Journal of Multidisciplinary Healthcare

Dovepress
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ORIGINAL RESEARCH

Construction and Application of a Training Program for ICU Nurses to Manage Artificial Airway Gasbags to Prevent Ventilator-Associated Pneumonia

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Purpose: To construct a training program for ICU nurses to manage artificial airway gasbags to prevent ventilator-associated pneumonia (VAP) and explore its application in ICU nurses.

Methods: From January to March 2023, 17 experts were consulted using the Delphi method to construct the draft of the training program. 52 ICU nurses were selected from a third-level, first-class hospital in Henan Province. They received training using the program for 4 weeks. The training effects were evaluated by examining the theoretical knowledge, testing operation skills, and the ICU medical staff gasbag management knowledge-attitude-behavior questionnaire before and one week after the training in April 2023.

Results: The coefficients of expert authority for the two round inquiries were 0.816 and 0.837, respectively. The coordination coefficient of expert opinions ranges from 0.2 to 0.3. The final training program for ICU nurses on managing artificial airway gasbags to prevent VAP was constructed and included 4 primary indicators, 25 secondary indicators, 47 tertiary indicators. After the training by the program, the scores of the ICU nurses' theoretical knowledge (before, 73.73 ± 8.54 VS after, 88.31 ± 6.29; $t = 11.017$, $P<0.001$) and technical operation (before, 75.29 ± 7.48 *VS* after, 86.92 ± 4.72; $t = 8.986$, $P<0.001$) were significantly increased. The total scores of the ICU nurses' knowledge-attitude-behavior on gasbag management (before, 76.67 ± 10.68 *VS* after, 109.04 ± 9.87; $t = 19.916$, $P<0.001$) were also significantly increased compared to the performance before training.

Conclusion: The training program for ICU nurses on managing artificial airway gasbags to prevent VAP based on the Miller pyramid model is scientific and practical and can enhance the knowledge-attitude-behavior level of ICU nurses. This training program constructed in this study can be recommended and applied after further verification for the ICU nurses to manage the artificial airway gasbags in order to reducing the occurrence of the VAP in the clinical practice.

Keywords: nursing management, evaluation and assessment, Miller pyramid model, airway management, intensive care

Introduction

Ventilator-associated pneumonia (VAP) refers to pneumonia that occurs more than 48 hours after the patient receives mechanical ventilation through a tracheotomy or tracheal intubation or within 48 hours after ventilator weaning and extubation.[1] VAP accounts for 5% to 40% of ICU-acquired infections.[2] VAP increases the mortality risk for patients with critical illness, prolongs their hospitalization time, burdens them economically, and directly affects their safety and quality of medical care.[3] Meanwhile, the occurrence of VAP is one of the main criteria for evaluating ICU nursing quality and the recovery of mechanically ventilated patients. Effective artificial airway gasbag management can reduce the incidence of VAP, shorten the patient's time of mechanical ventilation, and length of ICU stay, improve patient prognosis, and accelerate patient recovery.[4–6] It is critical for reducing complications related to artificial airways.[7] ICU nurses are indispensable as practitioners of artificial airway gasbag management. There is a consensus draft among experts on artificial airway gasbag management in China. However, specific and detailed clinical guidelines are inadequate.[8] Research has pointed out that ICU nurses had mediocre knowledge of artificial airway gasbag management, lacked

Received: 2 September 2023
Accepted: 23 November 2023
Published: 2 December 2023

awareness of its importance, and could not execute it properly.[9] Therefore, it is necessary to strengthen the education and training of nurses in VAP prevention and control in various ways to achieve VAP "zero-infection."

Miller pyramid model, which was proposed by Miller, uses the pyramid principle to divide the learning process into four levels, including professional theoretical knowledge, knowledge application ability, operational performance, and actual performance in practical work environments.[10] Recently, the Miller pyramid model has been extensively applied in nurse training programs. The nurses' knowledge and skills were significantly improved using the Miller pyramid model.[11–13] In this study, a training program for artificial airway gasbag management to prevent VAP was constructed using the Delphi method based on the Miller pyramid model. The effects of the training program application on the ICU nurses were evaluated in the clinical practice. The study will provide evidence for ICU nurses to scientifically manage artificial airway gasbags and prevent VAP in clinical practice. The ability of the ICU nurses to manage artificial airway gasbags would get improved and the occurrence of VAP would be greatly reduced after receiving the training program in the clinical practice.

