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Preventing Ventilator-Associated Pneumonia: A Multicenter Cross-Sectional Study of Knowledge, Attitudes, and Practices of Medical Staff in Chinese Hospitals

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Background: Ventilator-associated pneumonia (VAP) is a severe complication in mechanically ventilated patients. Understanding the knowledge, attitudes, and practices (KAP) of healthcare providers is crucial for prevention. This study aimed to assess the KAP regarding VAP among doctors and nurses in intensive care units (ICU) and respiratory departments across 9 hospitals in China.

Material/Methods: This multicenter cross-sectional study was conducted from April to June 2024 in 9 hospitals in China. A total of 224 participants, including 62 doctors and 162 nurses, completed a validated questionnaire in intensive care and respiratory departments. Statistical analyses included descriptive statistics, correlation, logistic regression, and structural equation modeling (SEM) for the nurse cohort.

Results: A total of 224 valid questionnaires were collected, with 62 from doctors and 162 from nurses. The KAP scores were 9.88±1.42, 41.67±2.86, and 30.45±4.12 for doctors, and 34.45±4.59 for nurses. For nurses, there was a positive correlation between knowledge and attitudes (r=0.212, *P*=0.007). SEM showed that knowledge directly affected attitudes (β=6.45, *P*<0.001), but did not significantly predict practices.

Conclusions: Medical staff showed adequate knowledge, positive attitudes, and good practices regarding VAP. However, structural modeling revealed that knowledge and attitudes did not significantly predict practices, suggesting the need to explore other factors and for targeted interventions for better VAP prevention.

Keywords: **Cross-Sectional Studies • Health Knowledge, Attitudes, Practice • Surveys and Questionnaires • Ventilator-Associated Pneumonia**

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Introduction

Despite decades of research, ventilator-associated pneumonia (VAP) remains one of the most common complications in mechanically ventilated patients [1]. As a major healthcare-associated infection, VAP prolongs the duration of mechanical ventilation (MV), extends hospital stays, and substantially increases healthcare costs [2]. VAP is notably prevalent in intensive care units, with a reported incidence ranging from 4.5 to 55.8 per 1000 ventilator days in China [3,4]. The mortality rates associated with VAP are alarmingly high, varying between 19.4% and 53% [3-5]. Clinically, VAP presents with symptoms such as fever, purulent sputum, leukocytosis, decreased oxygenation, and new or progressive infectious pulmonary infiltrates. The treatment of VAP is complex, depending on a variety of factors, including the age of the patient and the pathogens involved [6,7], which adds further challenges to patient management and recovery.

The knowledge, attitude, and practice (KAP) theory posits that knowledge serves as the foundation for behavioral change, while attitudes and beliefs act as the driving forces behind this change [8]. According to the KAP theory, the process of human behavioral change is structured in 3 sequential steps: acquiring knowledge, forming attitudes/beliefs, and establishing practices/behaviors [9]. It is important to note that merely acquiring knowledge does not automatically result in behavioral change; rather, it first influences perceptions, which then alter behavior through this shift in perception [10]. This sequence is critical in modifying the practice patterns of medical staff [11].

Numerous studies have highlighted a lack of sufficient knowledge among nurses, particularly in their non-participation in practices to prevent VAP in intensive care units (ICU). For instance, emergency and ICU nurses have shown inadequate knowledge regarding the prevention of VAP [12-14] and insufficient adherence to VAP prevention guidelines [15]. Studies focusing on physicians' KAP regarding VAP are scarce, particularly recent multicenter investigations. Recent cross-sectional surveys have assessed ICU nurses' knowledge and KAP related to VAP prevention in different settings, including a study in Palestine and a study in China. These studies provide context for interpreting our findings and for comparing knowledge, attitudes, and self-reported practices across regions and samples [16]. This discrepancy underscores the need for a focused investigation into the KAP of medical staff. Such research is essential for identifying deficiencies and developing targeted interventions aimed at enhancing VAP prevention practices, thereby improving patient outcomes. Therefore, we adopted the KAP framework to simultaneously evaluate medical staff's knowledge, attitudes, and self-reported practices regarding VAP prevention and management, particularly those working in ICUs and respiratory departments, which helps identify gaps across these domains and informs targeted interventions. KAP studies are designed to identify gaps in knowledge, attitudes, and practices within a specific population. By evaluating these domains, KAP studies provide important insights into how healthcare practices can be improved through targeted interventions. This study used a multicenter cross-sectional design across 9 hospitals in China. A validated questionnaire was used to assess healthcare workers' KAP regarding VAP. In addition, structural equation modeling (SEM) was conducted among nurses to examine the relationships among knowledge, attitudes, and practices [17].

Material and Methods

Ethics Statement

The study was approved by the Fujian Geriatric Hospital Ethics Committee (Approval number: #20240403), and informed consent was obtained from all participants.

Study Design and Participants

This multicenter cross-sectional study used convenience sampling to recruit healthcare providers between April and June 2024 across 9 hospitals in Fujian Province. Eligible participants were licensed physicians and registered nurses working in ICU and respiratory departments. Medical staff who refused to provide informed consent were excluded.

Questionnaire

The initial draft of the questionnaire was developed based on the "2018 Chinese guidelines for the diagnosis and treatment of adults with hospital-acquired and ventilator-associated pneumonia" [18]. Recommendation statements from the guideline were reviewed and translated into candidate questionnaire items. In particular, the knowledge domain was constructed to reflect 5 guideline-based areas: etiology and risk-related factors of VAP, prevention measures, diagnostic evaluation (including imaging and biomarkers), treatment principles, and rational antibiotic use. The attitude and practice items were then developed to assess participants' perceptions of the importance and management of VAP, as well as their self-reported implementation of these guideline-based prevention and management measures in routine clinical work. A total of 7 experts participated in the questionnaire revision, representing various relevant fields, including critical care medicine, critical care nursing, nursing management, pharmacy, respiratory medicine, and emergency medicine. Their professional experience ranged from 10 to 33 years. Content validity was ensured through expert panel review, and items were refined to align with guideline-based domains. A pilot study was conducted prior to the formal survey to assess the reliability and feasibility

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of the questionnaire. A total of 40 questionnaires were collected, of which 30 were valid. Due to the small number of physicians in the pilot sample (n=7), reliability analysis was performed only among nurses (n=23). The Cronbach's alpha coefficient was 0.822, indicating good internal consistency of the questionnaire.

