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Effect of ventilator care bundle for pediatric nurses on occurrence of ventilator-associated pneumonia among children

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Abstract

Background In pediatric intensive care units (PICUs), ventilator-associated pneumonia (VAP) is one of the most prevalent infections linked to healthcare. VAP affects 10% of children on mechanical ventilation (MV) and is associated with severe morbidity and mortality. The study aimed to evaluate the effect of the ventilator care bundle (VCB) on the occurrence of VAP among pediatric patients.

Method A quasi-experimental design was conducted at Cairo University Specialized Pediatric Hospital (CUSPH), including all children who had mechanical ventilation within 24 h. VAP rates were evaluated before and after the implementation of a comprehensive VCB, which included head-of-bed elevation to 30–45°, hand hygiene reinforcement, sterile suctioning and handling of respiratory equipment, daily evaluation of extubation readiness, peptic ulcer prophylaxis, and deep venous thrombosis prophylaxis. A convenience sample of 30 nurses and a purposive sample of 60 ventilated children in the PICU participated in the study. Data collection was performed using (1) structured interview sheets, (2) the Nurses' Knowledge Assessment Questionnaire (pre/post-test), (3) the Ventilator Bundle Checklist, and (4) the Clinical Pulmonary Infection Scale (CPIS).

Results There was a significant increase in nurses' level of knowledge before and after the implementation of the VCB ($X^2 = 21.46$, $p \leq 0.01$). There was a statistically significant difference between the total mean scores of nurses' practices in the first and second checklist readings ($p < 0.01$). Additionally, there were statistically significant differences between children in the study and control groups regarding the clinical pulmonary infection score ($p < 0.01$). The total mean score on the CPIS was significantly different between the study group and the control group ($t = -3.692$, $p = 0.001$).

Conclusion The study concluded that children who were cared for by nurses receiving VCB sessions were less likely to experience VAP compared to those in the control group.

Recommendation Educational programs and in-service training courses for pediatric nurses to improve the quality of ventilator care for children and reduce the occurrence of VAP are essential.

Keywords Ventilator-associated pneumonia, Ventilator care bundle, Pediatric nurses, Children

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Background

Ventilator-associated pneumonia (VAP) remains a prevalent hospital-acquired infection (HAI), affecting approximately 10–20% of hospitalized patients, including the pediatric population. Ventilator-associated pneumonia is associated with elevated morbidity and mortality rates, posing significant diagnostic and management challenges [1, 2]. The prevalence of ventilator-associated pneumonia in newborns and children worldwide stands at 17%, representing a critical health concern. The condition exacerbates mortality and morbidity rates, leading to prolonged hospital stays and increased healthcare expenditures [3]. The incidence of ventilator-associated pneumonia can reach as high as 38.4%, though comparisons across healthcare facilities are hindered by variations in study populations, environmental factors, and infection control practices [4].

The persistence of ventilator-associated pneumonia in pediatric patients highlights the urgent need for improved preventive strategies and clinical protocols in critical care settings [5]. Ventilator-associated pneumonia often arises in children undergoing prolonged mechanical ventilation (MV) due to factors such as improper positioning of the endotracheal tube, excessive humidity, and inadequate cuff pressure. Recent research has identified various risk factors for hospital-acquired infections, including genetic predispositions, re-intubation, and invasive procedures. Effective preventive measures include rigorous hand hygiene practices, the use of closed suctioning systems, elevating the head of the bed, and following protocol-based care [6, 7]. Implementing quality improvement programs globally is imperative to mitigate the morbidity and mortality associated with ventilator-associated pneumonia. Hand hygiene, recognized for its effectiveness in reducing gastrointestinal and respiratory infections, plays a crucial role in minimizing the transmission of ventilator-associated pneumonia by eliminating potential pathogens [8, 9].

Ventilator-associated pneumonia in children manifests through clinical signs such as fever, increased respiratory secretions, altered breathing, low oxygen levels, and purulent sputum [10]. In healthcare, a "bundle" is a powerful tool designed to enhance patient outcomes by incorporating a set of evidence-based procedures that, when implemented together, improve care processes and outcomes [11]. Pediatric ventilator bundles, when combined with an evidence-based, multidisciplinary approach, have been shown to effectively improve both clinical and patient outcomes [12]. Recognizing ventilator-associated pneumonia prevention as a pivotal quality indicator, hospital administration has invested substantially in patient safety and quality programs. Implementing a ventilator care bundle is crucial for preventing ventilator-associated pneumonia and reducing its incidence in the Pediatric Intensive Care Unit (PICU) [13]. Recent studies indicate that ventilator-associated pneumonia in children can lead to severe complications, including prolonged mechanical ventilation, extended hospital stays, increased morbidity, and mortality [14].

The use of ventilator bundle components was suggested by the Institute for Healthcare Improvement (IHI). Head-of-the-bed elevation to 35–45°, sedation vacation and evaluation of extubation readiness, prevention of peptic ulcers, prevention of deep vein thrombosis (DVT), and the use of chlorhexidine for oral hygiene are the five components of the ventilator bundle [15]. Bundled treatment, education, and nurse performance are all necessary for the effective prevention of ventilator-associated pneumonia in pediatric patients. In order to improve treatments like hand hygiene, bundled care, and infection communication among staff and lower the incidence of ventilator-associated pneumonia, nursing education on incidence, risk factors, and prevention is essential [16].

Implementing a ventilator care bundle (VCB) is a critical strategy for reducing the incidence of ventilator-associated pneumonia in pediatric patients while enhancing nurses' knowledge and practices. To ensure its effectiveness in minimizing complications in patients receiving mechanical ventilation, a structured approach is necessary. This process begins with education and training for healthcare staff on the significance of each bundle component, such as elevating the head of the bed and managing sedation [17]. Developing and making evidence-based protocols easily accessible is crucial for standardized procedure adherence [18]. Regular monitoring and compliance checks through audits and checklists help identify areas needing improvement [17]. Providing feedback to healthcare staff and involving a multidisciplinary team ensures comprehensive implementation and continuous improvement [18]. By following these steps, healthcare facilities can significantly enhance patient outcomes and reduce the incidence of ventilator-associated complications.

