International Journal of Nursing and Medical Investigation

International Peer Reviewed Journal

Review article

Ventilator-associated pneumonia: updates of pathogenesis, incidence, prevention strategies

Sherin Elsa Aniyan Samuel[1], and Gargee Karadkar[2*]

[1]Asian Heart Institute, Mumbai, Maharashtra, India
[2]Bharati Vidyapeeth College of Nursing, Navi Mumbai, Maharashtra, India

Abstract

Ventilator-associated pneumonia (VAP) is one of the most commonly encountered hospital-acquired infections in intensive care units and is associated with significant morbidity and high costs of care. The pathophysiology, epidemiology, treatment, and prevention of VAP have been extensively studied for decades, but a clear prevention strategy has not yet emerged. In this article, we will review pathogenesis, incidence, and prevention strategies with focus on teaching programme to prevent the disease.

Keywords: Ventilator-associated pneumonia, pathogenesis, prevention strategies.

***Corresponding author: Mrs. Gargee Karadkar,** Bharati Vidyapeeth College of Nursing, Navi Mumbai, Maharashtra, India Email:k_gargee@yahoo.com

1. Introduction

Ventilator-associated pneumonia (VAP) remains a common cause of intensive care unit (ICU) and hospital morbidity and mortality despite advances in diagnostic techniques and management. VAP is defined as pneumonia i.e., a nosocominal infection that occurs 48–72 hours or thereafter following endotracheal intubation, new or progressive infiltrate, signs of systemic infection (fever, altered white blood cell count) etc [1]. VAP is the leading cause of death among critically ill patients, with its associated mortality rate down [2] VAP take part in half of the hospital-acquired pneumonia[1,3] and estimated that 9–27 % mechanically ventilated patients highest risk being early in the course of hospitalization[4].

The main contributing factor of VAP is micro aspiration of or pharyngeal organisms from around the endotracheal tube's cuff into the distal bronchi, which leads to a proliferation of bacteria and its invasion of lung parenchyma [5]. The effectiveness of video assisted teaching programme on knowledge regarding non-pharmacological pain-relieving intervention for children among staff nurses in a selected hospital in India. A structured questionnaire is used to assess the knowledge of the staff nurse regarding non-pharmacological pain-relieving interventions for children in selected hospitals. In the pre-test more than half (53.3%) of the staff nurses had average knowledge, 40% of them had poor knowledge and 6.7% had good knowledge regarding non-pharmacological pain-relieving interventions before the video-assisted teaching program, but in the post-test there was significant improvement in the knowledge scores 80 % of nurses had good knowledge. None of the demographic variables were found to have a significant association with knowledge of the staff nurses. Hence, the video-assisted teaching regarding non-pharmacological pain-relieving interventions for children is effective in rendering knowledge and bringing awareness. [6] Video-assisted teaching was found to be effective.

Pathogenesis

In the Pathogenesis of ventilator-associated pneumonia (VAP) play a complex role in endotracheal tube, virulence of bacteria and host immunity. The major defense mechanisms include a cough, reflexes, airway barriers, mucous [7] and mucociliary clearance [8]. Mucociliary clearance is a complex process, the integrity

of which depends upon the composition of airway secretions, an effective mucociliary reflex, and an effective cough [8]. The pathogenic material can also collect in surrounding anatomic structures, such as the stomach, sinuses, nasopharynx, and oropharynx, with the replacement of normal flora by more virulent strains [9]. The concept that nosocomial pneumonia develops from the aspiration of colonized oropharyngeal or tracheal secretions is supported by studies demonstrating upper airway colonization with Aerobic gram-negative bacilli (AGNB) preceding the development of nosocomial pneumonia.