The final version of the questionnaire encompassed 4 sections: demographic data, knowledge, attitude, and practice. No cultural adaptation was required because the survey was developed for use in the Chinese clinical context and was administered to participants in Chinese; the English version is provided in the Supplementary Materials for reference. The knowledge dimension comprised 14 questions, with points awarded as follows: 1 point for each correct answer and 0 points for each incorrect answer. Possible scores range from 0 to 14 points. The attitude dimension included 9 questions, scored using a 5-point Likert scale. Possible scores ranged from 9 to 45. The practice dimension included 11 questions, also scored using a 5-point Likert scale. P1-P4 can only be answered by nurses, P5-8 can be answered by both doctors and nurses, and P9-11 can only be answered by doctors. Possible scores for doctors ranged from 7 to 35 and possible scores for nurses ranged from 8 to 40. Attaining scores above 70% of the maximum in each section indicated adequate knowledge, positive attitude, and proactive practice [19]. In addition, the logic question is the same as question 2 of the knowledge dimension – "Pneumonia occurring within 48 hours after MV withdrawal or extubation is not considered VAP" – but the choice order is not the same. The questionnaires with logical contradictions in the answers to these 2 questions were considered invalid.

Questionnaire Distribution and Quality Control

The authors contacted the head nurses of the critical care medicine departments of 9 hospitals and explained the study's purpose and process either by phone or face-to-face. With the consent of each head nurse, the questionnaires were distributed both online and offline. A convenience sampling strategy was used to recruit participants based on availability. For online distribution, the questionnaire was uploaded to the Wenjuanxing platform, and links were shared via WeChat and other platforms, with respondents invited to click on these links to complete the questionnaires. Offline distribution involved paper questionnaires, which were handed out and collected on-site by trained staff. Participation was voluntary, and the survey was administered anonymously without collecting personal identifiers. All questionnaire data were kept confidential and were used only for research purposes, with access limited to the study team.

Invalid responses were identified based on several criteria: completion time less than 80 s, logical inconsistencies in quality control questions, and anomalies in the baseline and knowledge sections.

Sample Size Calculation

In questionnaire-based studies, the sample size is commonly determined according to the subject-to-variable ratio to ensure adequate statistical stability. Previous methodological studies recommend recruiting several participants per questionnaire item [20]. The present questionnaire contained 34 items across the knowledge, attitude, and practice domains; therefore, the minimum required sample size was estimated to be at least 5 times the number of items (n=170). The final sample of 224 participants exceeded this requirement.

Statistical Analysis

Data analysis was conducted using R 4.3.2 and Stata 18.0 (Stata Corporation, College Station, TX, USA). In the formal study, questionnaire reliability and sampling adequacy were evaluated using Cronbach's alpha and the Kaiser-Meyer-Olkin (KMO) measure. Continuous variables were expressed as mean±standard deviation (SD), and categorical variables were presented as frequencies and percentages. The normality of continuous variables was assessed prior to analysis. For group comparisons, independent-sample *t* tests or one-way analysis of variance (ANOVA) were used for normally distributed data, while the Wilcoxon rank-sum test or Kruskal-Wallis test was applied for non-normally distributed data. Given the relatively small sample size of physicians, further inferential analyses were restricted to the nurse cohort to ensure statistical robustness. Spearman correlation analysis was used to evaluate the relationships among knowledge, attitude, and practice scores. To identify factors associated with KAP outcomes, logistic regression analyses were conducted. Knowledge, attitude, and practice scores were dichotomized based on the median values. Univariable logistic regression was first performed, and variables with a P value <0.10 were included in multivariable logistic regression models. Adjusted odds ratios (ORs) with 95% confidence intervals (CIs) were reported. SEM was further applied in the nurse cohort to examine the hypothesized relationships among knowledge, attitudes, and practices based on the KAP theoretical framework. The model specified direct paths from knowledge to attitude and practice, and from attitude to practice, as well as the indirect effect of knowledge on practice through attitude. Standardized path coefficients (β) and corresponding P values were estimated. Model fit was evaluated using multiple indices, including the root mean square error of approximation (RMSEA), standardized root mean square residual (SRMR), comparative fit index (CFI), Tucker-Lewis index (TLI), and incremental fit index (IFI). A 2-sided P value <0.05 was considered statistically significant. The study conclusions were derived based on the combined evidence from correlation analysis, logistic regression, and SEM, particularly focusing on the strength and significance of associations and structural pathways among KAP variables.

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Table 1. Demographic characteristics and KAP scores regarding ventilator-associated pneumonia among medical staff in 9 hospitals in China (April-June 2024, n=224).

	N (%)	Knowledge	*P*	Attitudes	P	Doctor practices		P	Nurse practices		P
		Mean±SD		Mean±SD		N (%)	Mean±SD		N (%)	Mean±SD	
Total	224 (100.0)	9.88±1.42		41.67±2.86		62 (100.0)	30.45±4.12		162 (100.0)	34.45±4.59	
Gender			0.073		0.531			0.397			0.655
Male	42 (18.8)	10.21±1.16		41.98±2.52		30 (48.4)	29.70±4.84		12 (7.4)	34.08±3.70	
Female	182 (81.2)	9.80±1.47		41.60±2.93		32 (51.6)	31.16±3.22		150 (92.6)	34.48±4.66	
Age, year			<0.001		0.669			0.731			0.158
<30	70 (31.2)	9.31±1.30		41.49±2.80		10 (16.1)	31.40±3.10		60 (37.0)	35.28±4.61	
30-39	106 (47.3)	10.26±1.18		41.93±2.40		38 (61.3)	30.42±4.14		68 (42.0)	34.13±4.60	
≥40	48 (21.4)	9.83±1.79		41.38±3.75		14 (22.6)	29.86±4.80		34 (21.0)	33.62±4.42	
Education			<0.001		0.043			0.730			0.097
Associate degree or below	60 (26.8)	9.33±1.22		41.32±2.86		0	0		60 (37.0)	35.52±4.31	
Bachelor's degree	128 (57.1)	9.95±1.49		41.54±3.04		27 (43.5)	29.89±4.94		102 (63.0)	33.82±4.66	
Master's degree	36 (16.1)	10.53±1.21		42.75±1.78		35 (56.5)	30.89±3.37				
Job			<0.001		0.002			/			/
Doctor	62 (27.7)	10.53±1.10		42.65±1.98		62 (100)	30.45±4.12		/	/	
Nurse	162 (72.3)	9.62±1.46		41.30±3.05		/	/		162 (100.0)	34.45±4.59	
Professional title			<0.001		0.230			0.124			0.094
None	89 (39.7)	9.54±1.36		41.58±2.67		20 (32.3)	30.05±4.65		69 (42.6)	35.29±5.01	
Junior	96 (42.9)	9.85±1.54		41.52±3.09		18 (29.0)	31.89±3.55		78 (48.1)	33.78±4.28	
Intermediate title or above	39 (17.4)	10.69±0.86		42.26±2.66		24 (38.7)	29.71±3.94		15 (9.3)	34.07±3.63	
Years of experience, year			0.012		0.515			0.629			0.073
≤5	66 (29.5)	9.58±1.38		41.35±2.94		19 (30.6)	30.32±4.93		47 (29.0)	35.77±4.24	
5-10	48 (21.4)	9.81±1.30		42.27±2.08		15 (24.2)	31.40±3.72		33 (20.4)	34.55±5.26	

Table 1 continued. Demographic characteristics and KAP scores regarding ventilator-associated pneumonia among medical staff in 9 hospitals in China (April-June 2024, n=224).

