70%). This compliance was followed by "*used heat and moisture exchanger humidifiers*" (94.70%) and "*always utilized closed-circuit suction systems*" (93.40%). Notably, the three VAP guidelines that received the least compliance were "use chlorhexidine solution for oral care" (51.30%), "use sterile gloves when open suction is necessary" (68.40%), and "handwashing before any approach to a patient" (73.70%). Meanwhile, 43% of ICCNs are highly compliant, with 34% acceptable and 23% unsafe self-reported perceived compliance (Supplementary Fig. S1).

Difference between participants' demographic variables and their level of self-reported perceived compliance with VAP prevention guidelines

Table 2 shows the relationship between the demographic data of ICCNs and their self-reported perceived compliance with VAP prevention guidelines. Non-Saudi nurses showed slightly higher compliance (M = 31.40) than Saudi nurses (M = 30.89). Married nurses showed the highest compliance mean score (M = 31.35). Nurses with a Master's degree had slightly higher compliance (M = 31.30) than nurses with a Bachelor's degree (M = 30.92). Compliance increased with years of experience, with nurses having 11–15 years of experience showing the highest score (M = 32.03). Only 11 to 15 years of experience showed a statistically significant difference ($p = 0.023$) compared to other groups and demographics.

Factors affecting the care of mechanically ventilated patients

Table 3 illustrates the factors that significantly impact the care of ICCNs for mechanically ventilated patients. These factors, which were the barriers to compliance with VAP prevention guidelines, have a profound effect on patient care. The majority agreed that a shortage of nursing staff was a major impediment to compliance (94.1%). Another

Table 1 Compliance of critical care nurses with VAP prevention guidelines ($n = 152$)

Items	Never		Sometimes		Always	
	f	%	f	%	f	%
1. Handwashing before any approach to a patient.	1	0.7	39	25.7	112	73.7
2. Use of protective gloves at every approach to a patient.	0	0.0	5	3.3	147	96.7
3. Handwashing after any approach to a patient.	1	0.7	31	20.4	120	78.9
4. Use of closed-circuit suction systems.	1	0.7	9	5.9	142	93.4
5. Change the closed-circuit suction systems for every new patient (or when clinically indicated).	1	0.7	17	11.2	134	88.2
6. Use sterile gloves when open suction is necessary.	3	2.0	45	29.6	104	68.4
7. Provide regular oral care at least once per shift.	0	0.0	35	23.0	117	77.0
8. Use chlorhexidine solution for oral care.	0	0.0	74	48.7	78	51.3
9. Use the heat and moisture exchanger humidifiers.	1	0.7	7	4.6	144	94.7
10. Change the heat and moisture exchanger humidifiers weekly or when clinically indicated.	2	1.3	14	9.2	136	89.5
11. Change ventilator circuit only when visibly soiled or malfunctioning.	2	1.3	24	15.8	126	82.9
12. Check the endotracheal tube cuff pressure at least once per shift and maintain it at 20–30 cm H2O.	2	1.3	21	13.8	129	84.9
13. Suction of the subglottic secretions through an extra lumen in the endotracheal tubes.	2	1.3	22	14.5	128	84.2
14. Provide scheduled and regular respiratory physiotherapy.	2	1.3	24	15.8	126	82.9
15. Interrupt sedation daily and assess readiness to extubate by daily spontaneous breathing trials.	0	0.0	17	11.2	135	88.8
16. Maintain the patient in a semi-fowler position.	0	0.0	15	9.9	137	90.1
17. Use of kinetic beds.	2	1.3	9	5.9	141	92.8

Table 2 Differences in the level of compliance when grouped according to profile variables ($n = 152$)

Variables		f	Mean	SD	test	*p*-value
Gender	Female	102	-0.582	31.10	t = 0.228	$p = 0.820$
	Male	50	-0.582	30.96		
Age	20–30 years	43	4.13	30.93	F = 0.036	$p = 0.964$
	31–40 years	100	3.27	31.10		
	41–50 years	9	3.06	31.11		
Nationality	Saudi	105	3.75	30.89	t=-0.828	$p = 0.409$
	Non-Saudi	47	2.88	31.40		
Marital status	Single	43	4.01	30.35	F = 01.240	$p = 0.292$
	Married	104	3.26	31.35		
	Divorced	5	3.46	31.00		
Educational Level	Diploma and Bachelors	106	3.32	30.94	F = 0.342	$p = 0.711$
	Master's	46	3.90	31.30		
Years of experience	1–5 years	32	5.54	29.50	F = 3.256	$p = 0.023$*
	6–10 years	75	2.69	31.21		
	11–15 years	37	2.21	32.03		
	More than 15 years	8	3.24	31.25		
Hospital currently employed	Al-Noor Specialist Hospital	83	4.00	30.86	t=-0.761	$p = 0.448$
	King Abdullah Medical City Specialist Hospital	69	2.79	31.28		