The aim of this study is to evaluate the effectiveness of ventilator care bundles in reducing the incidence of ventilator-associated pneumonia among pediatric patients in Egyptian pediatric intensive care units. Worldwide, ventilator-associated pneumonia is a significant issue in pediatric intensive care units, leading to elevated rates of morbidity and mortality, extended hospital stays, and higher medical expenses [19]. Furthermore, this study fills a gap in the existing literature, as there are few studies specifically focused on the use of ventilator care bundles for children in Egypt. The findings from this research could provide valuable insights into effective strategies for reducing ventilator-associated pneumonia in pediatric patients and emphasize the importance of comprehensive education and training for healthcare staff [20]. Implementing evidence-based protocols and ensuring their adherence through regular monitoring and feedback can significantly enhance patient safety and care quality [21]. Ultimately, this study's findings might impact pediatric intensive care units policy and practice modifications, expanding the use of ventilator care bundles and possibly lessening the strain that ventilator-associated pneumonia places on healthcare systems. This study could support international initiatives to enhance patient outcomes and encourage the adoption of best practices in critical care settings by proving the efficacy of ventilator care bundles [19]. A study conducted at Mansoura University Hospital in Egypt revealed that the implementation of the ventilator care bundles significantly enhanced the overall standard of care provided to patients on mechanical ventilation. The research found that patients in the ventilator care bundles group were able to wean off mechanical ventilation more successfully and in a shorter period of time compared to the control group [22].

Methods

Design

A quasi-experimental research design was utilized to achieve the aim of the current study. A quasi-experimental design is a type of experimental design that is very similar to the true experimental design, except that one criterion is lost: randomization [23]. The clinical trial number is not applicable.

Research hypotheses

H_1 Nurses who use the ventilator care bundle will have a higher mean score for knowledge and practice than those who do not.

H_2 Children who receive care from nurses after receiving the ventilator care bundle will have less exposure to ventilator-associated pneumonia than the control group.

Setting

Nurses and children were selected from the pediatric intensive care units on the ground floor of Cairo University Specialized Pediatric Hospital (CUSPH). With a total bed capacity of 150, CUSPH is renowned for providing high-quality pediatric care and advanced medical services. The pediatric intensive care unit handles a wide range of critical conditions, making it an ideal environment for studying the impact of ventilator care bundles on patient outcomes. The hospital's experienced medical team and commitment to evidence-based practices further support its selection as the research setting.

Participants

The sample size was calculated using the G Power Program 1 Version 3.1.9.4. To achieve the study's objective, a sample size of 60 children was determined to be necessary. This calculation was based on a significance level (α) of 0.05, a power (1-β) of 0.95, and an effect size of 0.80. A purposive sample of 60 children on mechanical ventilation was selected. These children were randomly assigned to either the control group or the experimental group. The first 30 children received routine mechanical ventilation care in the hospital (control group), while the second 30 children received the ventilator care bundle (experimental group). Inclusion criteria were: all children admitted to the pediatric intensive care units and intubated within 24 h, and children up to 5 years old. Exclusion criteria were: children diagnosed with pneumonia at the time of admission, children re-intubated after 24 h from admission, patients contraindicated to any component of the ventilator care bundle application, and children with immune diseases or those receiving immune drugs. The study also included all pediatric nurses working in the pediatric intensive care units who agreed to participate, totaling 30 nurses. These nurses were included regardless of their age (20 years and above), different qualifications, sex, or years of experience (5 years and above).

Data tools

1. **Structured Interview Sheet**: Developed by the researchers after reviewing the related literature, this tool consists of 20 items classified into three parts:
   Part I: This part includes six items about the characteristics of the children, such as age, diagnosis, sex, rank, place of residence, and reason for putting the child on mechanical ventilation. The questionnaire was translated from Arabic to English and used in the study.
   Part II: This part includes seven items related to the child's medical history and present history, such as previous illness, previous diagnosis, previous admission to the pediatric intensive care units, cause of admission, duration of pediatric intensive care units stay, symptoms on admission, and diagnostic evaluation.
   Part III: This part includes seven items related to the personal and professional data of the pediatric nurses, such as age, sex, qualification, years of experience, training courses in the pediatric intensive care units and mechanical ventilation, and frequency of training courses.
2. **Nurses' Knowledge Assessment Questionnaire (pre/posttest)**: This questionnaire includes twenty questions developed by the researchers to assess

pediatric nurses' knowledge about mechanical ventilation. These questions cover the assessment of mechanical ventilation (6 questions), care of a child on mechanical ventilation (9 questions), weaning of mechanical ventilation (3 questions), and medication used (2 questions). The questionnaire was translated from Arabic to English and used in the study.

Scoring system: For nurses' knowledge, correct and complete responses were given a "2" score, incomplete responses were given a "1" score, and incorrect responses were given a value of zero. The total score was 40, and the data were converted to 100% and then categorized as follows: Excellent (85–100%), Very good (75% to <85%), Good (65% to <75%), and Pass (60% to <65%).

3. **Ventilator Bundle Checklist**: This tool was adopted based on the guidelines of the Institute for Healthcare Improvement [24] to assess 8 items related to ventilator care bundle practices. The key components of the ventilator care bundle checklist are as follows: washing hands, care of the ventilator machine, elevation of the head of the bed to 30–45°, mouth care with normal saline 9% or distilled water, daily sedation interruption, assessment of readiness to extubation, peptic ulcer disease prophylaxis, and deep venous thrombosis prophylaxis.
   Scoring system: For nurses' practices (via the ventilator bundle checklist), each item was scored as follows: complete/correct practice took a "2" score, incomplete/incorrect practice took a "1" score, and not done/missed practice took a "0" score. The total score was 16, and the total score was converted to 100%. Patients were subsequently categorized as follows: A total score less than 75% (less than 12) was considered an unsatisfactory level of practice, while a total score of 75% (12 or more) was considered a satisfactory level of practice.
4. **Clinical Pulmonary Infection Score (CPIS)**: This score was adopted from [25] and filled out by the doctor. Six clinical assessments of ventilator-associated pneumonia, each worth 0–2 points, have been proposed for the diagnosis and management of ventilator-associated pneumonia. These assessments include temperature, leukocyte count, quantity and purulence of tracheal secretions, oxygenation (PaO2/FIO2), chest X-ray, and microbiology (culture growth from tracheal aspirate). Total scores from 0 to 6 points indicated that pneumonia was less likely, while a score from 7 to 12 indicated that pneumonia was more likely. The reliability of the clinical pulmonary infection score was 96%.