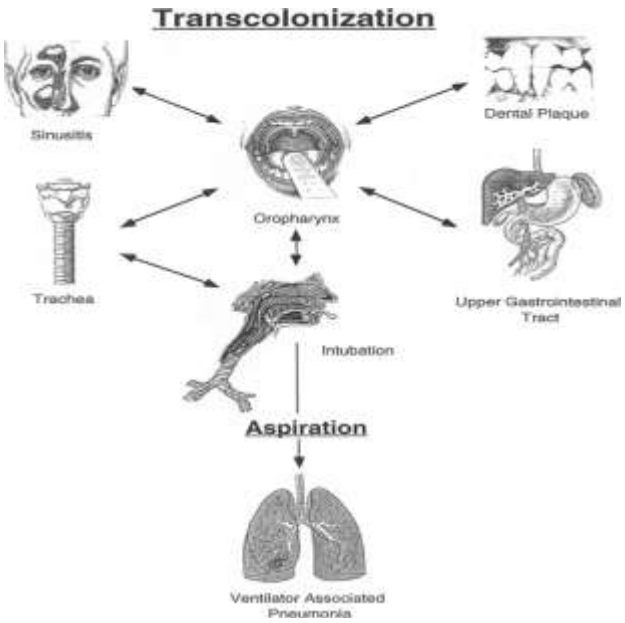

Fig no 1: Pathogenesis of ventilator-associated pneumonia.

Transcolonization of the oropharynx occurs with contiguous structures such as the sinuses, trachea, gastric contents, and periodontal areas. Contamination of the inner and outer surfaces of the endotracheal tube with oropharyngeal and tracheal secretions occurs as does contamination of the ventilator circuits [10]. During mechanical ventilation, inoculi of these contaminated secretions enter the distal airway and may induce an inflammatory response leading to pneumonia 370 frequently involves large numbers of bacteria and often precedes the development of nosocomial pneumonia [10]

The incidence of ventilator-associated pneumonia:

The incidence of VAP increased as the duration of mechanical ventilation increased and there was a total agreement in bacteriology between semi-quantitative ETAs (Endotracheal aspirate) and BALs (Broncho-alveolar damage) in our study. The overall mortality associated with VAP was observed to be 48.33%. Therefore, the researchers concluded that the incidence of VAP was 57.14% and the study proved that the incidence of VAP is directly proportional to the duration of mechanical ventilation. The most common pathogens causing VAP were Acinetobacter spp. and Pseudomonas aeruginosa and were associated with a high fatality rate [11].

In A comparative study the differences in incidence and outcome of ventilator-associated pneumonia in surgical and medical ICUs in a tertiary hospital in China where a total of 329 patients admitted to the MICU or SICU who were mechanically ventilated for ≥48 hrs were included. The findings showed that the incidence of VAP in the MICU was 25%, with 29.7 cases per 1000 ventilator days, and the incidence of VAP in the SICU was 26.7%, with 27.4 cases per 1000 ventilator days [12].

In the MICU patients without VAP spent 6.0 days on the ventilator and those with VAP spent 8.5 days (P<0.001); the length of stay (LOS) in the ICU was 9.0 days vs. 14.0 days for patients without and with VAP, respectively (P<0.001). The mortality in the MICU was 34.1% for patients without VAP vs. 55.8% for those with VAP (P=0.012), and 30-day mortalities were 31.8% and 41.9%, respectively (P=0.228); 60-day mortalities were 34.1% and 53.5%, respectively (P=0.024). In the SICU, patients without and with VAP were ventilated for 5.0 and 10.0 days, respectively (P<0.001). The ICU Length of Stay was 7.0 days for patients without VAP vs. 15.0 days for patients with VAP (P<0.001) [12].

The study concludes that prolonged time on ventilator and ICU stay increased the mortality in the MICU from VAP. There were no differences in the incidence of or mortality from VAP in the MICU and SICU [12].

In a study on Critical Care Nursing Interventions and Incidence of Ventilator-Associated Pneumonia in the Trauma Population, Retrospective and Correlational methods were used in the study. The sample for the study were the critical care staff nurses on the incidence of VAP included 1,987 ventilated patients in the Neuro-Trauma intensive care unit. Results showed that nursing staff was least compliant with oral care, only completing this 96% of the time, slightly more compliant with providing a sedation holiday for affected patients and documenting this occurrence (98.4%), peptic ulcer disease prophylaxis (98.5%), and providing deep vein thrombosis prophylaxis (99.1%) [13].

The indicator the staff was most compliant with was elevating the head of the bed (99.7%). VAP occurrence over the study period ranged from one to three per quarter (M=2.33, SD = 0.81), averaging 2.33 per quarter. The number of days patients were artificially ventilated ranged from 427 to 685 per quarter (M = 549.5, SD = 100.43). The study finally concluded that Ventilator Associated Pneumonia (VAP) in the Trauma Intensive Care Unit is the most commonly encountered infection in the intensive care unit and can be linked to increased morbidity, increased mortality, increased mechanical ventilation days, increased hospital length of stay, and increased cost.[13]

A prospective cohort study was conducted on Incidence, risk stratification, antibiogram of pathogens isolated and clinical outcome of ventilator-associated pneumonia,

(India). Wherein samples included of 107 patients taken on ventilatory support for two or more days and those not suffering from pneumonia prior were to be taken on a ventilator. Research showed that the incidence of VAP was 28.04% [14].