Material and Methods

The Construction of the Training Program

The Delphi method was applied to the construction of the training program on the ICU nurses to manage the artificial airway airbag to prevent VAP. The detailed Delphi process was shown on Figure 1.

Establishing a Research Group for the ICU Nurse Managing the Artificial Airway Gasbag to Prevent VAP

The research group comprised 10 members engaged in work related to intensive care, including 2 chief physicians, 1 professor of nursing, 2 associate professors of nursing, 3 chief nurses, and 2 respiratory therapists. The responsibilities of the research group included preliminarily drawing up the training program during the study, organizing regular seminars, reviewing project progress and quality, and coordinating issues during implementation. This study was approved by the Medical Ethics Committee of The affiliated Chest Hospital of Zhengzhou University (No. 2021-05-04).

Preparation of Expert Inquiry Questionnaire

The relevant literature was retrieved from Chinese databases (CNKI, Wanfang Medicine, CQVIP, and China Biomedical Journal Database) and English databases (PubMed, Web of Science, Embase, and Cochrane Library) in this study.

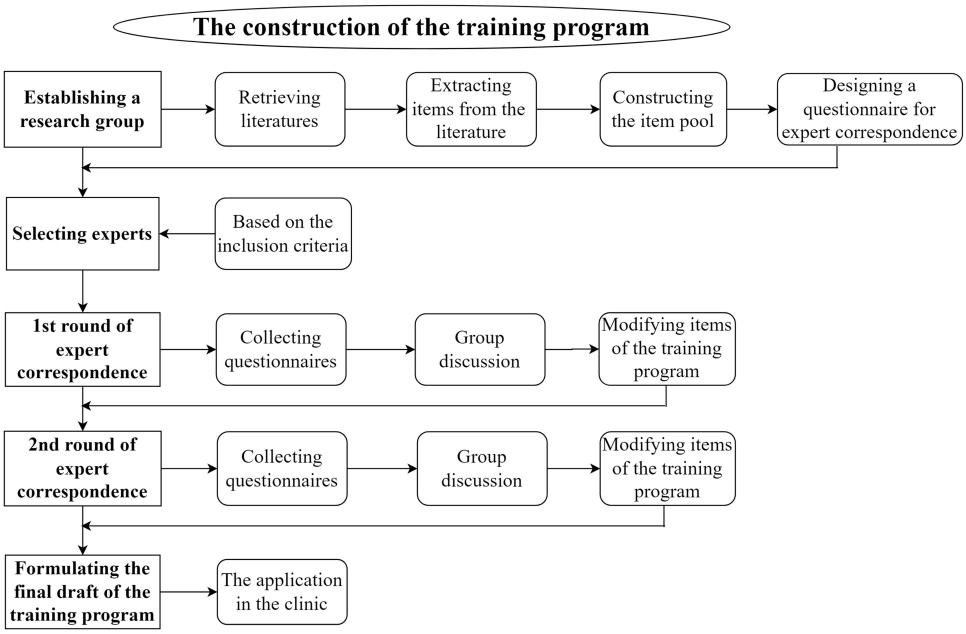

Figure 1 The Delphi process for construction of the training program for ICU nurses on artificial airway airbag management to prevent VAP.

Chinese keywords included "artificial airway/mechanical ventilation/tracheal intubation/tracheotomy", "gasbag pressure/gasbag pressure monitoring/gasbag pressure management/influencing factors of gasbag pressure", "VAP", "ICU nurses", and "training/specialist training/training program/training system/the Delphi method." English search terms contained "artificial airway/endotracheal tube cuff/tracheal tube cuff/cuff", "tracheal cuff pressure/monitoring of tracheal cuff pressure /management of tracheal cuff pressure/influencing factors of tracheal cuff pressure", "ventilator-associated pneumonia", "ICU nurse", "training/training program/experiential training/ Delphi."The retrieval duration was set from the establishment of databases to December 2022. Three research members summarized, organized, and extracted literature to form a questionnaire entry pool. All guidelines, expert consensuses, systematic evaluations, reviews, randomized comparisons, quasi-experimental studies, and qualitative studies related to the ICU nurses' artificial airway gasbag management and VAP prevention were included. Inclusion criteria: (1) Research type: Intervention or review articles on artificial airway gasbag management in Chinese or English; (2) Research subjects: ICU nurses. Exclusion criteria: (1) Repeated publications; (2) Full text unavailable. Based on the literature review, the research team developed a preliminary training program for ICU nurses on managing artificial airway gasbags to prevent VAP based on the Miller pyramid model. The training program included 4 primary indicators, 25 secondary indicators, and 51 tertiary indicators.

