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ORIGINAL RESEARCH INTENSIVE CARE

Development of ventilator-associated pneumonia (VAP) prevention model in the hospital based on Six Sigma and VAP Bundle

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ABSTRACT

Background & Objective: Ventilator-Associated Pneumonia (VAP) is the leading cause of death in Healthcare-Associated Infections (HCAI), with 30-day mortality of 59% of patients with ventilator devices. The aim of this research was to develop a VAP prevention model in the intensive care unit (ICU) based on Six Sigma and VAP Bundle, involving individual, organizational and work characteristics factors.

Methodology: This research was carried out in the ICU, Poltekkes Kemenkes Malang, Malang, Indonesia, using a cross-sectional design. The research subjects were nurses, selected using a simple random sampling technique. All variables were measured through filling out questionnaires. Next, the measurement data was analyzed using Partial Least Square (PLS), based on Six Sigma and VAP Bundle.

Results: Based on Six Sigma and VAP Bundle, the results of the analysis of the effects of the three factors on the implementation of VAP prevention were: 1) for individual factors, path coefficient = 0.189 and P = 0.000, so it was interpreted that this factor had a significant effect on the implementation of VAP prevention; 2) for organizational factors, path coefficient = 0.496 and P = 0.003, so it was interpreted that this factor also had a significant effect; 3) for the work characteristics factors, path coefficient = 0.289 and P = 0.000, so this factor also had a significant effect on the implementation of VAP prevention.

Conclusion: Based on the research results, a VAP prevention model based on Six Sigma and VAP bundle was successfully built in the ICU, which involved organizational factors, work characteristics and individual factors.

Abbreviations: HCAI - Healthcare-Associated Infections; HAP - Hospital-acquired pneumonia; PLS - Partial Least Square; SOP - standard operating procedure; VAP - ventilator-associated pneumonia;

Keywords: Ventilator-Associated Pneumonia, VAP, Prevention; Six Sigma, VAP Bundle; Intensive Care Unit; organizational factors; work characteristics; individual factors

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1. INTRODUCTION

Ventilator-Associated Pneumonia (VAP) is the leading cause of death in Healthcare-Associated Infections (HCAI) with 30-day mortality of 59% of patients with ventilator devices.[1] VAP is a common nosocomial infection with one of the main risk factors for the use of a mechanical ventilator, especially in Intensive Care

Unit (ICU) patients. VAP is pneumonia that occurs after 48 h in patients with the help of mechanical ventilation, either through an endotracheal tube or a tracheostomy.[2]

The VAP Bundle is a collection of evidence-based practices that when implemented together will result in a reduction in the incidence of VAP. VAP Bundle components include: 1) head elevation of 45° if possible, for example if the patient's hemodynamic status is stable, but if this is not possible, it can be adjusted to a position of more than 30°; 2) daily evaluation of extubation readiness; 3) use of an endotracheal tube with drainage of subglottic secretions; 4) oral care and decontamination with chlorhexidine; and 5) safe early enteral nutrition within 24-48 h after entering the ICU.[3]

The implementation of the VAP bundle is very dependent on nurse compliance. Of the five VAP bundles, some nurses have to work independently and some are the task of the delegation. The delegation's duties included readiness for extubation, use of subglottic drainage, and nutrition early after entering the ICU. Meanwhile, the independent duties of nurses include head elevation 45º and oral care. Hand hygiene is not included in the VAP bundle, but germs on the hands of officers such as *S. aureus*, gram-negative bacilli, or *Candida* species are a source of nosocomial infection.[4] With hand hygiene according to the protocol (six steps and five moments), it is said to reduce the incidence of HCAI.[5] One of the HCAIs that occur in the ICU is VAP.[6]

Six Sigma is a methodology that focuses on identifying and reducing variations in processes. Six Sigma consists of 5 steps which are further shortened to DMAIC, namely: Define, Measure, Analyze, Improve, Control. Each step is described as follows: 1) Define is identifying problems and determining objectives; 2) Measure is validating the problem, measuring the problem from existing data; 3) Analyze is looking for the most influential factors; 4) Improve is discussing ideas to improve quality; 5) Control is making plans and measurement designs so that good results can be sustained on an ongoing basis.[7]

Nurse compliance is the extent to which a nurse's behavior complies with the provisions given by the nurse leader or the hospital where he or she works. Compliance can be influenced by various factors such as education, age, environment, social conditions, procedures, interactions, knowledge, attitudes and so on.[8]

Although the VAP Bundle has been widely researched, the implementation of the VAP Bundle is very different in different locations. To be able to increase compliance behavior in implementing VAP prevention with the correct VAP bundle, it is necessary to identify problems and determine specific goals, regarding efforts to maximize the implementation of VAP bundles in the ICU.

Based on the background above, it is necessary to analyze problems related to VAP incidents in hospital ICUs using Six Sigma, so that the implementation of the VAP bundle can be maximized in order to prevent and suppress VAP incidents. For this reason, research is needed that aims to develop a VAP prevention model in the intensive care unit (ICU) based on Six Sigma and VAP Bundle, involving individual, organizational and work characteristics factors.