	N (%)	Knowledge	*P*	Attitudes	P	Doctor practices		P	Nurse practices		P
		Mean±SD		Mean±SD		N (%)	Mean±SD		N (%)	Mean±SD	
11-15	58 (25.9)	10.29±1.12		42.07±2.04		17 (27.4)	30.47±2.67		41 (25.3)	34.12±4.41	
≥16	52 (23.2)	9.85±1.78		41.10±3.88		11 (17.7)	29.36±5.12		41 (25.3)	33.20±4.34	
Department			0.058		0.213			0.459			0.565
ICU	168 (75.0)	10.02±1.22		41.60±2.76		37 (59.7)	31.00±3.15		131 (80.9)	34.56±4.46	
Respiratory Department	56 (25.0)	9.45±1.86		41.91±3.14		25 (40.3)	29.64±5.20		31 (19.1)	33.97±5.14	
Hospital			0.959		0.313			0.141			0.364
Tertiary hospital	200 (89.3)	9.87±1.46		41.74±2.86		55 (88.7)	30.84±3.71		145 (89.5)	34.52±4.63	
Secondary hospital	24 (10.7)	9.96±1.16		41.17±2.85		7 (11.3)	27.43±6.08		17 (10.5)	33.88±4.30	
Training on VAP			0.277		0.158			0.477			0.095
Yes	193 (86.2)	9.92±1.41		41.74±2.91		50 (80.6)	30.70±4.00		143 (88.3)	34.71±4.35	
No	31 (13.8)	9.61±1.52		41.26±2.48		12 (19.4)	29.42±4.62		19 (11.7)	32.53±5.92	
Average VAP patients each month			0.371		0.756			0.742			0.096
1-2 cases	147 (65.6)	9.75±1.60		41.56±2.98		37 (59.7)	30.11±4.61		110 (67.9)	33.95±4.89	
3-5 cases	49 (21.9)	10.16±0.94		41.86±2.52		17 (27.4)	30.65±3.46		32 (19.8)	35.16±3.31	
≥6 cases	28 (12.5)	10.04±1.04		41.93±2.81		8 (12.9)	31.62±3.02		20 (12.3)	36.10±4.24	
Average elderly VAP patients each month			0.144		0.743			0.153			0.082
0 case	54 (24.1)	9.48±1.68		41.41±3.32		14 (22.6)	29.07±2.56		40 (24.7)	34.25±5.34	
1-2 cases	111 (49.6)	10.01±1.46		41.86±2.63		33 (53.2)	30.82±4.97		78 (48.1)	33.85±4.47	
3-4 cases	33 (14.7)	9.97±0.81		41.36±3.02		10 (16.1)	31.20±3.16		23 (14.2)	34.87±3.65	
≥5 cases	26 (11.6)	10.00±1.23		41.85±2.62		5 (8.1)	30.40±2.88		21 (13.0)	36.62±3.97	

VAP – ventilator-associated pneumonia; ICU – intensive care unit; MV – mechanical ventilation; KAP – knowledge, attitudes, and practices; OR – odds ratio; CI – confidence interval; SEM – structural equation modeling; RMSEA – Root Mean Square Error of Approximation; SRMR – Standardized Root Mean Square Residual; IFI – Incremental Fit Index; TLI – Tucker-Lewis Index; CFI – Comparative Fit Index; SD – standard deviation.

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Table 2. Responses to knowledge items on ventilator-associated pneumonia among medical staff in 9 hospitals in China (April-June 2024, n=224).

Knowledge	Correct	Incorrect	Uncertain
1. VAP refers to pneumonia that occurs 48 hours after a patient with an endotracheal or tracheostomy tube has received mechanical	204 (91.1%)	18 (8%)	2 (0.9%)
2. Pneumonia occurring within 48 hours after mechanical ventilation withdrawal or extubation is not considered VAP	17 (7.6%)	201 (89.7%)	6 (2.7%)
3.3. Factors related to VAP mortality include: (a. Young people)	18 (8%)		
3 (b. Comorbid diabetes or chronic obstructive pulmonary disease)	217 (96.9%)		
3 (c. Septic shock (septicemic shock))	221 (98.7%)		
3 (d. Infection with highly resistant pathogens)	223 (99.6%)		
Question 3 scores	198 (88.4%)	26 (11.6%)	
4.4. Healthcare environment factors for VAP occurrence include: a. ICU length of stay	209 (93.3%)		
4 (b. Invasive procedures)	222 (99.1%)		
4 (c. Medications that lower gastric pH)	163 (72.8%)		
4 (d. Lower limb surgery)	91 (40.6%)		
4 (e. Indwelling gastric tubes)	151 (67.4%)		
Question 4 scores	22 (9.8%)	202 (90.2%)	
5.5. Mechanisms by which endotracheal intubation leads to VAP include: (a.a. Endotracheal intubation suppresses the proliferation of oropharyngeal colonizing bacteria, preventing secretions from entering the lower respiratory tract	169 (75.4%)		
5 (b.b. Endotracheal intubation limits effective coughing and interferes with ciliary clearance)	214 (95.5%)		
5 (c. Endotracheal intubation surfaces are prone to biofilm formation, causing small airway obstruction)	216 (96.4%)		
5 (d. Sedatives and analgesics used for intolerant patients inhibit coughing)	211 (94.2%)		
Question 5 scores	47 (21.0%)	177 (79.0%)	
6. To prevent VAP, patients and healthcare workers should be vaccinated against Haemophilus influenzae and Streptococcus pneumoniae	78 (34.8%)	97 (43.3%)	49 (21.9%)
7. To prevent VAP, non-invasive ventilation modes (high-flow nasal oxygen or non-invasive positive pressure ventilation) should be used whenever possible to avoid endotracheal intubation	215 (96%)	3 (1.3%)	6 (2.7%)
8. When performing care activities such as turning and back-patting, attention should be paid to the height of the ventilator tubing to prevent condensation from flowing back into the trachea	222 (99.1%)	0 (0%)	2 (0.9%)
9. To prevent VAP, parenteral nutrition should be provided to mechanically ventilated patients whenever possible	97 (43.3%)	122 (54.5%)	5 (2.2%)
10. For patients receiving mechanical ventilation, the necessity of invasive mechanical ventilation and endotracheal intubation should be assessed daily, and weaning or extubation should be performed as early as possible	222 (99.1%)	1 (0.4%)	1 (0.4%)

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Table 2 continued. Responses to knowledge items on ventilator-associated pneumonia among medical staff in 9 hospitals in China (April-June 2024, n=224).