The expert inquiry questionnaires were designed and consisted of three parts: (1) Introduction to the research background, purpose, significance, questionnaire collection time, and the contact information of the researchers; (2) Evaluation of the training program for ICU nurses on manage artificial airway gasbags to prevent VAP. This study used the Likert 5-level scoring method (1=not important, 2=not very important, 3=important, 4=relatively important, 5=very important) to evaluate the importance of the indicators. The importance score was limited between 1 and 5 points to ensure that inquiry results have practical reference value. Moreover, a column was added to collect expert suggestions on the ambiguous diction of the indicators, adding, deleting, and adjusting indicators; (3) The general information of experts, including personal information (name, gender, age, educational background, position, place of work, work seniority, professional field, and contact information) and their familiarity with evaluation content and judgment criteria.

Expert Selection

The selection of the experts was based on representativeness, universality, and authority. The inclusion criteria: (1) Hospital level: third-level first-class comprehensive hospitals; (2) Education level: for nurses, bachelor or above; for doctors, master or above; (3) Professional title: intermediate or higher; (4) At least ten years of experience in intensive care or management; (5) Volunteer to participate in this study and be willing to cooperate. Exclusion criteria: (1) Those who did not respond within the stated period at the expert inquiry stage; (2) Expert authority coefficient (Cr)<0.7.

This study inquired 17 experts from the research fields in intensive medicine, intensive nursing, nursing management, and nursing education. The experts included 7 men and 10 women. The average age of experts was (39.67 ± 2.18 years old), and the average working years were (19.21 ± 2.06 years). The experts were 10 with undergraduate, 5 with master, and 2 with PhD degrees. Among them, 1 had an intermediate professional title, 7 had an associate professor title, and 9 had a full professor title.

Expert Inquiry Implementation

From January to February 2023, researchers emailed inquiry questionnaires to experts. After collecting these questionnaires, the analysis was conducted on experts' suggestions for the indicators. After the research group's discussion, analysis, and modification, a second round of expert inquiry questionnaires was developed. From February to March 2023, the second round of expert inquiry was conducted with an interval of 2–3 weeks between the two rounds. When expert opinions tended to be consistent, the inquiry was terminated.

The Application of the Training Program

Training Subject

The ICU nurses from a third-level first-class hospital in Henan Province were selected for training.

Inclusion criteria: Having worked in the ICU for at least one month and possessing a nursing qualification certificate. Exclusion criteria: Nurses on sick leave or maternity leave. All trainees were voluntary and signed informed consent

forms. 52 nurses, including 43 females and 9 males, completed the training, and the performance was evaluated. Among them, 29 nurses were nurse-in-charge, 15 were senior nurses, and 8 were nurses. They aged between 23–43 years old (mean:32.8±4.7). Their working experiences ranged from 1–25 (mean:11.35 ± 5.22) years.

Implementation of the Training Program

Following the training object, content, methods, and course requirements, all trainers conducted the training program for ICU nurses on managing artificial airway gasbags to prevent VAP and familiarized themselves with training content and requirements. It has been noted that the optimal frequency for ICU nurses accepting VAP training is 3–5 times.[14] Based on the object and content of the training, the research team set the training frequency to 4 times. The training was held in April 2023. The total training length was eight courses, with each course 60 minutes. The training lasted for four weeks, with two hours each week. The theoretical content was available and learned from the 317 Nursing APP. It was required to complete the course anytime within a week. Practical teaching adopted one lesson with two lectures during the twice vocational study time every week. Nurses could choose any period to attend classes and complete the learning tasks. The specific course arrangement schedule is shown in Table 1. After 4 weeks of training, theoretical knowledge examination and operation assessments were carried out. The Knowledge-Attitude-Behavior Questionnaire of Gasbag Management for ICU Medical Staff was used to evaluate the training performance of the 52 ICU nurses.