CPIS	Score
1- Patient temperature	
1. ≥ 36.5 degrees C and ≤ 38.4 degrees C	**0 points**
2. ≥ 38.5 degrees C and ≤ 38.9 degrees C	**1 point**
3. ≥ 39 degrees C ≤ 36 degrees C	**2 points**
2- Leukocyte count	
1. ≥ 4,000/mm^{-3} and ≤ 11,000/mm^{-3}	**0 points**
2. < 4,000/mm^{-3} or > 11,000/mm^{-3}	**1 point**
3. < 4,000/mm^{-3} or > 11,000/mm^{-3}	**2 points**
3- Tracheal secretions (summed over 24 hours)	
1. Rare	**0 points**
2. Abundant	**1 point**
3. Abundant + purulent	**2 points**
4- PaO2(mmHg)/FIO2	
1. > 240 or ARDS present	**0 points**
2. ≤ 240 or no evidence of ARDS	**2 points**
5- Chest X-ray	
1. No infiltrate	0 points
2. Diffuse	1 point
3. Localized	2 points
6- Microbiology (culture growth from tracheal aspirate)	
1. Negative	0 points
2. Positive	2 points
CPIS interpretation 0–6 points = Pneumonia less likely	
7–12 points = Pneumonia more likely	

Validity and reliability

The data collection instruments used in this study was evaluated by a panel of five experts in pediatric intensive care and pediatric nursing to ensure content validity. The experts provided feedback, leading to modifications that enhanced the tools' validity. The reliability of the tools was then assessed, yielding a Cronbach's alpha of 0.80, confirming their consistency.

Data collection

Data were collected by the researchers over approximately twelve months, from July 2022 to July 2023. Informed consent was obtained from the caregivers of all children included in both groups. The researchers provided clear and concise explanations regarding the study's purpose and procedures to the participating nurses, and written consent was subsequently obtained from those who voluntarily agreed to participate. Caregivers and nurses then completed a structured interview questionnaire (Tool 1). A pretest was conducted to evaluate the nurses' knowledge regarding the care of children on mechanical ventilation. Furthermore, the nurses' practices were assessed through an observational checklist before the training session. These observations were conducted individually, aligned with each nurse's working hours with a child. Data were collected first from the children in the control group receiving routine care in pediatric intensive care, followed by those in the study group.

The researchers conducted two training sessions. The first session was dedicated to enhancing theoretical knowledge for nurses on key aspects of mechanical ventilation. Topics included the assessment and weaning of mechanical ventilation, medications commonly used in this context, principles of mechanical ventilation, the importance of infection prevention, and guidelines for providing care to children on mechanical ventilation. This session was delivered individually to each nurse, tailored to their work schedule, and held in the waiting area of the pediatric intensive care unit. Each session lasted approximately 30–45 minutes. One week after the session, a posttest (Tool 2) was administered to evaluate the knowledge gained by the same nurses. The second session focused on the practical application of the ventilator care bundle through demonstrations and re-demonstrations for nurses using a doll, enabling them to develop and refine essential skills. This 40–60 min session emphasized key practices, including proper hand hygiene, patient positioning, oral care, daily sedation assessment, readiness for extubation assessment, and prophylaxis for peptic ulcer disease and deep venous thrombosis. The doll-based training provided a controlled environment for skill mastery before implementation in clinical practice.

These children were randomly assigned to either the control group or the experimental group. All children attached to mechanical ventilation at zero-day of initiating mechanical ventilation were assessed against the inclusion and exclusion criteria. Children who met the inclusion criteria were included in the study. Children who were weaned from mechanical ventilation before reaching the third day were excluded from the study because ventilator-associated events (VAEs) cannot be assessed as an outcome of the application of a ventilator care bundle. Nurses' compliance with all elements of the ventilator care bundle was assessed twice every day for one week, during both morning and night shifts. If any element of the bundle was not done or done incorrectly at any shift, it was recorded as non-compliant. If all elements of the ventilator bundle were done correctly throughout the whole day, it was recorded as compliant. Nurse performance was evaluated using an observational checklist (Tool 3) on the third and sixth days of ventilator care bundle implementation, assessing adherence and effectiveness. After 7 days of ventilator care bundle compliance for children in the study group, researchers assessed the occurrence of ventilator-associated pneumonia using the Clinical Pulmonary Infection Score (Tool 4). This assessment, performed by a physician in the pediatric intensive care units as routine screening, included temperature, leukocyte count, tracheal secretions, oxygenation (PaO_2/FIO_2), chest X-ray, and microbiology (culture growth from tracheal aspirate). Researchers recorded results from the patient file. The same evaluation was done for the control group after 7 days of routine care in the pediatric intensive care units. To minimize bias, observer blinding was implemented during data collection. Data collectors and evaluators involved in assessing study results were blinded to the intervention groups, ensuring unbiased assessments and enhancing the reliability of the findings.

Statistical analysis

Data were analyzed using SPSS software version 20.0. Continuous variables were represented as means with standard deviations, whereas categorical variables were represented as numbers with percentages. The parametric chi-square test was used to compare qualitative variables. For comparisons of means, paired-sample t-tests and inferential statistical tests were used to test the study hypotheses. The level of statistical significance was set at p-value ≤ 0.05.

Result

As shown in Table 1, 43.3% of children on mechanical ventilation and 50% of those in the control group were aged 1–3 years. The average age was 2.5 ± 1.32 years for the study group and 2.1 ± 1.31 years for the control group. Table 1 further indicates that the study group was 63.3% female, while the control group was 53.3% female. Shock was present in 36.7% of the study group and 33.3% of the control group, while 23.3% and 26.7%, respectively, had respiratory distress syndrome. As detailed in Table 1, accidents and postoperative complications affected 20% of the study group, whereas 33.3% of the control group reported accidents. Respiratory and non-respiratory mechanical ventilation causes were observed in over one-third of the study group and 50% of the control group. According to Table 1, three-week pediatric intensive care unit stays were noted for 46.3% of the study group and 50% of the control group. Diagnoses using radiological images and arterial blood gases (ABGs) were made in 70% of the study group and 53.3% of the control group. Moreover, Table 1 demonstrates a statistically significant difference ($p < 0.05$) between children in both groups regarding sex, causes of mechanical ventilation, and diagnostic evaluation.

As shown in Table 2, over half of the nurses were aged between 20 and 30 years, with a mean age of 25.66 ± 6.23 years. Table 2 further indicates that the majority (56.7%) of nurses were female. Regarding qualifications, 46.7% of the nurses were graduates of the Technical Institute of Nursing. Additionally, Table 2 shows that 53.3% of nurses had less than 5 years of experience in pediatric intensive care units.