Knowledge	Correct	Incorrect	Uncertain
11. Mechanically ventilated patients requiring sedation should be regularly awakened and trained for spontaneous breathing, with the necessity of sedative use evaluated daily to discontinue use as early as possible	221 (98.7%)	2 (0.9%)	1 (0.4%)
12. For patients expected to require mechanical ventilation for more than 48 or 72 hours, endotracheal tubes with subglottic secretion drainage should be used	217 (96.9%)	2 (0.9%)	5 (2.2%)
13. To prevent VAP, if a respiratory infection patient encounters high airway pressure, the cuff pressure of the endotracheal tube should be 5 cmH_2O lower than the peak inspiratory pressure	138 (61.6%)	60 (26.8%)	26 (11.6%)
14. Ceftolozane/tazobactam is limited in its efficacy against anaerobic bacteria, gram-positive cocci, and Acinetobacter baumannii in VAP patients	183 (81.7%)	10 (4.5%)	31 (13.8%)

VAP – ventilator-associated pneumonia; ICU – intensive care unit; MV – mechanical ventilation; KAP – knowledge, attitudes, and practices; OR – odds ratio; CI – confidence interval; SEM – structural equation modeling; RMSEA – Root Mean Square Error of Approximation; SRMR – Standardized Root Mean Square Residual; IFI – Incremental Fit Index; TLI – Tucker-Lewis Index; CFI – Comparative Fit Index; SD – standard deviation.

Results

Basic Characteristics

Initially, a total of 290 questionnaires were collected in this study, excluding 4 cases of non-informed consent questionnaires, 5 cases of answer time shorter than 80 s, 53 cases of logical conflict in quality control questions, and 4 cases of abnormal answers, and the final valid questionnaires were 224, with an effective rate of 77.24%. In the formal study, the overall Cronbach's alpha coefficient for nurses was 0.858, and the Kaiser-Meyer-Olkin (KMO) measure of sampling adequacy was 0.856. Across the entire study population, the Cronbach's alpha coefficient was 0.8694, with a KMO value of 0.8524.

We assessed data from 62 doctors' questionnaires and 162 nurses' questionnaires. Among them, 182 (81.2%) were female. The mean knowledge, attitude, doctors' practice, and nurses' practice scores were 9.88±1.42 (possible range: 0-14), 41.67±2.86 (possible range: 9-45), 30.45±4.12 (possible range: 7-35), and 34.45±4.59 (possible range: 8-40), respectively (**Table 1**).

Distribution of Knowledge, Attitudes, and Practices

The distribution of knowledge dimensions showed that the 3 questions with the highest number of participants choosing the "Uncertain" option were "To prevent VAP, patients and healthcare workers should be vaccinated against *Haemophilus influenzae* and *Streptococcus pneumonia*". (K6) with 21.9%, "Ceftolozane/tazobactam is limited in its efficacy against anaerobic bacteria, gram-positive cocci, and *Acinetobacter baumannii* in VAP patients" (K14) with 13.8%, and "To prevent VAP, if a respiratory infection patient encounters high airway pressure, the cuff pressure of the endotracheal tube should be 5 cmH_2O lower than the peak inspiratory pressure" (K13) with 11.6% (**Table 2**).

Regarding attitudes, the vast majority of participants tended to be positive (more than 95% chose "strongly agree" or "agree"), with the only difference being that for the statement "The management of VAP is the same as that of ordinary pneumonia" (A6), 26.3% strongly agreed, 11.6% agreed, 45.5% disagreed, and 16.1% strongly disagreed (**Table 3**).

The doctor's responses to the practice dimension showed that 27.4% sometimes and 9.7% occasionally educate mechanically ventilated patients and their families about VAP prevention and control (P5), and some nurses had low activity for this item (14.2% sometimes and 4.3% occasionally). Meanwhile, 9.7% sometimes and 4.8% occasionally participate in training related to the diagnosis and care of VAP (P6). In addition, nurses' responses to the practice dimension showed that 16% sometimes and 5.6% occasionally stay updated with the latest guidelines on VAP and adjust diagnostic and care measures for VAP patients accordingly (P8) (**Table 4**).

Correlation Analysis

In the correlation analysis for nurses, positive correlations were found between knowledge and attitude (r=0.212, P=0.007), but

Table 3. Responses to attitude items on ventilator-associated pneumonia among medical staff in 9 hospitals in China (April-June 2024, n=224).

Attitude	Strongly agree	Agree	Neutral	Disagree	Strongly disagree
1. I believe it is necessary to assess the risk factors for VAP in mechanically ventilated patients	197 (87.9%)	25 (11.2%)	1 (0.4%)	1 (0.4%)	0 (0%)
2. I believe that proactive nursing interventions can prevent the occurrence of VAP	193 (86.2%)	28 (12.5%)	1 (0.4%)	2 (0.9%)	0 (0%)
3. I believe that early treatment of VAP positively impacts prognosis	194 (86.6%)	27 (12.1%)	1 (0.4%)	2 (0.9%)	0 (0%)
4. I am confident in helping VAP patients manage their condition	158 (70.5%)	63 (28.1%)	2 (0.9%)	1 (0.4%)	0 (0%)
5. I believe that proper nursing care is crucial for the recovery of patients diagnosed with VAP	190 (84.8%)	32 (14.3%)	1 (0.4%)	1 (0.4%)	0 (0%)
6. I believe that the management of VAP is the same as that of ordinary pneumonia	59 (26.3%)	26 (11.6%)	1 (0.4%)	102 (45.5%)	36 (16.1%)
7. I believe that healthcare providers need to be fully knowledgeable about the diagnosis, treatment, and care of VAP	193 (86.2%)	30 (13.4%)	1 (0.4%)	0 (0%)	0 (0%)
8. I believe that patient and family education regarding VAP is necessary	172 (76.8%)	51 (22.8%)	1 (0.4%)	0 (0%)	0 (0%)
9. I believe it is necessary to stay updated with VAP guidelines and the latest VAP prevention measures	192 (85.7%)	30 (13.4%)	2 (0.9%)	0 (0%)	0 (0%)

VAP – ventilator-associated pneumonia; ICU – intensive care unit; MV – mechanical ventilation; KAP – knowledge, attitudes, and practices; OR – odds ratio; CI – confidence interval; SEM – structural equation modeling; RMSEA – Root Mean Square Error of Approximation; SRMR – Standardized Root Mean Square Residual; IFI – Incremental Fit Index; TLI – Tucker-Lewis Index; CFI – Comparative Fit Index; SD – standard deviation.

neither the correlation between knowledge and practice nor the correlation between attitude and practice was significant.

Multivariate Logistic Regression Analysis

Multivariate logistic regression for nurses showed that aged 30 to 39 years old (odds ratio [OR]=6.683, 95% confidence interval [CI]: [1.246,35.852], *P*=0.027), with Bachelor/Master degree (OR=2.425, 95% CI: [1.079,5.450], *P*=0.032), working in respiratory department (OR=0.228, 95% CI: [0.087,0.600], *P*=0.003) were independently associated with nurses' knowledge (**Table 5**). Concurrently, knowledge score (OR=1.358, 95% CI: [1.055,1.748], *P*=0.018) was independently associated with positive attitude of nurse (**Table 6**). Moreover, "Had diagnosed or cared for an average of at less 5 cases of elderly VAP patients per month in the last year" (OR=3.981, 95% CI: [1.129,14.045], *P*=0.032) was independently associated with active practice of nurses (**Table 7**).