Evaluation Indicators of Training Effectiveness

Theoretical Knowledge Assessment

Through retrieving the literature based on expert consensuses, such as the"Interpretation of the Diagnosis and Treatment Guidelines for Chinese Adult Hospital Acquired Pneumonia and VAP (2018 Edition)" and the "Interpretation of the Prevention Strategies for VAP and Ventilator Related Events in SHEA Emergency Hospitals (2022 Edition)", the training team designed the examination paper to investigate the mastery of ICU nurses for the knowledge in VAP prevention. The examination papers included single-option and multiple-option questions, with two points for each question and a maximum score of 100 points. Nurses were evaluated for their theoretical knowledge one week before and after the training.

Operational Assessment

Based on the training, ICU nurses were assessed according to nursing operation standards. The operation procedure and scoring methods included 15 points for preparation and quality, 70 points for operation process and quality, and 15 points

Table 1 Schedule of the Training Program for ICU Nurses on Managing Artificial Airway Gasbags to Prevent VAP

Training Subjects	Class Hours	Training Contents	Training Forms	Training Teachers
Theoretical knowledge	2	Definition and pathogenic factors of VAP, the definition and type of artificial airway, the material, type, shape of gasbags, and other professional knowledge.	317 Nursing APP online training, theoretical teaching	Intensive care physicians
Knowledge application ability	2	Artificial airway evaluation, gasbag selection, and gasbag pressure adjustment.	317 nursing APP online training, theoretical teaching	Graduate nurse
Operation performance	3	Suction care, oral care, nebulization, and ventilator pipeline replacement and maintenance techniques	Offline training, demonstrative instruction	Respiratory therapist
Actual Performance in a real work environment	1	Correct timing and method of gasbag pressure measurement, gasbag inflation method, cleaning methods and precautions for gasbag secretions, inspection, judgment methods and handling of gasbag leakage, the pre-operation and precautions before gasbag deflation and extubating	Offline training, demonstrative instruction	Respiratory therapist

for final quality. Each part had a different weight, with a maximum score of 100 points. The trainers graded nurses' operations according to nursing operation standards one week before and after the training.

Knowledge-Attitude-Behavior Questionnaire of Gasbag Management for ICU Medical Staff

The knowledge-attitude-behavior questionnaire of artificial airway gasbag management for ICU medical staff was developed by Chinese scholar Chi Zhang.[9] It was divided into three dimensions and 42 items, including 19 items in the knowledge dimension, 8 in the attitude dimension, and 15 in the behavior dimension. The Cronbach's α coefficient of the total scale is 0.935. The content validity index is 0.926.

①Knowledge dimension of gasbag management (19 items), including relevant pressure range, measurement purpose and indication, influencing factors, complications, treatment measures, and contraindications. All questions were single-option using the Likert 5-level scoring method: "unknown" - 0 points, "understanding" - 1 point, "familiar" - 2 points, "general mastery" - 3 points, and "complete mastery" - 4 points. Questions 4 and 5 were reversely scored, ranging from 0 to 76 points. The higher the score, the better the mastery of artificial airway gasbag management knowledge.

②Attitude dimension of gasbag management (eight items): containing medical staff's recognition of the importance of gasbag management and the regulations of the department and hospital. The Likert 3-level scoring method was used: "disagree"- 0 points, "generally agree"- 1 point, and "totally agree"- 2 points. The questions were reversely scored and ranged from 0 to 16. The higher the score, the better the attitude toward gasbag management and the more mature the rules and regulations of the department and hospital.

③Behavior dimension of gasbag management (15 items): The Likert 5-level scoring method was adopted: "never" - 0 point, "occasional" - 1 point, "sometimes" - 2 points, "frequent" - 3 points, and "always" - 4 points, ranged from 0–52. The higher the total score, the better the gasbag management behavior.

Questionnaires were distributed one week before and after the training. Both surveys used unified guidelines. The questionnaires were filled out anonymously and collected on the spot. 52 questionnaires were collected, all valid with an effective response rate of 100%.