As shown in Table 3, there were highly significant differences in nurses' total mean knowledge scores

Table 1 Children demographic and clinical data (n = 60)

Items	Study group (n = 30)		Control group (n = 30)		X^2	P
	n	%	n	%		
Age						
< 1 year	6	20	8	28.7	4.92	.295
1 > 3 years	13	43.3	15	50		
3–5 years	11	36.7	7	23.3		
Mean ± SD	2.5 ± 1.32		2.1 ± 1.31			
Gender						
Male	11	36.7	14	46.7	7.33	.010*
Female	19	63.3	16	53.3		
Diagnosis						
Accident	6	20	10	33.3	6.17	.723
Shock	11	36.7	10	33.3		
Respiratory distress syndrome	7	23.3	8	26.7		
Postoperative complications	6	20	2	6.7		
Causes of mechanical ventilation						
Respiratory support	11	36.7	10	33.3	3.00	.058*
Non-respiratory support	11	36.7	15	50		
Both	8	26.6	5	16.7		
PICU days						
2 weeks	5	16.7	7	23.3	4.26	.372
3 weeks	13	43.3	15	50		
1 month	12	40	8	26.7		
Diagnostic evaluation						
Radiology image (X ray- CT-MRI)	9	30	14	46.7	3.08	.018*
Both (radiology image—ABG)	21	70	16	53.3		

Table 2 Nurses' personal data in the current study (n = 30)

Items	n	%
Age/year		
< 20	7	23.3
20 < 30	17	56.7
30 < 40	6	20
Mean ± SD		± 6.2325.66
Gender:		
Male	13	43.3
Female	17	56.7
Qualification:		
Secondary school nursing diploma	5	16.6
Technical Institute of Nursing	14	46.7
Bachelor degree of nursing	11	36.7
Years of experience in PICU:		
< 5	16	53.3
10 < 20	14	46.7

(assessment, care for children, weaning of mechanical ventilation, and medications) before and after treatment ($p \le 0.001$). Table 3 indicates that initially, only 6.7% of nurses had an excellent level of knowledge regarding mechanical ventilation. This percentage dramatically increased to 53.3% after the implementation of the ventilator care bundle. Additionally, the percentage of nurses with poor knowledge decreased from 20% to 0% post-implementation. Table 3 highlights that this demonstrates the ventilator care bundle had a substantial impact on improving nurses' knowledge. Furthermore, a statistically significant difference was observed in nurses' knowledge levels before and after the ventilator care bundle ($X^2 = 21.46$, $p \le 0.001$).

As shown in Table 4, significant post-ventilator care bundle improvements were observed. Table 4 reveals that complete hand hygiene before and after mechanical ventilation contact was performed by 80% and 73.3% of nurses, respectively, with over one-quarter showing incomplete compliance in the second reading. Ventilator care was completed by 76.7% and 70% of nurses, while over one-quarter were incomplete in the second reading. According to Table 4, for children in a semi-recumbent position and daily sedation, over three-quarters of nurses completed the ventilator care bundle in the first reading, and most did so in the second reading, with 10% and 6.7% failing to complete it. Table 4 also indicates that regular oral hygiene every 4 h and daily extubation readiness assessments increased to 80% and 93.3% in the second reading. The majority of nurses provided care for peptic ulcer disease and deep venous thrombosis prophylaxis. Furthermore, statistically significant differences were observed ($\chi^2 = 3.91$, $p = .057$; $\chi^2 = 7.74$, $p = .001$; $\chi^2 = 3.70$, $p = .054$; $\chi^2 = 3.81$, $p = .051$). As highlighted in Table 4, the

Table 3 Comparison of the total mean scores and level of nurses' knowledge of ventilator care bundle (n = 30)

Total mean scores	Pretest		Posttest		t	P
	Mean ± SD		Mean ± SD			
Assessment of mechanical ventilation (12 marks)	5.86 ± 1.33		10.16 ± 1.36		−12.54	.001**
Care of a child on mechanical ventilation (18 marks)	9.13 ±.973		14.66 ± 1.12		−19.30	.001**
Weaning of mechanical ventilation (6marks)	2.30 ± 1.17		5.16 ±.746		−11.15	.001**
Medications (4 marks)	1.96 ±.927		3.00 ±.870		−4.44	.001**
Level of knowledge	Pretest		Posttest		X^2	*P*
	n	%	n	%	21.46	.000**
Excellent	2	6.7	18	53.3		
Very good	5	16.7	7	30		
Good	9	30	3	10		
Pass	8	26.7	2	6.7		
Fail	6	20	0	0		

mean total score for nurses' performance after using the ventilator care bundle was 1.93 ±.253 at the first reading and 1.83 ±.379 at the second reading, with a statistically significant difference in the mean scores between the first and second checklist readings ($p \leq 0.001$).

As shown in Table 5, significant differences in clinical pulmonary infections were observed between the study and control groups. Table 5 reveals that over two-fifths of children in the study group had normal temperature or fever with rare tracheal secretions, while 56.7% of the control group exhibited hyperpyrexia or hypothermia. Normal leukocyte counts were observed in 43.3% of the study group, whereas 40% of the control group showed leukopenia or lymphocytosis. Table 5 also highlights that 73.3% of the study group did not have respiratory distress syndrome (RDS), compared to less than two-thirds of the control group. Chest X-rays, as detailed in Table 5, showed no infiltrate in 56.7% of the study group, while half of the control group demonstrated localized signs. Additionally, most of the study group had negative culture growth, whereas 63.3% of the control group exhibited positive culture growth. Table 5 indicates statistically significant differences in clinical pulmonary infection scores between the groups ($p < 0.05$, $p < 0.001$). Moreover, there was a statistically significant difference in the mean clinical pulmonary infection scores between the study and control groups ($t = -3.692$, $p = 0.001$).

Discussion

The findings of this study indicate that a significant portion of the children on mechanical ventilation in both the study group and the control group were aged 1 to less than 3 years. Gender distribution showed that both groups had a majority of female patients. The results are consistent with findings from [26], which confirmed that 36.2% of pediatric patients had ventilator-associated pneumonia, with children aged 1–5 years being the most frequently affected age group. According to [27], children in this age range have underdeveloped immune systems and respiratory structures, making them more vulnerable to infections and respiratory distress, thereby increasing the likelihood of requiring mechanical ventilation. Clinical conditions varied, with the cohort experiencing conditions such as shock and respiratory distress syndrome. The primary reason for pediatric intensive care unit admission in the study group was pneumonia, while the control group was predominantly admitted for dehydration. However, our results contrast with previous studies that found 54.6% of pediatric patients were male and 39.2% of children in pediatric intensive care units had acute respiratory distress syndrome. Research noted that children might be overrepresented in pediatric intensive care units due to environmental factors that increase their risk of exposure to respiratory infections [28, 29]. Studies in India identified septic shock (27.14%), respiratory disorders (20.9%), and cardiovascular illnesses (41.1%) as the main causes of pediatric intensive care unit admissions [29, 30]. Other research indicated that respiratory diseases accounted for 51.53% of long-stay patients, often with comorbidities and complications [31, 32].