SEM

The fit of the SEM model yielded indices demonstrating good model fit (**Table 8**), with RMSEA=0.000, SRMR=0.002, IFI=1.000, TLI=1.037, and CFI=1.000, all indicating an excellent fit. **Figure 1** presents the specified SEM for the nurse cohort. The model includes the 3 constructs knowledge, attitude, and practice, with their corresponding observed questionnaire items (k1-k14, a1-a9, and p1-p8) and measurement error terms. Standardized path coefficients are displayed on the arrows, and curved double-headed arrows indicate correlated residuals among selected practice items. The results showed that knowledge directly affected attitude (β=0.448, 95% CI: 0.312-0.584, *P*<0.001), while the direct effect of knowledge on practice was β=0.051 (95% CI: -0.130 to 0.232, *P*=0.579) and the direct effect of attitude on practice was β=-0.130 (95% CI: -0.291 to 0.031, *P*=0.113), neither of which reached statistical significance (**Figure 1, Table 9**).

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Table 4. Responses to practice items on ventilator-associated pneumonia among medical staff in 9 hospitals in China (April-June 2024, n=224)

Practice	Always	Often	Sometimes	Rarely	Never
Doctor					
1. I educate mechanically ventilated patients and their families about VAP prevention and control	30 (48.4%)	9 (14.5%)	17 (27.4%)	6 (9.7%)	0 (0%)
2. I actively participate in training related to the diagnosis and care of VAP	37 (59.7%)	16 (25.8%)	6 (9.7%)	3 (4.8%)	0 (0%)
3. I pay special attention to the condition of VAP patients during shift handovers	35 (56.5%)	21 (33.9%)	5 (8.1%)	1 (1.6%)	0 (0%)
4. I stay updated with the latest guidelines on VAP and adjust diagnostic and care measures for VAP patients accordingly	25 (40.3%)	33 (53.2%)	2 (3.2%)	2 (3.2%)	0 (0%)
5. After clinically diagnosing VAP, I promptly perform etiological examinations and initiate empirical anti-infective treatment for VAP patients	27 (43.5%)	33 (53.2%)	0 (0%)	2 (3.2%)	0 (0%)
6. For VAP patients at high risk of multidrug-resistant infections and with a mortality risk >15%, I conduct empirical treatment based on the presence of septic shock	31 (50%)	27 (43.5%)	2 (3.2%)	2 (3.2%)	0 (0%)
7. After obtaining etiological results, I de-escalate antibiotics for VAP patients to reduce antibiotic overuse and the emergence of new antibiotic resistance	34 (54.8%)	26 (41.9%)	1 (1.6%)	1 (1.6%)	0 (0%)
Nurse					
1. To prevent VAP, I use chlorhexidine for routine oral care of patients	68 (42%)	53 (32.7%)	16 (9.9%)	5 (3.1%)	20 (12.3%)
2. To prevent VAP, I strictly adhere to aseptic technique guidelines when performing airway-related procedures on mechanically ventilated patients	80 (49.4%)	78 (48.1%)	4 (2.5%)	0 (0%)	0 (0%)
3. To prevent VAP, I assess the sedation status of mechanically ventilated patients daily to avoid unnecessary deep sedation	86 (53.1%)	69 (42.6%)	7 (4.3%)	0 (0%)	0 (0%)
4. Upon VAP confirmation, I perform bedside isolation and airway management for VAP patients	83 (51.2%)	73 (45.1%)	5 (3.1%)	0 (0%)	1 (0.6%)
5. I educate mechanically ventilated patients and their families about VAP prevention and control	81 (50%)	47 (29%)	23 (14.2%)	7 (4.3%)	4 (2.5%)
6. I actively participate in training related to the diagnosis and care of VAP	83 (51.2%)	52 (32.1%)	19 (11.7%)	6 (3.7%)	2 (1.2%)
7. I pay special attention to the condition of VAP patients during shift handovers	86 (53.1%)	64 (39.5%)	10 (6.2%)	2 (1.2%)	0 (0%)
8. I stay updated with the latest guidelines on VAP and adjust diagnostic and care measures for VAP patients accordingly	79 (48.8%)	48 (29.6%)	26 (16%)	9 (5.6%)	0 (0%)

VAP – ventilator-associated pneumonia; ICU – intensive care unit; MV – mechanical ventilation; KAP – knowledge, attitudes, and practices; OR – odds ratio; CI – confidence interval; SEM – structural equation modeling; RMSEA – Root Mean Square Error of Approximation; SRMR – Standardized Root Mean Square Residual; IFI – Incremental Fit Index; TLI – Tucker-Lewis Index; CFI – Comparative Fit Index; SD – standard deviation.

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Table 5. Univariable and multivariable logistic regression of factors associated with nurses' knowledge score on ventilator-associated pneumonia (n=162).

Nurse knowledge	Univariable analysis OR (95%CI)	P	Multivariable analysis OR (95%CI)	P
Gender				
Male				
Female	0.436 (0.094, 1.528)	0.227		
Age				
≤30 years old				
30-39 years old	3.360 (1.634, 7.093)	0.001	6.683 (1.246, 35.852)	0.027
≥40 years old	2.262 (0.966, 5.455)	0.063	8.944 (0.836, 95.685)	0.070
Education				
Associate degree or below				
Bachelor/master degree	3.281 (1.702, 6.452)	0.001	2.425 (1.079, 5.450)	0.032
Professional title				
None				
Junior	1.561 (0.813, 3.019)	0.183	1.121 (0.442, 2.843)	0.810
Intermediate or above	6.691 (1.684, 44.866)	0.017	3.590 (0.518, 24.899)	0.196
Years of experience				
≤5 years				
5-10 years	1.486 (0.609, 3.674)	0.386	0.618 (0.161, 2.369)	0.483
11-15 years	3.377 (1.402, 8.544)	0.008	0.313 (0.046, 2.133)	0.235
≥16 years	1.935 (0.832, 4.595)	0.129	0.147 (0.014, 1.587)	0.114
Department				
ICU				
Respiratory department	0.318 (0.136, 0.709)	0.006	0.228 (0.087, 0.600)	0.003
Hospital level				
Tertiary hospital				
Secondary hospital	1.037 (0.377, 3.001)	0.944		
Training on VAP				
Yes				
No	0.780 (0.297, 2.077)	0.613		
Average VAP patients each month				
1-2 cases				
3-5 cases	1.424 (0.636, 3.331)	0.399		
≥6 cases	0.746 (0.284, 1.958)	0.547		

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Table 5 continued. Univariable and multivariable logistic regression of factors associated with nurses' knowledge score on ventilator-associated pneumonia (n=162).