Mortality in VAP group was 46.67%, while in the non-VAP group was 27.28%. High APACHE II score was associated with a high mortality rate as well as increased incidence of VAP. The most common organisms isolated from an endotracheal aspirate of patients who developed VAP were Pseudomonas aeruginosa, Methicillin-resistant Staphylococcus aureus (MRSA), Klebsiella pneumonia and Acinetobacter baumannii. Most strains of Pseudomonas (55.56%) were resistant to commonly used beta-lactam antibiotics known to be effective against Pseudomonas [14].

All strains of Staphylococcus aureus were MRSA and most isolates of K. pneumoniae (85.71%) were extended-spectrum beta-lactamase producing. About 50% isolates of Acinetobacter were resistant to carbapenems. Mortality was highest for infections caused by A. baumannii (83.33%) and K. pneumonia (71.42%).The research study concluded that, APACHE II score can be used to stratify the risk of development of VAP and overall risk of mortality. Drug-resistant strains of various organisms are an important cause of VAP in our setting [14].

In the recent study on Comparing the incidence and impact of ventilator-associated complications (VAC) and infection-related ventilator-associated complications (IVAC) to ventilator-associated pneumonia (VAP) in RUMC, USA. A retrospective cohort study of 259 patients who received mechanical ventilation in the MICU at RUMC between October 1st, 2011 and September 30, 2012, was assessed for VAP, VAC and IVAC wherein the findings revealed that the VAC rate was 9.6 per 1000 ventilator days, and IVAC was 4.46 per 1000 ventilator days. The VAP rate for the same time period was 11.9 per 1000 ventilator days. The ICU lengths of stay, hospital length of stay and ventilator days were significantly higher in VAC, IVAC and VAP [15].

In a retrospective study samples included the ventilated patients of 2 SICUs at tertiary care academic level 1 trauma center where the findings identified that prior to initiation of the bundle; VAP was seen at a rate of 10.2 cases/1000 ventilator days. Compliance with the VAP bundle increased over the study period from 53% and 63% to 91% and 81% in each respective SICU. The rate of VAP decreased to 3.4 cases/1000 ventilator days [16].

Prevention of ventilator associated pneumonia:

Staff nurses play a very crucial role in preventing the VAP in patients; therefore staff nurses need to have an awareness of the problem as well as knowledge on its prevention strategies and care practices. Skilled and knowledgeable staff nurses are extremely important in order to make appropriate decisions in patient care and minimize risks of patients developing VAP. In the recent study on Ventilator-Associated Pneumonia in an ICU of a Tertiary Care Hospital in India where the VAP patients have a higher mortality rate, longer duration of mechanical ventilation and longer duration of hospital stay than in VAP patients [17].

A prospective active before-after surveillance study on Effectiveness of a multidimensional approach for prevention of ventilator-associated pneumonia in 11 adult intensive care units from 10 cities of Turkey: findings of the International Nosocomial Infection Control Consortium (INICC), 2013.

The study was divided into two phases. In phase 1, active prospective surveillance of VAP was conducted using the definitions of the centers for Disease Control and Prevention National Health Safety Network, and the INICC methods. In phase 2, we implemented the multidimensional approach for VAP. The INICC multidimensional approach included the following measures: Bundle of infection control interventions, Education, Outcome surveillance, Process surveillance, Feedback of VAP rates, and performance feedback of infection control practices. Through the time series analysis the study findings revealed that in phase 1, 2,376 mechanical ventilators (MV)-days was recorded, and in phase 2, after implementing the multidimensional approach, 28,181 MV-days was recorded [18].

The rate of VAP was 31.14 per 1,000 MV-days during phase 1, and 16.82 per 1,000 MV-days during phase 2, amounting to a 46 % VAP rate reduction (RR, 0.54; 95 % CI, 0.42-0.7; P value, 0.0001.). The study concluded that The INICC multidimensional approach was associated with a significant reduction in the VAP rate in these adult ICUs of Turkey [18].