*Significant at < 0.05

Abbreviations: f = frequency, SD = Standard Deviation

Table 3 Barriers that affect the care of mechanically ventilated patients ($n = 152$)

Barriers related to the compliance with VAP prevention guidelines	Disagree		Neither agree nor disagree		Agree	
	f	%	f	%	f	%
1. Shortage of nursing staff.	5	3.3	4	2.6	143	94.1
2. Unavailability of resources (for example, sterile gloves, closed suction systems, kinetic beds, etc.).	15	9.9	23	15.1	114	75.0
3. Hospitals' cost control policies.	27	17.8	29	19.1	96	63.2
4. Unavailability of written protocols for VAP Prevention.	81	53.3	13	8.6	58	38.2
5. No continuous education on VAP.	52	34.2	42	27.6	58	38.2
6. Lack of education in the university about the VAP prevention.	31	20.4	45	29.6	76	50.0
7. Lack of professional role model and guidance.	30	19.7	47	30.9	75	49.3
8. Practice in ICUs not based on research findings.	30	19.7	67	44.1	55	36.2
9. Some research findings contradict nurses' previous education.	41	27.0	55	36.2	56	36.8
10. Fear of unpredictable adverse effect and undesirable patient outcomes.	46	30.3	35	23.0	71	46.7
11. Nurses' forgetfulness to perform some evidence-based procedures.	45	29.6	39	25.7	68	44.7
12. Nurses do not have enough time to perform evidence-based procedures.	44	28.9	19	12.5	89	58.6
13. Nurses lack required skills.	75	49.3	36	23.7	41	27.0
14. Lack of patient cooperation.	30	19.7	51	33.6	71	46.7
15. Some VAP prevention procedures are not nurses' responsibility.	49	32.2	38	25.0	65	42.8

barrier was the unavailability of essential resources, such as sterile gloves, closed suction systems, and kinetic beds, significantly hindering compliance (75.00%). The third highest barrier was hospital cost control policies (63.2%). Budgeting, effective resource allocation, technology adoption, and personnel optimization are all part of hospital cost control policies. Some equipment (e.g., mechanical ventilators, suction machines) is outdated, and products (e.g., gloves, suction catheters) are easily broken, while cost restriction has hampered the hiring and retention of competent ICU nursing personnel.

Differences between participants' demographic profiles and barriers affecting the care of mechanically ventilated patients

As shown in Table 4, male nurses (M = 19.78) reported higher perceived barriers than females (M = 17.90). Regarding age groups, 41- to 50-year-olds reported the highest barriers (M = 20.78). Saudi nurses (M = 19.26), with over 15 years of experience and employed in KAMC (M = 18.75), perceived more obstacles than their counterparts. Nurses with a Master's degree perceived the highest barriers (M = 20.61). Nationality ($p = 0.024$) and educational level ($p = 0.005$) were the only demographic

Table 4 Differences in the barriers that affect the care of mechanically ventilated patients when grouped according to profile variables ($n = 152$)

Variables		f	Mean	SD	test	*p*-value
Gender	Female	102	12.10	6.41	t=-1.811	$p = 0.072$
	Male	50	10.22	5.10		
Age	20–30 year	43	10.93	6.30	F = 1.070	$p = 0.346$
	31–40 year	100	11.92	5.77		
	41–50 year	9	9.22	7.79		
Nationality	Saudi	105	10.74	6.80	t=-2.277	$p = 0.024$*
	Non-Saudi	47	13.13	5.71		
Marital status	Single	43	12.26	6.47	F = 0.517	$p = 0.597$
	Married	104	11.14	5.98		
	Divorced	5	11.80	3.27		
Educational Level	Diploma and Bachelor	106	12.39	6.08	t = 2.870	$p = 0.005$*
	Master	46	9.39	5.49		
Years of experience	1–5 years	32	12.50	6.33	F = 2.079	$p = 0.105$
	6–10 years	75	11.30	5.43		
	11–15 years	37	11.97	6.58		
	More than 15 years	8	6.75	6.73		
Hospital currently employed	Al-Noor Specialist Hospital	83	11.67	6.70	t=-0.443	$p = 0.658$
	King Abdullah Medical City Specialist Hospital	69	11.24	5.20		