Nurse knowledge	Univariable analysis OR (95%CI)	P	Multivariable analysis OR (95%CI)	P
Average elderly VAP patients each month				
0 case				
1-2 cases	1.448 (0.669, 3.139)	0.347		
3-4 cases	1.407 (0.500, 4.087)	0.521		
≥5 cases	0.995 (0.344, 2.897)	0.993		

VAP – ventilator-associated pneumonia; ICU – intensive care unit; MV – mechanical ventilation; KAP – knowledge, attitudes, and practices; OR – odds ratio; CI – confidence interval; SEM – structural equation modeling; RMSEA – Root Mean Square Error of Approximation; SRMR – Standardized Root Mean Square Residual; IFI – Incremental Fit Index; TLI – Tucker-Lewis Index; CFI – Comparative Fit Index; SD – standard deviation.

Table 6. Univariable and multivariable logistic regression of factors associated with nurses' attitudes toward ventilator-associated pneumonia (n=162).

Nurse attitudes	Univariable analysis OR (95%CI)	P	Multivariable analysis OR (95%CI)	P
Knowledge	1.359 (1.059, 1.744)	0.016	1.358 (1.055, 1.748)	0.018
Gender				
Male				
Female	1.193 (0.364, 4.188)	0.772		
Age				
≥30 year old				
30-39 years old	0.902 (0.448, 1.815)	0.773		
≤40 years old	1.016 (0.435, 2.365)	0.971		
Education				
Associate degree or below				
Bachelor/master	0.939 (0.495, 1.785)	0.847		
Professional title				
None				
Junior	1.058 (0.551, 2.037)	0.865		
Intermediate title or above	1.950 (0.634, 6.390)	0.250		
Years of experience				
≤5 years				
5-10 years	1.271 (0.518, 3.128)	0.600		
11-15 years	1.166 (0.501, 2.723)	0.721		
≥16 years	1.166 (0.501, 2.723)	0.721		

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Table 6 continued. Univariable and multivariable logistic regression of factors associated with nurses' attitudes toward ventilator-associated pneumonia (n=162).

Nurse attitudes	Univariable analysis OR (95%CI)	P	Multivariable analysis OR (95%CI)	P
Department				
ICU				
Respiratory department	1.343 (0.611, 2.965)	0.462		
Hospital level				
Tertiary hospital				
Secondary hospital	0.815 (0.282, 2.239)	0.694		
Training on VAP				
Yes				
No	0.383 (0.119, 1.060)	0.080	0.385 (0.129, 1.152)	0.088
Average VAP patients each month				
1-2 cases				
3-5 cases	0.694 (0.303, 1.540)	0.376		
≥6 cases	1.414 (0.543, 3.768)	0.478		
Average elderly VAP patients each month				
0 case				
1-2 cases	1.221 (0.568, 2.658)	0.611		
3-4 cases	0.870 (0.299, 2.463)	0.794		
≥5 cases	1.488 (0.515, 4.368)	0.463		

VAP – ventilator-associated pneumonia; ICU – intensive care unit; MV – mechanical ventilation; KAP – knowledge, attitudes, and practices; OR – odds ratio; CI – confidence interval; SEM – structural equation modeling; RMSEA – Root Mean Square Error of Approximation; SRMR – Standardized Root Mean Square Residual; IFI – Incremental Fit Index; TLI – Tucker-Lewis Index; CFI – Comparative Fit Index; SD – standard deviation.

Table 7. Univariable and multivariable logistic regression of factors associated with nurses' practices regarding ventilator-associated pneumonia (n=162).

Nurse practices	Univariable analysis OR (95%CI)	P	Multivariable analysis OR (95%CI)	P
Knowledge	1.178 (0.943, 1.473)	0.149	1.126 (0.883, 1.434)	0.339
Attitude	1.066 (0.961, 1.182)	0.226	1.044 (0.932, 1.169)	0.460
Gender				
Male				
Female	1.133 (0.322, 3.716)	0.838		
Age				
≥30 years old				
30-39 years old	0.818 (0.396, 1.676)	0.583		
≤40 years old	0.682 (0.288, 1.619)	0.383		

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Table 7 continued. Univariable and multivariable logistic regression of factors associated with nurses' practices regarding ventilator-associated pneumonia (n=162).

Nurse practices	Univariable analysis OR (95%CI)	P	Multivariable analysis OR (95%CI)	P
Education				
Associate degree or below				
Bachelor/master degree	0.611 (0.308, 1.184)	0.150		
Professional title				
None				
Junior	0.690 (0.352, 1.341)	0.276		
Intermediate or above	1.067 (0.337, 3.751)	0.915		
Years of experience				
≤5 years				
5-10 years	1.032 (0.404, 2.691)	0.947		
11-15 years	0.807 (0.336, 1.931)	0.628		
≥16 years	0.542 (0.227, 1.274)	0.163		
Department				
ICU				
Respiratory department	0.726 (0.329, 1.618)	0.427		
Hospital level				
Tertiary hospital				
Secondary hospital	0.528 (0.188, 1.458)	0.215		
Training on VAP				
Yes				
No	0.530 (0.199, 1.396)	0.196		
Average VAP patients each month				
1-2 cases				
3-5 cases	2.053 (0.895, 5.054)	0.100		
≥6 cases	2.410 (0.866, 7.829)	0.110		
Average elderly VAP patients each month				
0 case				
1-2 cases	1.438 (0.667, 3.110)	0.354	1.370 (0.629, 2.982)	0.428
3-4 cases	2.286 (0.794, 7.071)	0.135	2.198 (0.734, 6.579)	0.159
≥5 cases	4.250 (1.303, 16.817)	0.024	3.981 (1.129, 14.045)	0.032

VAP – ventilator-associated pneumonia; ICU – intensive care unit; MV – mechanical ventilation; KAP – knowledge, attitudes, and practices; OR – odds ratio; CI – confidence interval; SEM – structural equation modeling; RMSEA – Root Mean Square Error of Approximation; SRMR – Standardized Root Mean Square Residual; IFI – Incremental Fit Index; TLI – Tucker-Lewis Index; CFI – Comparative Fit Index; SD – standard deviation.

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Table 8. Model fit indices for the structural equation model in nurses (n=162).

Indicators	Reference	Results
RMSEA	<0.08 Good	0.071
SRMR	<0.08 Good	0.099
TLI	>0.8 Good	0.855
CFI	>0.8 Good	0.867

VAP – ventilator-associated pneumonia; ICU – intensive care unit; MV – mechanical ventilation; KAP – knowledge, attitudes, and practices; OR – odds ratio; CI – confidence interval; SEM – structural equation modeling; RMSEA – Root Mean Square Error of Approximation; SRMR – Standardized Root Mean Square Residual; IFI – Incremental Fit Index; TLI – Tucker-Lewis Index; CFI – Comparative Fit Index; SD – standard deviation.