Statistical Methods

Excel and SPSS 20.0 were employed for the statistical analysis of all data. The positivity of experts was expressed by the questionnaire recovery rate (%) and question-raising rate (%). The authority level of experts was represented by the authority degree coefficient (Cr), and the coordination degree of expert opinions was denoted by the coefficient of variation (CV) and coordination coefficient (Kendall's W). Items were modified, added, or subtracted based on the score average and coefficient of variation and the importance and feasibility ratings given by experts. The measurement data were expressed as mean ± standard deviation. The paired *t*-test was used to compare the scores before and after training. The statistically significant difference was set at $P<0.05$.

Results

The Construction of a Training Program

Expert Positiveness and Authority

In the two rounds of expert inquiries, 17 questionnaires were sent out, respectively, with a recovery rate of 100%. In the first round, 9 experts (52.94%) proposed suggestions, while 3 experts (17.6%) provided constructive advice in the second round. The expert authority coefficients in the two rounds were 0.816 and 0.837, respectively, indicating high authority, good representativeness, and high credibility of the inquiry.

Concentration and Coordination of Expert Opinions

The first and second round of inquiries included 80 and 75 indicators, respectively. The average importance assigned to each indicator by experts was greater than 3.5 points. The variation coefficients of the average importance values assigned to each indicator in the two rounds of expert inquiries were all less than 0.25, indicating that expert opinions are relatively consistent. After two rounds of expert inquiries, 70.6% of experts provided suggestions. The coordination coefficients of expert opinions in the two rounds range from 0.2 to 0.3. The Kendall test has statistical significance.

Indicator Modification After Two Rounds of Expert Inquiries

In this study, the indicator inclusion criteria were as follows: mean for importance > 3.5 points and the coefficient of variation < 0.25.[15] After the first round of expert inquiry, detailed contents for training and examination in the tertiary indicators were added after the group discussion. In order to have ICU nurses informed of the latest academic trends and guidelines, guideline interpretations were recommended to be added. The "Expert Consensus on Artificial Airway Gasbag Management" was added to the secondary indicators. The suggestion about the need to assess trachea diameter in the airway evaluation raised by the experts was not adopted after group discussion because of the ICU nurses unable to judge the trachea diameter by effective measuring tools and monitor the gasbag pressure dynamically in clinical practice. The suggestions about the indicators related to gasbag pressure adjustment were added. For example, the factors causing the changes in gasbags and the temporary increase of airbag pressure induced by the patients' restless state should be added. Some tertiary indicators related to the methods used to monitor the airbag pressure were merged. So, the original 51 tertiary indicators were modified to 47 indicators and the second round of inquiry questionnaires was formed. The expressions of some indicators and the order of tertiary indicators in part of knowledge were adjusted after the second round of expert inquiry. The experts were generally satisfied with the revised training program. Finally, the training program on managing artificial airway gasbags to prevent VAP was constructed. It included 4 primary indicators, 25 secondary indicators, 47 tertiary indicators (Table 2).

The Application Effect of the Training Program on the Performance of ICU Nurses

52 ICU nurses were trained using the training program constructed in this study. The score of theoretical knowledge and technical operation were significantly increased after the training with the constructed training program for the ICU nurses on managing artificial airway and gasbags to prevent VAP compared to the score obtained before the training ($P<0.001$). In addition, the score of the gasbag management knowledge, gasbag management attitude, gasbag management behavior and the total score evaluated by the ICU nurses were all significantly improved after training with the program compared to those obtained by the nurses before training ($P<0.001$) (Table 3).

Discussion

This study is based on the standardized Miller pyramid model for training and evaluating clinical competence proposed by the American medical educationist Miller.[10] The first draft was constructed based on the literature review and expert inquiry using the Delphi method. The advantage of the Delphi method is that all participating experts are anonymous to each other. It enables experts to express their views equally. After induction, summary, and modification, consensus was finally formed, which avoided interference and reflected the actual ideas of experts.[16] The 17 inquiry experts selected for this study were from third-level, first-class comprehensive hospitals or medical colleges in Shandong, Hubei, and Henan province. They have rich clinical and teaching experience. Among them, 10 experts have worked for more than 20 years. 7 experts had a master's degree or above representing a high-education structure. A total of 16 experts had title with associate professor and above. The expert authority coefficients in the two rounds of inquiries are 0.816 and 0.837, indicating high expert authority. The experts provided guiding opinions on the construction of the training program from various perspectives which ensured the rigor and reliability of the training program. So, the training program for ICU nurses on managing artificial airway gasbag to prevent VAP based on the Miller pyramid model is reliable.