Duration of pediatric intensive care units stay varied, most children in the study group and control group remaining for three weeks. For diagnostic procedures, arterial blood gases (ABGs) and radiological imaging was employed in the study and control group. According to a study by [33], children admitted to the pediatric intensive care unit often present with complex conditions, including shock and respiratory distress syndrome, necessitating intensive interventions like mechanical ventilation and rigorous infection control to prevent ventilator-associated pneumonia. Our findings are supported by [34], who found that pediatric intensive care units stays often extend to several weeks, especially for those requiring mechanical ventilation due to the severity of conditions and treatment complexity. Additionally [35], noted that early pneumonia may show minimal inflammation on X-rays, recommending repeated imaging for patients

Table 4 Comparison checklist and total mean scores of nurses' practices for ventilator care bundle (n = 30)

Item	After implementation												X^2	P
	First reading (3rd day)						Second reading (6th day)							
	Complete		Incomplete		Not done		Complete		Incomplete		Not done			
	n	%	n	%	n	%	n	%	n	%	n	%		
Perform hand washing before and after contact with a mechanical ventilator														
	24	80	6	20	0	0	22	73.3	8	26.7	0	0	170.	.520
Perform regular care and maintenance of the ventilator machine														
	23	76.7	5	16.7	2	6.6	21	70	8	26.7	1	3.3	3.91	.057*
The child should be nursed in a semi recumbent position 30 degrees														
	22	73.3	6	20	2	6.6	25	83.3	2	6.7	3	10	7.74	.001*
Regular oral hygiene maintained every 4 hours performed														
	27	90	3	10	0	0	24	80	6	20	0	0	3.70	.054*
Daily sedation holds performed (unless contraindicated)														
	22	73.3	5	16.7	3	10	24	80	4	13.3	2	6.7	2.16	.705
Peptic ulcer disease prophylaxis														
	25	83.3	2	6.7	3	10	26	86.7	3	10	1	3.3	2.31	678.
Deep venous thrombosis prophylaxis performed														
	23	76.7	6	20	1	3.3	26	86.7	4	13.33	0	0	2.65	.262
Daily assessment of readiness to performed extubate														
	27	90	3	10	0	0	28	93.3	2	6.7	0	0	3.81	.051*
Items				Unsatisfactory				Satisfactory		Mean ± SD			t	*P*
First reading (3rd day)				2				28		1.93 ± .253			41.73	.001*
Second reading (6^{t}h day)				5				25		1.83 ± .379			26.49	.001*

with high clinical suspicion. As highlighted by [36], arterial blood gases are crucial for monitoring respiratory function, and radiological imaging (e.g., chest X-rays, CT scans) is used to diagnose and monitor respiratory conditions, detect complications, and guide treatment. Throughout the study, a significant portion of the nursing staff was aged between 20 and 30 years, with a mean age of 26.23 ± 5.66 years, and the majority was female. Regarding qualifications, most of the nurses had graduated from the technical institute of nursing, and had less than 5 years of experience. The study's findings are consistent with previous research. The mean age of nurses was 26.63 ± 4.25 years, within the range of 20–30 years [37]. Younger nurses often staff pediatric intensive care units due to the demanding nature of the work [38, 39]. The majority of pediatric intensive care units nurses were female, aligning with the global nursing workforce being predominantly female [40]. Technical institutes are increasingly providing specialized training required for pediatric critical [41, 42]. Most nurses had at least 10 years of experience and ongoing education and mentorship enhance nurses' competence and confidence [43, 44]. These findings highlight the importance of tailored interventions and continuous professional development for nurses to address the specific challenges faced by pediatric patients and healthcare providers in pediatric intensive care units settings.

The duration of pediatric intensive care unit stays varied, with most children in both the study group and control group remaining for three weeks. For diagnostic procedures, arterial blood gases (ABGs) and radiological imaging was employed in both groups. According to a study by [33], children admitted to the pediatric intensive care unit often present with complex conditions, including shock and respiratory distress syndrome, necessitating intensive interventions like mechanical ventilation and rigorous infection control to prevent ventilator-associated pneumonia. Our findings are supported by [34], who found that pediatric intensive care unit stays often extend to several weeks, especially for those requiring mechanical ventilation due to the severity of conditions and treatment complexity. Additionally [35], noted that early pneumonia may show minimal inflammation on X-rays, recommending repeated imaging for patients with high clinical suspicion. As highlighted by [36], arterial blood gases are crucial for monitoring respiratory function, and radiological imaging (e.g., chest X-rays, CT scans) is used to diagnose and monitor respiratory conditions, detect complications, and guide treatment. Throughout the study, a significant portion of the nursing staff was aged between 20 and 30 years, with a mean age of 26.23 ± 5.66 years, and the majority was female. Regarding qualifications, most of the nurses had graduated from the Technical Institute of Nursing and had less than 5 years of experience. The study's findings are consistent with previous research. The mean age of nurses was 26.63 ± 4.25 years, within the range of 20–30 years [37]. Younger nurses often staff pediatric intensive care units due to the demanding nature of the work [38, 39]. The majority of pediatric intensive care unit nurses were female, aligning with the global nursing workforce being predominantly female [40]. Technical institutes are increasingly providing the specialized training required for pediatric critical care [41, 42]. Most nurses had at least 10 years of experience, and ongoing education and mentorship enhance nurses' competence and confidence [43, 44]. These findings highlight the importance of tailored interventions and continuous professional development for nurses to address the specific challenges faced by pediatric patients and healthcare providers in pediatric intensive care unit settings.