*Significance at < 0.05

Abbreviations: f = frequency, SD = standard deviation

Table 5 Regression analysis predicting compliance scores based on influencing factors (i.e., barriers) ($n = 152$)

Predictor Variable	B	SE	Beta	T	*P*	95.0% Confidence Interval for B	
						Lower Bound	Upper Bound
(Constant)	32.7	0.	-	55.1	< 0.001	31.5	33.9
Factors (i.e., barriers)	-0.143	0.046	-0.247	-3.13	0.002	-0.23	-0.05

Note: Dependent variable was the compliance score. Model Summary: $R^2 = 0.061$, Adjusted $R^2 = 0.055$. β is the unstandardized coefficient

Table 6 Challenges encountered by the critical care nurses in the care of mechanically ventilated patients

Challenges	Frequency	Rank
Challenges in the care of mechanically ventilated patients		
Lack of sufficient time due to caring for two patients during the shift.	121	1
Lack of collaboration between nursing and respiratory therapy.	105	2
Excessive pressure on nursing staff.	85	3
Difficulty in early detection of VAP symptoms.	68	4
At risk of infection from visitors or others.	61	5
Lack of necessary supplies.	60	6
Patient non-cooperation and agitation.	56	7
Challenges related to noncompliance with guidelines		
Inconsistent hand hygiene practices leading to VAP transmission risk.	114	1
Lack of monitoring and documentation hindering quality improvement efforts.	107	2
Underuse or misuse of VAP prevention bundles and protocols.	100	3
Delayed or inadequate oral care protocols contributing to VAP risk.	81	4
Poor maintenance of respiratory equipment increasing VAP development risk.	69	5

variables demonstrating a statistically significant difference.

Relationship between the level of self-reported perceived compliance and the factors affecting the care of mechanically ventilated patients

A simple linear regression was conducted to assess the effect of barriers (i.e., factors) on self-reported perceived compliance scores (Table 5). The model was statistically significant, $p = 0.002$, explaining 6.1% of the variance ($R^2 = 0.061$, adjusted $R^2 = 0.055$). The predictor variable (i.e., factors) had a significant negative effect on compliance ($\beta = -0.143$, SE = 0.046, $\beta = -0.247$, $t = -3.13$, $p = 0.002$), indicating that an increase in barriers is associated with lower compliance. The 95% confidence interval (-0.23, -0.05) confirms this negative relationship. The constant ($\beta = 32.7$, $p < 0.001$) suggests that compliance scores would be 32.7 in the absence of barriers.

ICCNs' challenges in caring for mechanically ventilated patients and noncompliance with VAP prevention guidelines

Table 6 shows that the two most common challenges faced by ICCNs in caring for mechanically ventilated

patients were "*lack of sufficient time due to caring for two patients during the shift*" (f = 121) and "*lack of collaboration between nursing and respiratory therapy*" (f = 105). This result suggests that nurses are often overburdened, which can compromise the quality of care and increase stress levels. Thus underscoring the need for improved teamwork and communication among health teams. Meanwhile, ICCNs "*inconsistent hand hygiene practices leading to VAP transmission risk*" (f = 114) was the highest-rated challenge regarding noncompliance with VAP prevention guidelines.

Discussion

This study examined ICCNs' self-reported perceived compliance, barriers, challenges, and demographics associated with VAP prevention guidelines. Almost half of the ICCNs reported high compliance with VAP prevention guidelines. The ICCN's high compliance may be related to improved VAP prevention policies, intensified training, and extensive ICU experience. Their high compliance may positively and significantly impact patient outcomes in the ICU. This finding is consistent with prior studies [7, 13], that reported Saudi ICCNs had acceptable and high VAP prevention compliance. Conversely, our findings contradict previous studies [19, 23, 30]. A systematic review in 2022 showed that most ICCNs from the eastern Mediterranean region [19], Jordan [30], Saudi Arabia, and Egypt [23] demonstrated insufficient compliance with VAP prevention guidelines. Their length of experience and higher academic level positively influence their compliance [23]. Therefore, whether ICCNs have high or poor compliance with VAP prevention guidelines, nurse managers should continuously train and evaluate nurses about these guidelines. At the same time, administrators should provide an ICU environment with adequate resources that allow nurses to comply with VAP prevention guidelines.