2. METHODOLOGY

This research was a survey-based study with a cross-sectional design. The population of this study was all nurses in the ICU at Lavalette Hospital Malang who cared for patients with pneumonia who were on ventilators. The sample size was 100 nurses, selected using a simple random sampling technique.

This research studied four latent variables, three of which were independent variables, namely: 1) individual factors with 2 indicators, namely: experience and knowledge; 2) organizational factors with 3 indicators, namely: rewards, organizational structure and training; and 3) work characteristics with 2 indicators, namely: feedback and performance goals. While the remainder was the dependent variable, namely VAP prevention with 5 indicators, namely: define, measure, analyze, improve and control. All of indicators were measured by filling out a questionnaire distributed via Google Form.

After the data for each indicator was collected completely, a modeling analysis of the implementation of VAP prevention by nurses was then carried out using Structural Equation Modeling (SEM). All data collected was of the categorical type, so the data was analyzed using the appropriate method, namely Partial Least Square (PLS). The first stage of analysis was the outer model which aimed to analyze the validity of each indicator; while the second stage of analysis was an inner model which aimed to analyze the influence of each independent variable (individual, organizational and work characteristics factors) on the dependent variable (VAP prevention).

As scientific research involved humans, this research received ethical approval by the Health Research

Table 1: The respondents' characteristics in the development of pneumonia associated ventilator prevention model in the hospital

Respondents' characteristics		N (%)
Age (y)	• 20-30	25 (25)
	• 31-40	45 (45)
	• > 40	30 (30)
Sex	• Male	35 (35)
	• Female	65 (65)
Working duration (y)	• < 5	20 (20)
	• 5-10	60 (60)

Table 1: The respondents' characteristics in the development of pneumonia associated ventilator prevention model in the hospital

Respondents' characteristics		N (%)
	• > 15	20 (20)
Highest education	• Diploma	70 (70)
	• Bachelor	30 (30)

Table 2: The individual, organizational, and work characteristics in implementing the ventilator-associated pneumonia prevention model

No.	Variable	Poor (%)	Fair (%)	Good (%)
1.	Knowledge	18	28	54
2.	Experience	13	21	66
3.	Reward system	19	30	51
4.	Training & development	3	22	75
4.	Structure of the organization	16	24	60
5.	Objective performance	22	24	54
6.	Feedback	10	30	60
7.	Define	25	45	30
8.	Measure	13	42	45
9.	Analyze	16	36	48
10.	Improve	10	36	54
11.	Control	10	42	48

Table 3: The result of hypothetical test in developing the ventilator-associated pneumonia prevention model

Variables	Path coefficient	P-value
The influence of individual factors on the implementation of prevention of ventilator-associated pneumonia (VAP)	0.189	0.000
The influence of organizational factors on the implementation of prevention of ventilator-associated pneumonia (VAP)	0.496	0.003
The influence of work characteristic factors on the prevention of ventilator-associated pneumonia (VAP)	0.289	0.000
P < 0.05 considered as significant		

Ethics Committee of the Health Polytechnic, Ministry of Health, Malang, Indonesia. All participants agreed to be involved as research subjects by signing informed consent.

3. RESULTS

The majority of nurses of ICU were in their 31- 40 y of age (45%). They were mostly female (65%), they had been working there for about 5 to 10 y (60%), and their highest education was diploma of nursing (70%) (Table 1).

For individual factors, most of the indicators were in the good category, each of which was knowledge = 54% and experience = 66%. For organizational factors, most of the indicators were in the good category, e.g., reward system = 51%, training = 75% and organizational structure = 60.2%. For work characteristics, most of the indicators were in the categorical category, e.g., feedback = 60% and objective performance = 54%. As for the prevention of VAP, one indicator was mostly in the moderate 45%, category, namely define = and the other four indicators were mostly in the good category (Table 2).

In outer model, it can be seen that all indicators had an outer loading >0.5, so it can be concluded that all indicators were valid for measuring their respective latent variables (Figure 1).

In the inner model, it can be seen that the path coefficient for the influence of individual factors on the prevention of VAP = 0.189, with P = 0.000; so it was concluded that individual factors significantly influence the prevention of VAP. The path coefficient for the influence of organizational factors on the prevention of VAP = 0.496, with P = 0.003; so it was concluded that organizational factors significantly influence the prevention of VAP. While the path coefficient for the effect of work characteristics on the prevention of VAP = 0.289, with P = 0.000; so it was concluded that work characteristics have a significant effect on the prevention of VAP (Table 3).

The hypothetical test can be explained as follows: 1) the individual factors (knowledge, experience) 2) the organizational factors (reward, training, organization structure) and 3) the work characteristic factors (objective performance, feedback). All three influence the VAP prevention (Figure 2).