As an essential link to artificial airway management, gasbag management is critical in successfully implementing mechanical ventilation and preventing VAP and related complications. Corrected and effective gasbag management is essential in reducing the incidence of VAP.[17–19] However, most of these measures require nurses to complete them manually. It leads to a large workload and the quality of nursing is variable. The related training is necessary to be strengthened. The Miller pyramid model emphasizes that elementary knowledge should be grasped first to promote improving professional knowledge and skills.[20] Chinese scholars have constructed a training program based on this model for operating room nurses. The application of this training program achieved good effects. It enabled new nurses to master theoretical knowledge, enhance their professional skills and core competency, and quickly fulfill their job roles.[21] Common bundled mechanical ventilation care is based on evidence-based medicine and integrates verified nursing measures into a comprehensive nursing plan. The training program on managing artificial airway gasbags to

Table 2 The Final Constructed Training Program on Managing Artificial Airway Gasbags to Prevent VAP for ICU Nurses

Primary Indicators	Secondary Indicators	Tertiary Indicators
I-1 Theoretical knowledge	II-1 Definition and etiology of VAP	III-1 Factors of patients: age ≥ 60, number of underlying diseases, posture, oral hygiene.
		III-2 Exogenous factors: ICU environment, invasive procedures, cross infection, and the usage of antacids and antibiotics.
	II-2 Definition and types of artificial airways	
	II-3 Gasbag material, type, and shape	III-3 Gasbag material: natural rubber, polyvinyl chloride, polyurethane
		III-4 Gasbag type: low capacity high pressure, high capacity low pressure
		III-5 Gasbag shape: conical, cylindrical, spherical
	II-4 Matching degree of the tracheae of and gasbag pressure in patients	III-6 If the gasbag pressure is too high when the gasbag is not filled, gaps can easily form between the gasbag and the tracheal wall.
		III-7 If the gasbag pressure is too low, the gasbag can hardly fit the tracheal wall after filling and cannot seal the trachea.
	II-5 Factors affecting gasbag pressure.	III-8 During and after suction for five minutes, the gasbag pressure is higher than before.
		III-9 During turning over and five minutes after turning over, the gasbag pressure is higher than before.
		III-10 The gasbag pressure during oral care is higher than before.
		III-11 The gasbag pressure during swallowing is higher than before.
	II-6 Gasbag Pressure Monitoring	III-12 Intermittent monitoring techniques: Finger pinching method, quantitative inflation method, minimum closed volume method, minimum leakage method, modified sphygmomanometer monitoring method, volume-time curve method, pressure gauge measurement, traditional pressure gauge measurement, and improved gasbag pressure measurement.
		III-13 Continuous monitoring technology: disposable pressure sensor continuous monitoring method, handheld pressure gauge continuous monitoring method, and auto-regulation gasbag pressure continuous monitoring method
	II-7 The Role and Significance of Gasbag Management	
	II-8 Interpretation of Expert Consensus on Artificial Airway Gasbag Management	III-14 Guideline interpretation of diagnosis, prevention, and treatment for VAP
		III-15 Prevention strategies for VAP, ventilator-associated events, and non-ventilator-associated hospital-acquired pneumonia in hospitals
		III-16 Guidelines for the diagnosis and treatment of hospital-acquired pneumonia and VAP in Chinese adults

(*Continued*)

https://doi.org/10.2147/JMDH.S438316

Table 2 (Continued).