In another Randomized controlled trial on the mechanical ventilated ICU patients on the Subglottic secretion drainage for preventing VAP Research findings showed that the subglottic drainage of secretions was estimated to reduce the risk of VAP by 48% (fixed-effect relative risk (RR) = 0.52, 95% confidence interval (CI), 0.42-0.65). When comparing subglottic drainage and control groups, the summary relative risk for ICU mortality was 1.05 (95% CI, 0.86-1.28) and for hospital, mortality was 0.96 (95% CI, 0.81-1.12). Overall subglottic drainage effect on days of mechanical ventilation was -1.04 days (95% CI, -2.79-0.71) [19].

This meta-analysis of published randomized control trials shows that almost one-half of cases of VAP may be prevented with the use of specialized endotracheal tubes designed to drain subglottic secretions. Time on mechanical ventilation may be reduced and time to development of VAP may be increased, but no reduction in ICU or hospital mortality has been observed in published trials [19].

In 2011 conducted an observational study on Reduction in ventilator-associated pneumonia in a mixed intensive care unit after initiation of a novel hand hygiene program wherein a total of 1, 262 and 1,331 patients were evaluated during consecutive 12 month periods. The findings showed that VAP per 1000 vent days was

significantly reduced after introduction of the program [3.7 vs. 6.9] P < .001. The reduction in catheter-related bloodstream infection (CRBSI) per 1000 line days was not significant [1.5 vs. 2.6], P = .09. Observed hand hygiene increased during the study period. There was no significant difference in mortality [20].

Knowledge of staff nurses related to the prevention of ventilator-associated pneumonia: The study on Improving Quality of Care for Mechanically Ventilated Patients in Long-Term Care through Full Compliance with the Ventilator. In-depth interviews were conducted with 15 staff nurses from the site on their knowledge of VAP and the ventilator bundle. Through ground theory analysis the study proved that the staff nurses had poor understanding and compliance with the Ventilator Bundle protocol. The research concluded that the evidence from this study could yield a quality improvement model for long-term-care facilities and ventilator units in particular and the goal was to improve nursing staff's knowledge about VAP and the ventilator bundle, reduce VAP morbidity and mortality, and ensure that mechanically ventilated patients receive the best quality of care [21].