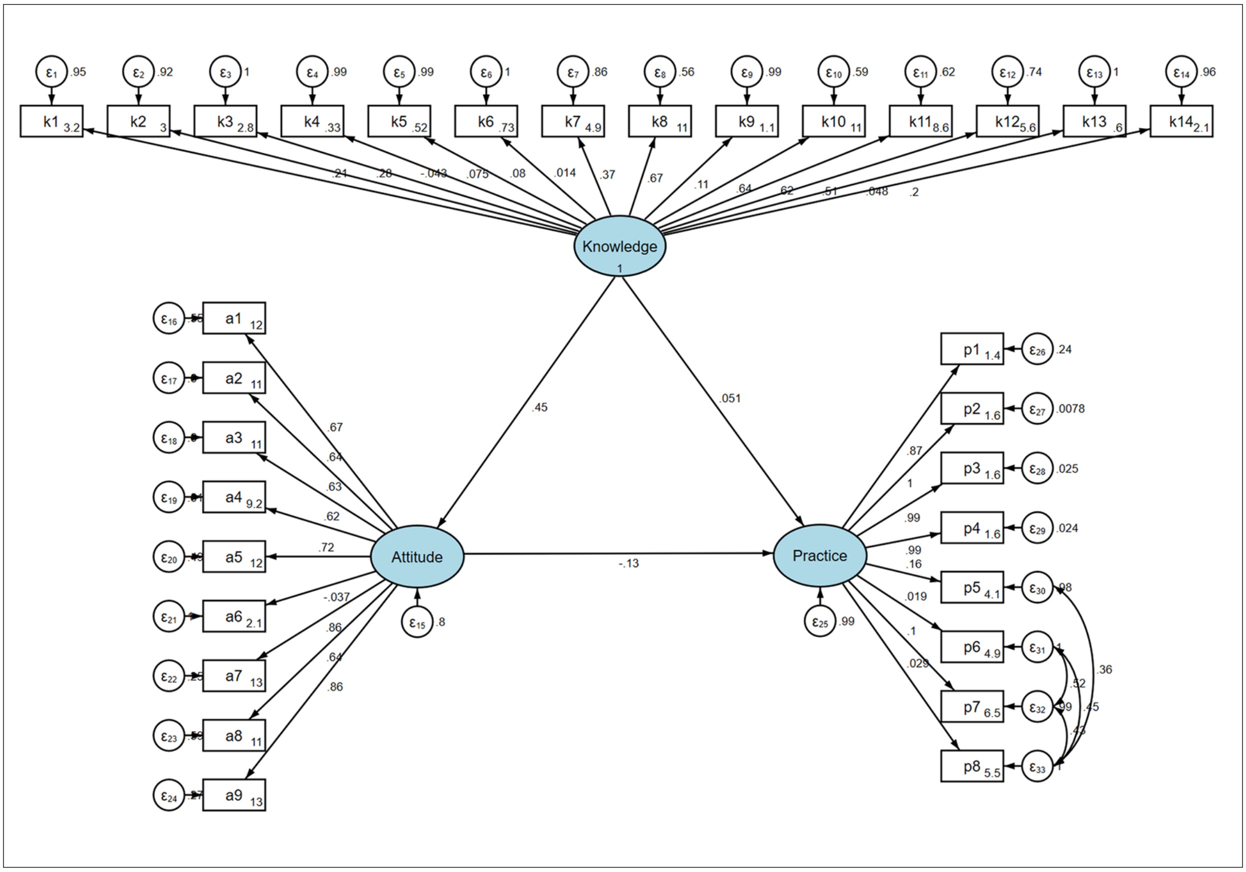

Figure 1. Structural equation model of nurses' knowledge, attitudes, and practices regarding ventilator-associated pneumonia.

Discussion

In this multicenter cross-sectional study across 9 hospitals, medical staff showed adequate knowledge, generally positive attitudes, and good self-reported practices regarding VAP. Among nurses, knowledge was positively correlated with attitudes, and SEM indicated a direct effect of knowledge on attitudes. In contrast, neither knowledge nor attitudes showed a significant direct association with practice in the nurse cohort. Similar surveys in ICU nurse samples have reported that knowledge about VAP prevention is often acceptable while gaps remain in how preventive measures are carried out in daily work. Our results are in line with this general pattern in that practice scores were relatively high, yet practice was not explained by knowledge or attitudes in the SEM and correlation analyses. This suggests that factors beyond individual KAP may contribute to reported practice in our setting.

The absence of a significant correlation between knowledge or attitudes and practice scores may be explained by multiple contextual and systemic factors. Prior research has indicated that organizational culture and established workflows in ICU and respiratory departments can strongly influence adherence to preventive practices, sometimes independent of individual knowledge levels [21,22]. High workload and time constraints may compel staff to prioritize tasks that are mandated

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Table 9. Standardized path coefficients from the structural equation model in nurses (n=162).

Model paths		Total effects		Direct effect		Indirect effect	
		β (95% CI)	P	β (95% CI)	P	β (95% CI)	P
Asum							
	Ksum	0.448 (0.312, 0.584)	<0.001	0.448 (0.312, 0.584)	<0.001		
Psum							
	Asum	-0.130 (-0.291, 0.031)	0.113	-0.130 (-0.291, 0.031)	0.113		
	Ksum	-0.007 (-0.163, 0.149)	0.930	0.051 (-0.130, 0.232)	0.579	-0.058 (-0.133, 0.165)	0.127

VAP – ventilator-associated pneumonia; ICU – intensive care unit; MV – mechanical ventilation; KAP – knowledge, attitudes, and practices; OR – odds ratio; CI – confidence interval; SEM – structural equation modeling; RMSEA – Root Mean Square Error of Approximation; SRMR – Standardized Root Mean Square Residual; IFI – Incremental Fit Index; TLI – Tucker-Lewis Index; CFI – Comparative Fit Index; SD – standard deviation.

by institutional protocols, potentially leading to the uniform implementation of certain practices regardless of personal attitudes or understanding. Additionally, resource availability – such as access to diagnostic tools, disinfectants, or specialized equipment – can facilitate or limit the execution of best practices. Management oversight and periodic audits may also enforce compliance, creating high practice scores that do not necessarily reflect intrinsic motivation. Finally, teamwork dynamics and interprofessional communication play a crucial role; well-coordinated teams may sustain high practice performance even in the presence of variability in individual knowledge or attitudes. Additionally, 37.9% of participants believed that the management of VAP is the same as that of ordinary pneumonia. This reflects a notable misconception that may stem from insufficient understanding of the specific pathogens involved in VAP and their distinctive antimicrobial resistance profiles. Such misunderstanding could lead to inappropriate empirical therapy, delayed initiation of targeted treatment, and, ultimately, poorer patient outcomes. It also suggests that clinical training programs should emphasize the unique etiological characteristics and management strategies of VAP, differentiating it clearly from community-acquired or other forms of pneumonia to prevent suboptimal care. These programs should be designed to translate theoretical understanding into practical skills, ensuring that healthcare providers are equipped not only with the necessary information but also with the ability to apply this knowledge effectively in clinical settings.