Primary Indicators	Secondary Indicators	Tertiary Indicators
I-2 Knowledge application ability	II-9 Evaluation of artificial airways	III-17 Select a suitable type of artificial airways, determine gasbag position after establishment, and handover the depth of endotracheal tubes for each shift
		III-18 Regularly evaluate the fixed state of artificial airways and adjust at any time to guarantee proper fixation
	II-10 Gasbag selection	III-19 Recommend using new types of tracheal cannula containing silicone gasbags to prevent VAP
		III-20 Recommend using polyurethane gasbags to prevent VAP in patients with short-term tracheal intubation
		III-21 Do not recommend using conical gasbags to prevent hospital-acquired pneumonia in ICU patients
	II-11 Gasbag inflation method	III-22 Do not use the finger-touch method to inflate gasbags
		III-23 Recommend using a gasbag pressure gauge to objectively measure gasbag pressure and an automatic inflation pump to maintain it.
		III-24 The minimum closure technique should not be used in gasbag inflation as a routine, except when gasbag pressure cannot be measured.
	II-12 Gasbag inflation timing	III-25 Gasbag pressure adjustment should avoid influencing factors such as suction, turning over, oral care, swallowing, writing, and restlessness and be performed in a quiet state of patients.
		III-26 Regularly monitor the gasbag pressure of the endotracheal tube. The gasbag pressure should be manually measured every 4–6 hours without an automatic inflation device.
		III-27 Recommend continuously controlling the gasbag pressure of the endotracheal tube. The timing of gasbag inflation should be guided by the relative risks of aspiration, patient coughing during activity, and tracheal and catheter displacement.
	II-13 Gasbag pressure regulation	III-28 Maintain the pressure between 25–30 cmH_2O after gasbag inflation.
		III-29 For manual measurement, the inflation pressure should be higher than the ideal target value of 2 cmH_2O.
		III-30 If the patient's condition allows, PEEP should be raised within a specific range, at least ≥ 5 cmH_2O. When the patient's airway pressure is low and spontaneous breathing is weak, the gasbag pressure should be appropriately increased during suction.
		III-31 For patients who do not need mechanical ventilation during tracheotomy and have good autonomous airway protection ability, the gasbag can be deflated entirely or replaced with a non-gasbag cannula
	II-14 Gasbag leakage assessment	III-32 The reasons for gasbag leakage can be distinguished by the clinical Evaluation of the patient's ventilator parameters and artificial airway and chest radiography
		III-33 If the performance of the gasbag is intact, and there is still air leakage, change the artificial airway position or type, increase the gasbag pressure, or decline the airway peak pressure.
		III-34 When the gasbag is damaged with apparent leakage, an experienced doctor should replace the tracheal tube.
	II-15 Gasbag residue disposal	III-35 Gasbag residues should be disposed of regularly before deflating the gasbag to prevent VAP.
		III-36 For patients with artificial airways, use subglottic secretion drainage to remove gasbag residuals.
		III-37 Effective measures for preventing VAP: intermittent subglottic secretion drainage is recommended.
	II-16 Gasbag leakage test	III-38 For patients who meet extubation criteria but have a high risk of stridor after extubation, should use the cuff-leak test to evaluate upper airway patency.
		III-39 Positive judgment criteria for cuff-leak test: Compare the exhalation volumes of adult patients during gasbag inflation and after deflation. If the difference is ≤ 110 mL or ≤ 15% of tidal volume, it indicates a blockage in the upper respiratory tract. A cuff-leak test should be conducted for populations with a high risk of stridor after extubation.

I-3 Operation performance	II-17 Operation for the tracheal suction	III-40 Measure the gasbag pressure within ten minutes before and after suction
		III-41 Perform aspiration of subglottic secretion before each suction
	II-18 Oral care operating techniques	III-42 Patients with intact buccal mucosa should receive oral care every six hours.
		III-43 Patients having oral mucosal rupture or infection should receive oral care every four hours with chlorhexidine or gargles containing chlorhexidine.
		III-44 Gasbag pressure should be measured ten minutes before and after oral care.
	II-19 Atomization technology	III-45 Measure the gasbag pressure within 30 minutes before and after aerosol inhalation
	II-20 Replacement and maintenance technologies of ventilator pipes	
	II-21 Position management	III-46 If the patient's condition allows, avoid the supine position and raise the head of the bed (30° - 45°).
		III-47 Measure the gasbag pressure within ten minutes before and after turning over patients.
I-4 Actual performance in a real work environment	II-22 Correct inflation method and the method and timing of gasbag pressure measurement	
	II-23 Disposal methods and precautions for gasbag secretions	
	II-24 Gasbag leakage inspection and judgment	
	II-25 Pre-operation and precautions before deflating the gasbag and unplugging	

https://doi.org/10.2147/JMDH.S438316

Table 3 Comparison of the Training Effect for the ICU Nurses Between the Pre- and Post-Training (Score, mean±SD)