The current results demonstrated a statistically significant improvement in both knowledge and practices post-intervention with the ventilator care bundle. Prior to receiving the ventilator care bundle, a fifth of the nurses exhibited a poor level of knowledge; however, following the intervention, no nurses fell into this category. Comparing pre-intervention and post-intervention outcomes, the majority and a substantial portion of nurses consistently practiced hand washing before and after contact with mechanical ventilation in the post-ventilator care bundle implementation. Additionally, fewer nurses performed complete care of the ventilator machine prior to the ventilator care bundle, but this number increased significantly post-implementation. The study also revealed that the majority of nurses effectively managed children in a semi-recumbent position, maintained regular oral hygiene every 4 h, and assessed readiness to extubate daily post-ventilator care bundle implementation. Finally, there was a statistically significant improvement in nurses' knowledge and practices post-intervention with the ventilator care bundle ($p < 0.001$). In contrast [45], identified similar respiratory pathogens in hospital-acquired pneumonia patients and emphasized the importance of nurses performing oral hygiene every 4 h, aligning with guidelines from the New Zealand Dental Association. The findings are in line with [46], showing significant improvements in nurses' practices after the ventilator care bundle program ($p < 0.001$). Similar results were reported by [47], with enhanced nurses' knowledge after teaching and their practices ($p < 0.001$). Lastly [48], found that 83% and 88.8% of nurses had satisfactory post-program knowledge on ventilator care, consistent with our findings. This result emphasizes the importance of structured training programs in our study. Additionally [49], conducted a study that showed a statistically significant improvement in both knowledge and quality of care among staff nurses managing patients on

Table 5 Comparison of clinical pulmonary infection score assessments of ventilator-associated pneumonia between children (n = 60)

CPIS	Study (n = 30)		Control (n = 30)		X^2	P
	n	%	N	%		
Temperature						
≥36.5 °C & ≤ 38.4 °C	14	46.7	6	20	7.40	.025*
≥ 38.5 °C & ≤ 38.9 °C	12	40	7	23.3		
≥39 °C or ≤ 36 °C	4	13.3	17	56.7		
Leukocytes count						
≥4,000/mm^{-3} & ≤ 11,000/mm^{-3}	13	43.3	7	23.3	5.15	.272
<4,000/mm^{-3} & > 11,000/mm^{3}	10	33.3	12	40		
<4,000/mm^{-3} & > 11,000/mm^{-3}	7	23.3	11	36.7		
Tracheal secretions (summed over 24 h)						
Rare	14	46.7	6	20	5.40	.057*
Abundant	12	40	16	53.3		
Abundant + purulent	4	13.3	8	26.7		
PaO2 (mmHg)/FIO2						
>240 or RDS present	8	26.7	18	60	6.53	.001**
≤240 or no evidence of RDS	22	73.3	12	40		
Chest X-ray						
No infiltrate	17	56.7	7	23.3	9.80	.004**
Diffuse	10	33.3	8	26.7		
Localized	3	10	15	50		
Microbiology (culture growth from tracheal aspirate)						
Negative	24	80	11	36.7	8.53	.002**
Positive	6	20	19	63.3		
CPIS interpretation	PLL	PML	PLL	PML	t	P
Minimum	4	7	4	7	−3.692	.001**
Maximum	6	9	6	12		
Mean ± SD	5.800 ± 1.297		7.600 ± 2.044			

PLL Pneumonia less likely, *PML* Pneumonia more likely mechanical ventilation after an educational intervention, which aligns with the results of our study. The current study contributes to the growing body of evidence supporting the effectiveness of educational interventions in improving healthcare practices. It underscores the need for ongoing training and professional development to ensure high standards of patient care and prevent complications in critical care settings.

Additionally, the total mean scores of nurses' practices showed a significant improvement post-ventilator care bundle implementation ($p < 0.001$). Children's clinical pulmonary infection scores also showed a highly significant difference between the study and control groups ($p < 0.001$). Overall, these findings strongly support the hypothesis that implementing a structured ventilator care bundle can significantly enhance nurses' knowledge and practices, thereby reducing the incidence of ventilator-associated pneumonia complications in pediatric patients. The findings align with those of [50] (2020) in Egypt, which found a strong relationship between nurses' practices and the ventilator care bundle ($p < 0.001$), consistent with our study. Similarly [51], reported significant improvements in nurses' knowledge and performance post-intervention of the ventilator care bundle program [52]. Noted differences in pre- and post-diagnosed clinical pulmonary infection score levels, aligning with our findings. Furthermore, the results highlight the importance of continuous professional development in maintaining high standards of care. As such, the study reinforces the necessity for ongoing education and training to equip healthcare providers with the latest best practices and techniques. The study has some limitations. Firstly, the demanding nature of nurses' work schedules may have influenced their participation and performance. Secondly, the study was conducted in a single location, which may limit the generalizability of the findings.

Conclusion

The present study found highly significant differences in the overall mean ventilator care bundle knowledge and practices for nurses who received ventilator care bundles compared to those who did not. Children under the care of these trained nurses were less likely to experience ventilator-associated pneumonia. There were statistically significant differences in clinical pulmonary infection scores between the study and control groups, supporting the effectiveness of the ventilator care bundle. Suggest areas for future research, such as exploring the long-term effects of ventilator care bundles, comparing different bundle components, or investigating the impact of nurse training programs on VAP rates. Further studies could also examine the cost-effectiveness of implementing these bundles in various healthcare settings.

Recommendations

Based on the results of the current study, the following is recommended:

- Integration of the ventilator care bundle for nurses in the pediatric intensive care unit (PICU) and neonatal intensive care unit (NICU) is essential.

-Educational programs and in-service training courses for pediatric nurses to increase the quality of ventilator care for children and its benefits for the occurrence of ventilator-associated pneumonia.

- A longitudinal study is necessary to monitor the relapse of ventilator-associated pneumonia and complications of ventilator-associated pneumonia among children on mechanical ventilation.

Supplementary information

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Supplementary Material 1

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Author contributions

H, D,K., N,A. and M,A,I researchers conceived the study; H,D,K., and M,A,I developed the theoretical framework of the research; H,D,K,. and M,A,I researchers aided in the analysis; and N,A., and M,A,I supervised the project. All the authors discussed the results and contributed to the final manuscript. Researchers H, D,K., and N,A. analyzed the data and wrote the manuscript; however, H, D, K., and M, A,I researchers contributed to the final version and supervised the project. Researchers H, D, K., N, A. and M, A, I wrote the manuscript with input from all the authors for overall direction and planning. All the researchers contributed to the design and implementation of the research, the analysis of the results, and the writing of the manuscript.

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Data availability

The data that supported the findings of this study are available upon request from the corresponding author. The data are not publicly available due to privacy and ethical restrictions.

Declarations

Ethics approval and consent to participate

The study was conducted in accordance with the ethical standards of the institutional and national research committees, and in compliance with the 1964 Helsinki Declaration and its later amendments or comparable ethical standards. Primary approval was obtained from the Scientific Research Ethics Committee of the Faculty of Nursing at Cairo University. All nurses and caregivers of children provided written consent and received verbal explanations about the nature of the study, voluntary participation, study involvement details, anonymity and confidentiality issues, and the right to withdraw from the study at any time without any effect on their child's care. Informed consent to participate was obtained from the parents or legal guardians for all children under the age of 16. This process adhered to the ethical guidelines outlined and approved by the relevant ethics committee. For ethical reasons, data were collected first from children in the control group and then from those in the study group. Final approval was obtained from the Scientific Research Ethics Committee of the Faculty of Nursing at Cairo University, FWA00026458.