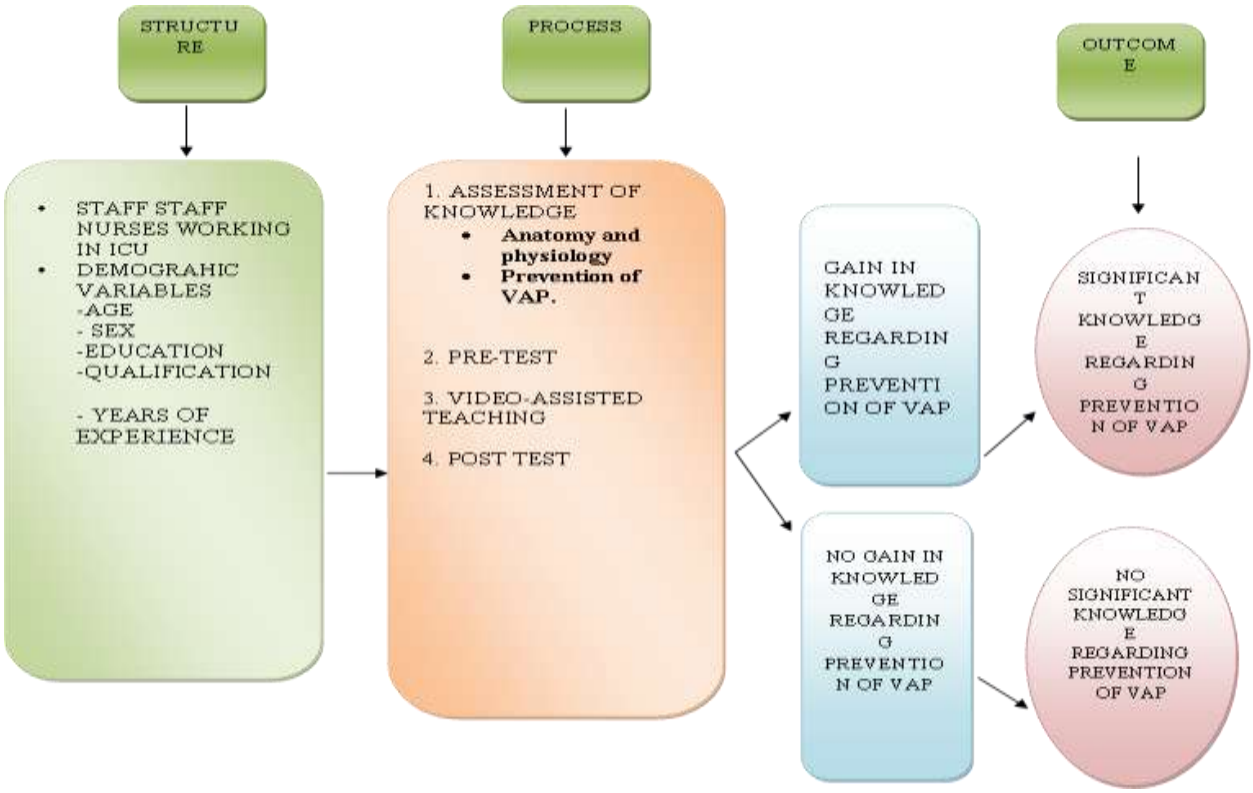

Fig 2: Donabedian model [22]

Another study on the Impact of the Structured Teaching Program for Prevention of Ventilator-Associated Pneumonia on Knowledge and Practices of Intensive Care Staff nurses at Central Quwesna Hospital, Eygpt. Where in a quasi-experimental study was utilized and the samples included were the 30 staff nurses.

From the research findings, the study findings revealed that 30% of respondents were in the age group of 21-25 years followed by 36.7% in the age group of 26-30 years and 33.3% in the age group of above 30 years with a mean age of 32.32 years. Also, in relation to gender, 76.7% of staff nurses were found to be females. Concerning total clinical experience, 43.3% of the staff nurses had 1-5 years of clinical experience, 30% had 6-10 years of clinical experience and 26.7% had above 10 years of clinical experience [23].

With respect to professional educational qualification, it was observed that 23.3% of the respondents were having bachelor degree in nursing and 76.7% of respondents had technical institute degree in Nursing from this it was clear that none of the staff nurses in the study samples had satisfactorily total knowledge score at the pre-program implementation, however, the knowledge score increased after the post test [23].

Concluding to these findings the current study shows that staff nurses were having unsatisfactory total knowledge and practice at pre-program implementation, however, scores of total knowledge increased immediately after the program. On the other hand, it was observed that there was an association between age, years of experience, knowledge, and practice of intensive care staff nurses on prevention of VAP. As also were found to have an impact on knowledge and practice scores the current study recommended developing manuals, information booklets and self-

instructional modules in the areas of Prevention of VAP [23].

Study on the impact of staff nurses' adherence to sedation vacations on ventilator-associated pneumonia prevention at Georgia State University, US which included a correlational design of three components: abstraction of patient data from the electronic medical record (EMR) (*n*=79 with VAP and *n*=79 without VAP), administration of surveys to ICU staff nurses (*N*=34), and vignettes related to SVs (Sedation vacation) [24].

Analyses included descriptive statistics, t-tests, correlations, and analysis of covariance and the samples were the 79 staff nurses of the Intensive Care Unit. The research findings showed that the average staff nurses had low scores on the vignettes (*M*=6.97, *SD*=2.21; possible range =0-14) and adherence rate of staff nurses' implementation of SVs, determined using EMR data, was also low (*M*=24%; *SD*=23%). There were higher rates of SV adherence in patients without VAP ($p<.001$), with an ICU LOS $\leq$ 13 days ($p<.01$), and a duration of MV $\leq$ 6 days ($p=.04$). Concluding to these findings, it indicates that even with established protocols, staff nurses may not consistently implement the evidence-based interventions that have been shown to prevent nosocomial infections. Future research is needed to improve nursing practice and the quality of care in this patient population [24].

Another study was on Critical Care Staff nurses Knowledge and Compliance with Ventilator-Associated Pneumonia Bundle at Cairo University Hospitals, Eygpt. A convenience sample of 45 critical care staff nurses of the ICU (medical, surgical and coronary units) and the design used for the study was the descriptive exploratory design. .The results of 20- items questionnaire revealed unsatisfactory knowledge scores (mean= 7.46 + 2.37) and most of the staff nurses were not compliant with ventilator associated pneumonia bundle practices (average mean = 8.62 + 7.9 out of 29) and there was no specific protocol to follow for VAP prevention. Therefore there should be a need for the in-service education and evidenced based guidelines regarding Ventilator Associated Pneumonia [25].