Performance	n	Pre-Training	Post-Training	t	*P*
Theoretical knowledge	52	73.73±8.54	88.31±6.29	11.017	<0.001
Technical operation	52	75.29±7.48	86.92±4.72	8.986	<0.001
Gasbag management Knowledge	52	36.62±8.20	58.44±7.67	13.776	<0.001
Gasbag management attitude	52	5.87±1.92	11.46±2.19	14.364	<0.001
Gasbag management behavior	52	34.19±6.59	39.13±4.06	8.489	<0.001
Total scores for the gasbag management	52	76.67±10.68	109.04±9.87	19.916	<0.001

prevent VAP was constructed using the Delphi expert inquiry method based on the Miller pyramid model. The training program was scientific and reasonable in training the ICU nurses on managing artificial airway gasbags to prevent VAP.

The program on artificial airway gasbag management contains gasbag pressure monitoring, artificial airway evaluation, gasbag material selection, gasbag secretion disposal, and gasbag leakage assessment. The training program in this study focused on optimizing gasbag management. It provided new ideas for ICU nurses to manage artificial airway gasbags and prevent VAP scientifically. The online and offline training were utilized through the 317 nursing APP platform. All courses can be learned by replaying the course to facilitate ICU nurses working mode in two shifts. It solved the problem of training at a fixed site and scheduled time. Therefore, online training was popular in nurse training and had solid clinical practicality. The performance on the knowledge and operating skills were improved dramatically after the training using this program.

The training program on managing artificial airway gasbags can effectively improve the level of knowledge-attitude-practice for ICU Nurses to prevent VAP. The level of the nurses' knowledge about VAP prevention is a crucial factor that threatens patient safety and affects nursing quality.[22] The level of the ICU nurses in preventing VAP in third-level first-class comprehensive hospitals is moderate. The compliance of various measures needs to be further strengthened.[23] The unsatisfactory clinical compliance in VAP care measures among nurses is related to various factors, such as lack of VAP-related knowledge, insufficient clinical experience, and failure to form good standardized operational behavior.[24] The theoretical knowledge, operation skills, and knowledge-attitude-practice of ICU nurses on artificial airway gasbag management to prevent VAP after the training was much higher than before. The ICU nurses mastered the theoretical knowledge of VAP prevention. The operation skills in tracheal suction, oral care, atomization technology, ventilator operation, pipeline maintenance, and gasbag pressure monitoring were further normalized. The training program for ICU nurses to manage artificial airway gasbags and prevent VAP based on the Miller pyramid model cultivated their ability to prevent VAP from professional theoretical knowledge, knowledge application ability, operational performance, and actual performance in natural work environments. It effectively enhanced the knowledge-attitude-behavior level of ICU nurses.

The training effects of the nurses was excellent by evaluating each indicator in this study. However, there are still some limitations of the study. This study is a single-center study with pre and post-comparison methods. It will be better to set a paralleled control group in the application part of the training program. The training effects by examining the performance of each indicator were evaluated one week after the end of the program. A long-term effects of the training program on artificial airway gasbag management and VAP prevention need to be further investigated by evaluating the nurse's performance 3 or 6 months following the training in order to generalize the efficacy of the training program. In addition, the selection of 52 trainees for participating the training program were based on the voluntary. It would potentially exaggerate the training effects due to selection bias of the trainees.

Conclusion

In conclusion, the training program for ICU nurses on artificial airway gasbag management and VAP prevention was constructed through two rounds of expert inquiries using the Delphi method in this study. It is scientific and practical. It improved the cognitive competence of ICU nurses in artificial airway gasbag management and VAP prevention. However,

This training program for the nurses on managing the artificial airway gasbag and preventing VAP need to be further improved in the future clinical practice. The various assessment methods can be adopted in future research. For example, the case report and paper writing can also be used to evaluate the performance of the ICU nurses in addition to theoretical exams and skill operation assessments to meet the requirements of disciplinary development and clinical practice.

Funding

This study was supported by Henan Province 2020 Medical Science and Technology Research Program Joint Construction Project [No. LHGJ20200227].

Disclosure

The authors report no conflicts of interest in this work.

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