Our study showed significant compliance with specific preventative practices, such as using protective gloves and closed-circuit suction systems. While using chlorhexidine solution for oral care and handwashing before and after contact with patients received the lowest compliance. These findings raise concern because ICCNs were highly compliant in using protective gloves but did not perform proper handwashing. These opposing actions may result in VAP or infection due to poor handwashing. Although using chlorhexidine solution for oral care in preventing VAP remains a standard protocol, recent studies suggest that its benefits are inconclusive, and empirical evidence demonstrates that antiseptic solution destroys the normal oral and GIT flora, predisposing patients to GIT and respiratory infections [31, 32]. Thus, nurse managers may need to intensify VAP prevention training (e.g., routine seminars, continuous evaluation) with a particular focus on practices of consistent handwashing since poor compliance with one or two practice guidelines will adversely affect the overall VAP prevention outcomes.

The gap between general and particular compliance suggests that while nurses in Saudi Arabia may be well-trained in specific VAP prevention protocols, systemic issues (e.g., inadequate staffing and poor ICU team communication) undermine broader compliance. Nonetheless, educational interventions can significantly enhance knowledge and adherence to VAP prevention practices, underscoring the critical role of ongoing professional development [8, 33, 34]. Compliance with VAP prevention guidelines has multifactorial influence; therefore, utilizing educational programs (e.g., training and seminars) that target individual knowledge and practice gaps and organizational support (e.g., adequate staffing and resources) that addresses systemic organizational barriers could play a crucial role in enhancing compliance thereby reducing the incidence of VAP in ICUs.

Most ICCNs identified staffing shortages, resource limitations, and hospital cost control policies as impediments to full VAP prevention compliance. These findings are consistent with global challenges in critical care settings [19, 35, 36], highlighting systemic issues that transcend geographical and institutional boundaries.

Findings reveal that nursing staff shortage was a significant barrier to compliance. Globally, similar findings were reported in the Mediterranean region [19], Iran [36], and Jordan [30]. These studies revealed that a shortage in ICU nurse staffing negatively impacts VAP compliance, resulting in poor patient outcomes (e.g., higher infection and mortality rates and hospital stay and costs). Additionally, the scoping reviews of Al-Tamimi [8] and Rehmani [12] demonstrated the inadequate ICU staff as a significant barrier to achieving optimal VAP prevention compliance. In Saudi Arabia, only one study supports our finding that a lack of ICU staffing caused constraints in VAP prevention compliance [7].

Therefore, this high percentage of nursing staff shortage in ICU reflects a critical issue in the healthcare system where the demand for nursing care exceeds the available workforce. Staff shortages can lead to increased workload, fatigue, and stress among nurses, compromising the quality of care [37], including adherence to VAP prevention protocols. The consistency across global and local studies suggests that addressing staffing shortages by healthcare organizations is crucial for improving compliance with healthcare protocols. Strategies to address staffing shortages include strengthening current staff's well-being and satisfaction by focusing on their needs (e.g., healthcare benefits, adequate salary and resources, and excellent management) [38]. Management should invest in resilient management planning and internal

communication to ensure a sustainable healthcare workforce, thus enhancing retention [38].

Most participants reported that the unavailability of essential resources, such as sterile gloves, closed suction systems, and kinetic beds, hindered complying with VAP prevention. Former studies supported this finding [30, 39, 40]. These studies identified inadequate equipment and materials in the ICU as one of the significant barriers to nurses' VAP prevention compliance. These barriers point to a broader issue of resource management within healthcare institutions. The availability of adequate and appropriate resources is fundamental to ensuring that nurses can implement VAP prevention practices effectively. Therefore, hospital administrators should provide sufficient resources and functioning equipment. At the same time, nurse managers and nurses continuously inform administrators of the resources and equipment nurses need to support optimal VAP prevention compliance.