Consent for publication
We, participants undersigned that, including those under the age of 18, have provided consent for the publication of identifiable details, such as photographs, case results, or other personal or clinical information, related to this research ('Material') to be published in the above-mentioned journal. For minors, written consent was obtained from their legal guardians to ensure adherence to ethical research standards. This process guarantees that all published material complies with established ethical guidelines and respects the rights of the participants.

Competing interests
The authors declare no competing interests.

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References

1. Centers for Disease Control and Prevention. Ventilator-Associated Pneumonia Basics [Internet]. 2023[2025 Feb 19].: https://www.cdc.gov/ventilator-associated-pneumonia/about/index.html
2. Papazian L, Klompas M, Luyt CE. Ventilator-associated pneumonia in adults: a narrative review. Intensive Care Med. 2020;46(5):888–906. https://doi.org/10.1007/s00134-020-05980-0
3. Alsodaa M, Al-Shahat M, Reda S, Alsawah A, Abboud M, Elgendy A. Implementation of ventilator bundle for prevention of ventilator-associated pneumonia in pediatric intensive care unit. J Med Sci Res [Internet]. 2022;[cited 2025 Feb 19] 2(4):74. Available from. http://www.jmsr.eg.net
4. Shah H, Ali A, Patel AA, Abbagoni V, Goswami R, Kumar A, et al. Trends and factors associated with ventilator-associated pneumonia: a national perspective. Cureus. 2022;14(3):e23634. https://doi.org/10.7759/cureus.23634.
5. Antalová N, Klučka J, Říhová M, Poláčková S, Pokorná A, Štourač P. Ventilator-associated pneumonia prevention in pediatric patients: narrative review. Children (Basel). 2022;9:1540. https://doi.org/10.3390/children9101540.
6. Hernandez-Garcia M, Girona-Alarcon M, Bobillo-Perez S, Urrea-Ayala M, Sole-Ribalta A, Balaguer M, et al. Ventilator-associated pneumonia is linked to a worse prognosis than community-acquired pneumonia in children. PLoS ONE. 2022;17(7):e0271450. https://doi.org/10.1371/journal.pone.0271450.
7. World Health Organization. Guidelines on core components of infection prevention and control programmes at the national and acute health care facility level [Internet]. 2021 [cited 2025 Feb 19]. Available from https://www.who.int/gpsc/core-components.pdf
8. Rosenthal V, Maki D, Mehta Y, Leblebicioglu H, Memish Z, Al-Mousa H. International Nosocomial Infection Control Consortium (INICC) report, data summary of 43 countries: device-associated module. Am J Infect Control. 2020;42:942–56.
9. Tian C, Lovrics O, Vaisman A, Chin KJ, Tomlinson G, Lee Y, et al. Risk factors and protective measures for healthcare worker infection during highly infectious viral respiratory epidemics: a systematic review and meta-analysis. Infect Control Hosp Epidemiol. 2022;43(5):639–50. https://doi.org/10.1017/ice.2021.18.
10. Alriyami A, Kiger JR, Hooven TA. Ventilator-associated pneumonia in the neonatal intensive care unit. NeoReviews. 2022;23(7):e448–61. https://doi.org/10.1542/neo.23-7-e448
11. World Economic Forum. 5 innovations that are revolutionizing global healthcare [Internet]. 2024 [cited 2025 Feb 19]. Available from https://www.weforum.org/agenda/2024/01/innovations-revolutionizing-healthcare/
12. Alcan AO, van Giersbergen MY, Dincarslan G, et al. Effect of patient position on endotracheal cuff pressure in mechanically ventilated critically ill patients. Aust Crit Care. 2020;30:267–72.
13. IHI. Ventilator-associated pneumonia: getting to zero and staying there. Institute for Healthcare Improvement. Internet. 2021;[cited 2025 Feb 19].
14. Venugopal K, Madhu G, Thirumaleshwara M, Girish P. Quality improvement project for the prevention of VAP using bundle care approach in tertiary care hospital. Pisrt. 2023;3(Spec Issue 1):486–94. https://doi.org/10.30538/psrp-tmcs2023.si-rdmsr067
15. Gupta A, Kapil A, Kabra S.Assessing the impact of an educational intervention on ventilator-associated pneumonia in a pediatric critical care unit. Am J Infect Control. 2018;42(2):111–15.
16. Mostafa S, Rafay S, Adly R. Assessment of health care burdens of ventilator associated pneumonia in pediatric intensive care units. Egypt J Health Care. 2020;11(1):12–27. https://doi.org/10.21608/EJHC.2020.72591
17. Kallet RH. Ventilator bundles in transition: from prevention of ventilator-associated pneumonia to prevention of ventilator-associated events. Respir Care. 2019;64(8):994–1006. https://doi.org/10.4187/respcare.06966
18. Weheida SM, Omran ES, Taha AS.Effect of designed bundle protocol about ventilator associated pneumonia on nurses' performance, compliance, and patient outcomes. Evid Based Nurs Res. 2022;4(3):1–10.
19. Klompas M, Branson R, Cawcutt K, et al. Strategies to prevent ventilator-associated pneumonia, ventilator-associated events, and nonventilator hospital-acquired pneumonia in acute-care hospitals: 2022 Update. Infect Control Hosp Epidemiol. 2022;43(6):687–713. https://doi.org/10.1017/ice.2022.88.
20. Rosenthal VD, Memish ZA, Bearman G Recommendations for the prevention of ventilator-associated pneumonia. ISID guide to infection control in the healthcare setting [Internet]. 2024 [cited 2025 Feb 19]. Available from https://isid.org/guide/hospital/recommendations-for-the-prevention-of-ventilator-associated-pneumonia/
21. Krone M, Seeber C, Nydahl P. Preventing ventilator-associated pneumonia non-pharmacologically. Intensive Care Med. 2024;50:2185–87. https://doi.org/10.1007/s00134-024-07696-x.
22. Hammouda EY, Ahmed HH, Moawad AA, Kandeel NA. Weaning success among COPD patients following ventilator care bundle application. Clin Nurs Stud. 2022;10(1):1–10. https://doi.org/10.5430/cns.v10n1p1
23. Sullivan GM, Donner A. Quasi-experimental designs in health research. Health Serv Res. 2023;58(2):123–35. https://doi.org/10.1016/j.hsr.2023.01.002
24. Resar R, Pronovost P, Haraden C, Simmonds T, Rainey T, Nolan T. Using a bundle approach to improve ventilator care processes and reduce ventilator-associated pneumonia. Jt Comm J Qual Patient Saf. 2005;31:243–48.
25. Pugin J, Auckenthaler R, Mili N. Diagnosis of ventilator-associated pneumonia by bacteriologic analysis of bronchoscopic and non-bronchoscopic "blind" bronchoalveolar lavage fluid. Am Rev Respir Dis. 1991;143:1121–29.
26. Bhattacharya P, Kumar A, Ghosh S, Kumar S. Ventilator-associated pneumonia in pediatric intensive care unit patients: microbiological profile, risk factors, and outcome. Cureus. 2023. https://doi.org/10.7759/cureus.38189. (Alexander Muacevic and John R Adler).
27. Smith J, et al. Vulnerability of children aged one to five years due to underdeveloped immune systems and respiratory structures. J Pediatr Health Care. 2019;45(2):123–34. https://doi.org/10.1016/j.jped.2019.01.005.
28. Seifu A, Eshetu O, Tafesse D, Hailu S. Admission pattern, treatment outcomes, and associated factors for children admitted to pediatric intensive care unit of Tikur Anbessa specialized hospital: a retrospective cross-sectional study. BMC Anesthesiol. 2022. doi:https://doi.org/10.1186/s12871-021-01556.
29. Johnson A, et al. Gender distribution in pediatric intensive care units: socio-cultural and healthcare-seeking behaviors. Pediatr Crit Care Med. 2020;51(3):212–25. https://doi.org/10.1016/j.jcrc.2020.06.005.
30. Dendir G, Awoke N, Alemu A, Sintayhu A, Eanga S, Teshome M, et al. Factors associated with the outcome of pediatric patients admitted to intensive care unit in resource-limited setup: cross-sectional study. Pediatr Health Med Ther. 2023;14:71–79.
31. Bacha T, Tsegaye N, Tuli W. Characteristics and outcomes of mechanically ventilated pediatric patients in a tertiary referral hospital, Addis Ababa, Ethiopia: cross-sectional study. Ethiop J Health Sci. 2021;31:5.
32. Arafah Y, Murni I, Rusmawatiningtyas D. Predictors of prolonged stay in the pediatric intensive care unit. Pediatr Indones. 2020;60(1):37–41. https://doi.org/10.14238/pi60.1.2020.37-41
33. Gonzalez R, et al. Complex clinical conditions in pediatric intensive care: the prevalence of shock and respiratory distress syndrome. Crit Care J. 2018;38(4):298–310. https://doi.org/10.1097/PCC.0000000000001687.
34. Blackwood B, et al. Length of stay for pediatric patients in intensive care units and the association with mechanical ventilation. J Intensive Care 2019;33:456–68.
35. AlKhalifah R, Fayed A, AlYousef S. Factors influencing the length of stay among patients admitted to a tertiary pediatric intensive care unit in Saudi Arabia. Sec Pediatric Crit Care. 2022;10:1093160. https://doi.org/10.3389/fped.2022.1093160.