Another study conducted on the effectiveness of an evidence-based nursing care program to reduce ventilator-associated pneumonia in a Korean ICU. Samples in the study are 27 convenient Medical ICU staff nurses which were surveyed for their awareness of VAP prevention and self-evaluation of VAP prevention [26].

The research showed that staff nurses' VAP prevention awareness ($p=.008$) and would increase the staff nurses' subjective ($p=.003$) and objective ($p \leq .001$) VAP prevention performance evaluations was supported. That incidence of VAP would decrease from a pre-intervention VAP rate of 17.382 (number of occurrences/1000 ventilator days) to a post-intervention rate of 11.044, was not statistically significant ($p=.074$). The research finally concluded that an intervention VAP prevention program promoted ICU staff nurses' VAP prevention awareness and performance and could, therefore, help decrease the VAP rate [25].

A quantitative cross-sectional survey study was on Critical care staff nurses' knowledge of, adherence to and barriers towards evidence-based guidelines for the prevention of ventilator-associated pneumonia. Two multiple-choice questionnaires were distributed to 101 critical care staff nurses in a single academic center in Finland in the autumn of 2010 [27].

The research analyzed that the mean score on the knowledge test was 59.9%. More experienced staff nurses performed significantly better than their less-experienced colleagues ($p = 0.029$). The overall, self-reported adherence was 84.0%. The research concluded that the main self-reported barriers towards evidence-based guidelines were inadequate resources and disagreement with the results as well as lack of time, skills, knowledge and guidance. There is an ongoing need for improvements in education and effective implementation strategies. The results could be used to inform local practice and stimulate debate on measures to prevent ventilator-associated pneumonia. Education guidelines, as well as ventilator bundles and instruments, should be developed and updated to improve infection control [27].

Video-assisted teaching

An pre-experimental study on the Effectiveness of Video-Assisted Teaching Program Regarding Knowledge on Biomedical Waste Management among Staff Nurses of Karad, (India). One group pretest posttest design was used among 60 staff nurses wherein pretest was conducted before administration of the video-assisted teaching and the post test was conducted after 7 days [28].

The findings concluded that after administering the video-assisted teaching program the mean knowledge score was increased to 26.033 from 17.383 that of the pretest knowledge mean scores. The paired‘t’ value was 12.947 giving the p-value < 0.001 which is considered to be extremely significant and thereby indicates a significant improvement in knowledge of staff nurses regarding Biomedical Waste management. Therefore it concluded that there was an evident increase in the knowledge scores among staff nurses after administering of the video-assisted teaching program[28]

In 2014, a study on the effectiveness of video assisted teaching programme on knowledge regarding nonpharmacological pain-relieving intervention for children among staff nurses in a selected hospital in India. A structured questionnaire was used to assess the knowledge of the staff nurse regarding nonpharmacological pain-relieving interventions for children in selected hospitals [29].

In the pre-test more than half (53.3%) of the staff nurses had average knowledge, 40% of them had poor knowledge and 6.7% had good knowledge regarding non-pharmacological pain-relieving interventions before the video-assisted teaching program, but in the post-test

there was significant improvement in the knowledge scores 80 % of nurses had good knowledge. None of the demographic variables was found to have significant association with knowledge of the staff nurses. Hence the video assisted teaching regarding non pharmacological pain relieving interventions for children was effective in rendering knowledge and bringing awareness. [29]

Another study was on to assess the effectiveness of VAT on knowledge and attitude regarding Needle Stick Injury among 60 staff nurses of selected hospitals. Pre and Post test Design was used by the convenient sampling techniques. The results findings showed the Pre-test mean knowledge and attitude score was 9.5 and 33.66 respectively which was increased in Post-test to 15.16 and 34.64 respectively and "t" test value knowledge ($t=2.235$ <0.0001) attitude ($t= 0.3866$ at $p<0.001$) which is considered to be extremely significant of knowledge and there was no significant in attitude change. Thus, researcher concluded that there was a significant gain in knowledge regarding NSI after administering video assisted teaching (VAT). [30]

Such studies have demonstrated and help the staff nurses to gain knowledge by the effective use of video-assisted teaching.

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