The findings of this study are generally consistent with previous research in different settings.

Recent cross-sectional studies among ICU nurses have reported similar assessments of VAP prevention-related knowledge, attitudes, and/or practices, providing additional context for comparison with our findings [23]. Studies conducted in 2014 and 2018 reported adequate knowledge among ICU nurses but identified gaps in the implementation of VAP prevention guidelines [12,13,15], which parallels our observation of high practice scores that are not significantly correlated with knowledge or attitudes. Similarly, research published in 2020 and 2018 noted that adherence to VAP prevention measures often depends on institutional protocols rather than solely on individual understanding [14,15], supporting the interpretation that organizational factors may drive practice behaviors. Minor discrepancies arise in the magnitude of knowledge scores, which may be attributable to differences in measurement tools, local guideline dissemination, and the availability of continuing education programs. Overall, our results align with the broader literature in suggesting that while knowledge and attitudes are important, they are not the sole determinants of preventive practices in clinical settings.

This study revealed significant differences in knowledge and attitudes among healthcare providers toward VAP. Higher knowledge scores were prominently observed in doctors compared to nurses, which might be attributed to their deeper clinical training and direct involvement in diagnostic processes. These findings are consistent with literature suggesting that higher professional education correlates with greater clinical knowledge [24,25]. Conversely, attitudes did not show significant differences across most demographic variables, indicating a uniformly recognized importance of VAP management across all groups, despite differences in knowledge levels.

In terms of practice, specifically among nurses, no significant differences were observed when analyzed alone. However, multivariate logistic regression analysis showed that nurses who had more frequent contact with elderly VAP patients were more likely to engage in active practice. This suggests that hands-on experience with VAP cases enhances practice engagement, supporting by previous study, which highlighted the impact of direct patient care experience on clinical practice

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levels [26,27]. For nurses, several factors were independently associated with better knowledge and positive attitudes. Age 30 to 39 years, higher education levels (Bachelor's/Master's degree), and working in the respiratory department were significant predictors of better knowledge. These results reinforce the notion that targeted education and specific departmental exposure are crucial in enhancing knowledge, which in turn positively influences attitudes. These findings align with previous research indicating that specialization within a specific medical area enhances both knowledge and attitudes towards disease management [28,29].

The correlation analyses and SEM results further demonstrated that while knowledge significantly impacts attitudes it does not translate effectively into practice, nor does attitude directly influence practice. This gap highlights a critical area for intervention, suggesting that while educational and awareness programs are effective at modifying knowledge and attitudes, they may not be sufficient to alter practices. This discrepancy might be due to the need for more practical, hands-on training sessions that link knowledge with everyday clinical routines [30,31].

The distribution of knowledge about VAP among healthcare providers varied significantly across several key areas, with notable deficiencies in understanding the criteria for post-extubation VAP diagnosis and the healthcare environment factors contributing to VAP occurrence. For example, a significant majority of respondents incorrectly identified pneumonia within 48 h of MV withdrawal as VAP, highlighting a critical gap in understanding VAP diagnostics. To address misconceptions, healthcare institutions should develop regular, mandatory training sessions that include up-to-date research and guidelines [22]. These sessions should be tailored to include case studies and real-world scenarios to help clarify common misunderstandings, such as the distinction between early onset and late onset VAP and its implications for treatment and management [32,33].

Attitudes toward VAP management were generally positive, with most respondents acknowledging the severity and impact of VAP on patient outcomes. However, there was a noticeable disparity in beliefs regarding the management of VAP compared to ordinary pneumonia, where a significant minority viewed them as similar. This misperception could undermine the specialized care required for VAP patients and potentially lead to suboptimal management practices. Educational campaigns should therefore focus not only on knowledge but also on changing attitudes by highlighting the differences in clinical management between VAP and other types of pneumonia [21]. These should include detailed discussions on the specific challenges and complexities of VAP, emphasizing the need for specialized care plans. Regular workshops and seminars discussing recent case studies and the latest research on VAP could also help reinforce the unique aspects of managing this condition [34,35].

Practices related to the prevention and management of VAP showed variability, with particularly lower adherence noted in more proactive measures like routine oral care with chlorhexidine and the assessment of sedation levels to prevent VAP. This suggests a gap between knowledge and practice, as well as potential barriers to implementing best practices, such as workload or lack of resources. To enhance practice adherence, hospitals could implement checklist-based protocols to ensure compliance with VAP prevention measures, particularly in ICU settings where the risk is highest. Additionally, the introduction of routine audits and feedback sessions could help reinforce the importance of these practices and identify areas for improvement [36-38].

This study had limitations. First, its cross-sectional nature limits our ability to draw causal inferences about the relationships between knowledge, attitudes, and practices regarding KAP. Second, the use of self-reported questionnaires might introduce response bias, as participants may provide socially desirable answers or may not accurately recall their actual practices. Third, we used a convenience sampling strategy, recruiting participants based on availability from selected departments. As a non-probability sampling method, this approach may introduce selection bias and limit the representativeness of the study population. Participants who were more accessible or more willing to respond may differ systematically from those who did not participate, which could affect the observed KAP levels. Therefore, caution is warranted when generalizing these findings to other healthcare settings or regions. Fourth, the study was conducted across a limited number of hospitals, which may affect the generalizability of the findings to other healthcare settings or geographic regions. As the study was conducted within China, the findings may not fully generalize to other countries or to regions with different clinical settings. Fifth, due to the small sample size of doctors, it is difficult to obtain reliable model fitting results, so no more in-depth statistical analysis was conducted. Finally, the practice dimension was based on self-reported responses and may not fully capture day-today bedside behaviors. The exclusion criteria for invalid questionnaires and the analytic approach used for the nurse cohort (median dichotomization in logistic regression and SEM) should be considered when interpreting the estimated associations.

Conclusions

Healthcare providers demonstrated adequate knowledge, positive attitudes, and generally good self-reported practices regarding VAP. However, knowledge and attitudes were not significantly associated with practice in the nurse cohort, suggesting that practice may be influenced by factors beyond individual

KAP. Targeted interventions addressing these additional factors may help improve VAP prevention.

Acknowledgments

We used AI-assisted language tools to polish the English writing and improve readability of this manuscript. These tools were used only for language editing and did not generate scientific content or contribute to the study design, data collection, data processing, statistical analysis, result interpretation, or any research-related decision-making. The authors take full responsibility for the content of the manuscript.

Ethics Approval and Consent to Participate

This study was approved by the Medical Ethics Committee of Fujian Geriatric Hospital (20240403), and written informed consent was obtained from all participants. All methods were performed in accordance with relevant guidelines. All procedures were performed in accordance with the ethical standards laid down in the 1964 Declaration of Helsinki and its later amendments.

Availability of Data and Materials

All data generated or analyzed during this study are included in this published article.

Declaration of Figures' Authenticity

All figures submitted have been created by the authors who confirm that the images are original with no duplication and have not been previously published in whole or in part.

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