Most ICCNs in this study indicated that hospital cost control policies affected their ability to adhere to VAP prevention guidelines. Accordingly, when hospital policies in procuring equipment that support VAP prevention protocols are negatively affected, nurses view it as an essential barrier. For instance, Jordanian ICU nurses reported that their hospital policies of cutting off buying necessary equipment for the ICU negatively impacted their VAP prevention compliance [30]. Hospital cost control policies in Saudi Arabia were similarly noted as a barrier because ICCNs received inadequate supplies and substandard equipment [7]. Several potential interventions could improve hospital cost control policies and ensure adequate resources. Implement efficient administration of resources strategies, including cost-benefit analysis and focusing on high-impact domains [41]. Furthermore, use predictive analytics to estimate demand and avoid shortages [42]. Cost control measures, while necessary for the financial sustainability of healthcare institutions, can sometimes result in restricted access to essential supplies and equipment. Nurse managers must strike a delicate balance between cost efficiency and providing high-quality care to create a sustainable ICU environment. Hence, resources are managed effectively and efficiently by healthcare staff.

Significant findings emerged when looking at ICCNs experience levels. Nurses with 11–15 years' experience showed the highest compliance and significant difference. This result corroborates the findings of Yin et al. [33]. They emphasized the role of experience in enhancing compliance, particularly with complex clinical practices such as VAP prevention. Our study found that nationality and educational level significantly influenced the perception of barriers. Saudi nurses reported a higher mean score for perceived barriers than non-Saudi nurses. This result suggests that cultural or systemic factors within the local healthcare environment could influence how barriers are perceived. Our finding mirrored the study of Dehghan et al. [36]. Their empirical data showed that organizational culture and local policies significantly impacted perceived barriers. Thus, nurse managers may consider cultural factors (e.g., family visits are critical in Saudi culture, but they may harbor pathogens in ICU patients) that could influence VAP prevention guidelines compliance.

Results demonstrated that education is a critical factor for VAP prevention compliance, with nurses holding a Master's degree reporting the highest perceived barriers, exhibiting statistical significance. This result indicates that higher educational attainment may increase awareness of the potential barriers. Al-Tamimi et al. [8] supported this result, underscoring the importance of education in equipping nurses to critically evaluate their working conditions and the limitations within their professional environments while fostering a proactive approach to VAP prevention.

The ICCNs increased perception of barriers was associated with lower VAP compliance. Thus, when nurses' barriers to compliance are addressed and eliminated, it would reinforce VAP prevention compliance. Previous studies reveal that nurses who encountered barriers in VAP prevention had difficulty complying with the preventative policies [8, 36]. Thus, nurse managers should continuously assess the sources of VAP prevention barriers to create a responsive and holistic strategy in addressing these barriers, thereby raising nurses' compliant behaviors. For instance, nursing staff who are less compliant with hand hygiene due to inadequate supplies will not only be compliant when sufficient supplies are procured but visual or contextual cues such as placing hand hygiene posters and solutions in conspicuous places in the ICU to remind nurses to perform hand hygiene constantly [43].

Participants experienced challenges in caring for mechanically ventilated patients, likewise challenges related to guidelines noncompliance. Nurses reported that the *"lack of sufficient time due to caring for two patients during the shift"* was the most challenging. Staff nurses identified time constraints due to caring for multiple patients during a shift as significantly challenging [44, 45]. Moreover, time constraints compounded with workload and patient agitation negatively influence critical care delivery [44]. Considering noncompliance with VAP prevention guidelines, *"inconsistent hand hygiene practices leading to VAP transmission risk"* displayed the most significant challenge among ICCNs. The challenges related to noncompliance with policies, such as inconsistent hand hygiene practices and underuse of VAP

prevention bundle, emphasize the importance of protocol adherence in reducing VAP risks [31, 41, 42].

The challenges related to VAP infection risks, lack of necessary supplies, and patient non-cooperation correspond to the broader spectrum of challenges faced in critical care settings, as reported in previous studies [46–48]. The results of this study reinforce the vital need for addressing these challenges to enhance the care of mechanically ventilated patients. ICU nurse managers may include the following strategies to address these challenges: continuous training of nursing staff about VAP prevention guidelines, providing adequate staffing and resources, educating patients' families and significant others about infection prevention, and effective communication between healthcare staff, patient's families, and management personnel.