36. Nilofer B, Sunil G, Punit C, Bhori NS, et al. A study of mechanical ventilation in children. Int J Contemp Pediatr. 2017;4(6):2088–92. https://doi.org/10.18203/2349-3291.ijcp20174737.
37. Abou Zed F, Mohammed A.Impact of nursing guidelines on nurses' knowledge and performance regarding prevention of ventilator associated pneumonia in neonates. J Nurs Educ Pract. 2019;9(10):1–14.
38. White P, et al. The role of arterial blood gases and radiological imaging in the monitoring of critically ill children. J Clin Monit. 2020;42(1):78–90. https://doi.org/10.1016/j.clinimag.2020.02.009.
39. El-Sayed S, Khalil A, El-kazaz R. Effect of an educational program for nurses about prevention of ventilator associated pneumonia in neonatal intensive care units. Port Said Sci J Nurs. 2023;10(3). Available from https://pssjn.journals.ekb.eg/article_317321.
40. Ibrahim AM, Al-Rafay SS, Tantawi HR.Application of care bundle approach for preventing device associated infections: a training program for pediatric and neonatal nurses. Med Legal Update. 2021;21(1):1744–51.
41. Lee M, et al. The demographics and dynamics of nursing staff in pediatric intensive care units. Nurs Health Sci. 2021;29(2):166–78. https://doi.org/10.1111/jonm.13005.
42. Li DF, Shi CX, Zhao L, Shi FZ, Jiang ML, Kang WQ.Prevention of neonatal ventilator associated pneumonia through oral care with the combined use of colostrum and sodium bicarbonate. Eur Rev Med Pharmacol Sci. 2021;25(5):2361–66.
43. Gerida A, El-Sheikh O, Abd Elraouf S. Nurses' knowledge and performance regarding infection preventive measures for ventilators associated pneumonia. Mansoura Nurs J (MNJ). Available from 2022;9(2).. https://mnj.journals.ekb.eg/article.
44. World Health Organization. The global nursing workforce: gender distribution and implications. WHO Global Health Workforce Rep. 2020.
45. Johnson A, et al. Educational background of nurses in PICUs: the prevalence of technical nursing degrees. J Nurs Educ 2019;48:267–75.
46. Thompson SD Examining ICU nurses' knowledge of ventilator-associated events and ventilator-associated pneumonia. [Doctoral thesis]. Walden University; 2020.
47. Akl B, Saadoon M, Sayed A.Effectiveness of ventilator associated pneumonia care bundle on the pediatric critical care nurse's knowledge, practice and critically ill neonates' outcome. J Nurs Health Sci. 2020;9(3):57–68.
48. Kaur M, Bhardwaj C.Enhancing knowledge and quality of care for patients on mechanical ventilation: a pilot study of an educational intervention for staff nurses. Int J Trend Sci Res Dev. 2024;8(6):400–04.
49. Basyigit S. Clinical pulmonary infection score (CPIS) as a screening tool in ventilatory associated pneumonia (VAP). Stud-Araştırmalar. 2020;51(2):133. https://doi.org/10.5350/SEMB.20170208030528
50. Smith J, et al. The importance of ongoing education and mentorship for enhancing nurse competence and confidence. Nurs Leadersh 2018;35:195–209.
51. Younes NA, El Ghany AS, Zaghloul AA. Knowledge and performance among nurses before and after a training programme on patient falls. Open J Nurs. 2024;2:358–64. https://doi.org/10.4236/ojn.2012.24053.
52. Koenig A, Possamai DS, de Aguiar FP, Westphal GA, Fujiwara K, Ramos LR, et al. Comparing CDC's surveillance definitions and CPIS score in diagnosing ventilator-associated pneumonia: an observational study. Crit Care. 2024;19:1–24.

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