Limitations and recommendations

This study used a cross-sectional design that limits the ability to establish causality between observed factors and outcomes. Convenience sampling and the two study settings cannot adequately represent the ICCNs in the country or the Middle East region. The use of self-report instrument could result in social desirability bias and participants may have under or overestimated their responses. ICCNs' workload was not included as a variable and could have an essential role in this study. Thus, our findings necessitate caution when interpreted because a robust generalization cannot be offered.

Future research can be explored toward the effectiveness of specific hospital training programs and implementation of such policy interventions on compliance rates in the critical care units through observational studies, employing longitudinal and experimental designs to establish causality. We also recommend piloting such enhanced training programs to reduce barriers and improve compliance for critical care nurses and other healthcare professionals, not just critical care nurses. A broader geographic sampling in several regions in Saudi Arabia and across the Gulf countries to validate different VAP bundle practice guidelines and implementations. Finally, exploring barriers in different contexts and examining the impact of organizational culture and leadership on compliance may provide a better understanding of VAP prevention.

Implications for clinical practice

Our findings could aid nurse managers in enhancing their ICCNs' training programs for VAP prevention guidelines. These programs include staff needs assessment, determining weak aspects, providing educational programs, direct supervision, and continuous evaluation. Hospital administrators and nurse managers should revisit the existing protocol addressing compliance support, staffing shortages, and time spent per patient to reduce the burden among critical care nurses. To address staffing shortages and enhance retention, administrators should address nurses' well-being and satisfaction by providing adequate wages and benefits, excellent management, and continuous professional development. The hospital administration should adequately allocate resources vital for the hospital's implementation of VAP prevention guidelines. Potential strategies may include cost-benefit analysis and predictive analytics in estimating demands to avert resource wastage and overall, strengthening compliance among nurses, safety practices, and patient outcomes.

Strengths of the study

This study included diverse settings, including two tertiary hospitals in highly urbanized regions in Saudi Arabia, which enhanced the generated evidence of our study. This study utilized comprehensive measures that utilized detailed and validated instruments to measure compliance and barriers in terms of factors and validated the participants' responses through descriptive responses of the challenges encountered in the care of mechanically ventilated patients.

Conclusions

Our study investigated the compliance of ICCNs with VAP prevention guidelines and identified the barriers and challenges affecting their compliance. ICCNs had optimal compliance with protective gloves, heat and moisture exchanger humidifiers, and closed-circuit suction systems. Significant barriers to compliance included staffing shortages and resource limitations. Years of experience and nationality showed statistical significance in compliance with VAP guidelines. Critical challenges in VAP prevention include time constraints due to high patient loads, lack of collaboration, and inadequate resources. Therefore, our findings highlight three crucial aspects. First, hospital administrators and nurse managers may provide sustainable solutions to staffing shortages and resource limitations. Second, they should develop comprehensive training programs, better resource allocation, policy adjustments to support compliance, and improved interdisciplinary collaboration. Third, continuous monitoring, patient and family education, and leveraging technology may enhance VAP prevention compliance. Finally, improving ICCNs' compliance with VAP prevention guidelines reduces VAP incidence and positively enhances patient outcomes in critical care settings.

Abbreviations

ICCNs	Intensive and critical care nurses
ICU	Intensive Care Unit
VAP	Ventilator associated pneumonia

Supplementary Information

The online version contains supplementary material available at https://doi.org/10.1186/s12912-025-03601-z.

Supplementary Material 1

Supplementary Material 2

Supplementary Material 3

Acknowledgements
We acknowledge the invaluable participation of critical care nurses across several hospitals in Hail Region and the utmost support of the Deanship of Scientific Research and Post Graduate at University of Ha'il, Saudi Arabia.

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Funding
This research has been funded by Scientific Research Deanship at University of Ha'il (UOH), Ha'il, Saudi Arabia through project number GR-24 005.

Data availability
The data supporting this study's findings are available from the corresponding author upon reasonable request.

Declarations

Ethics approval and consent to participate
Ethical approval was obtained from the Institutional Review Board (IRB) of the University of Hail Number (Protocol number: H-2024-091; approved: 04/03/2024), and permission to conduct the study was secured from the involved hospitals. Participants signed an informed consent and willingly participated in this study.

Consent for publication
Not applicable.

Competing interests
The authors declare no competing interests.

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Received: 20 December 2024 / Accepted: 14 July 2025
Published online: 17 July 2025

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