The final implementation of the VAP prevention shows the following results: the model that was formed from three factors significantly influenced the implementation of the VAP prevention; from the biggest influencing factor (organizational factor), the medium influence (the work characteristic factor), to the smallest influence (the individual factor). These factors influenced the implementation of the VAP

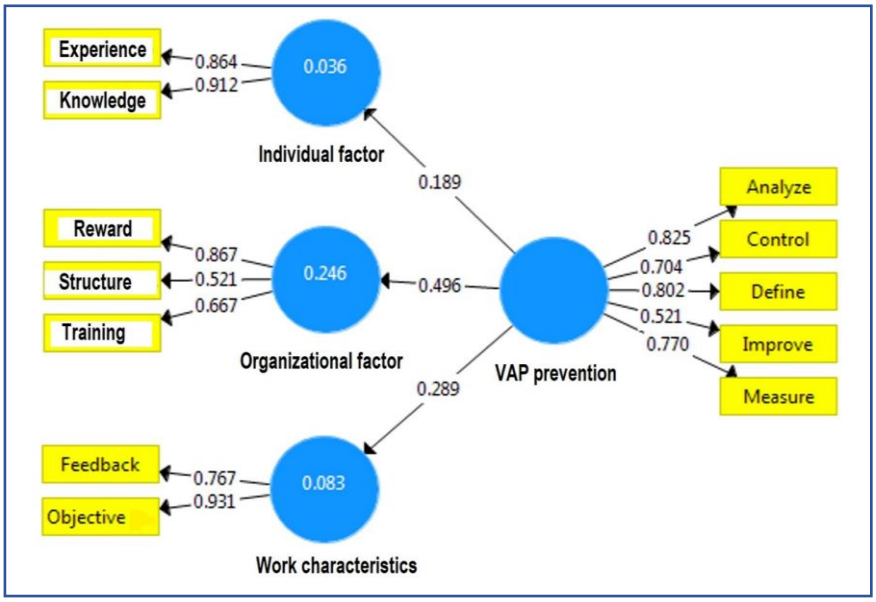

Figure 1: The score for the outer loading in developing the VAP prevention model

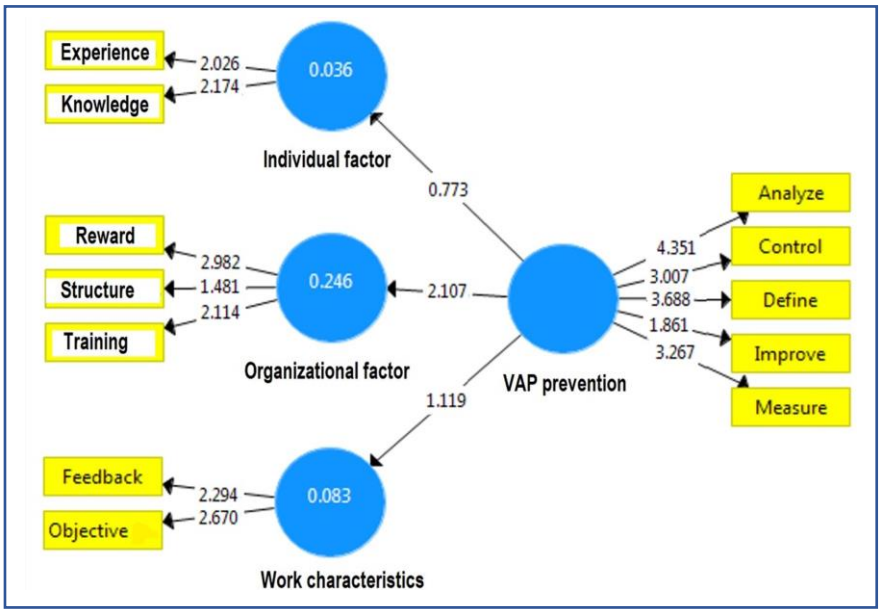

Figure 2: The result of an analytical test in developing the VAP prevention model

prevention based on six sigma and VAP bundle theory which consists of five aspects (define, measure, analyze, improve, control), and the VAP bundle which consists of five stages (elevation of the bed [head of bed] 30º-45º, assessment of readiness for extubation, venous thrombosis prophylaxis, peptic ulcer prophylaxis, oral care, hand hygiene).

4. DISCUSSION

Individual factors include indicators of knowledge and experience. The results of this study indicate that individual factors contribute to the implementation of the VAP prevention model. On knowledge and experience of nurses, most of the respondents were in a good category. Knowledge and experience here are related to the implementation of VAP prevention carried out by nurses from the stage of definition, measure, analyze, improve, control. This is supported by study that individual variables are grouped into indicators of knowledge and experience.[9]

The indicators of knowledge and skills are the main factors that influence behavior and individuals. The knowledge and skills possessed by nurses related to the implementation of VAP prevention are adjusted to the SPO owned by the hospital, so there is a need for clinical direction and monitoring from the card to maximize it. This aims to improve the abilities and skills of nurses. Besides, the role of the nursing committee which consists of a sub-committee of ethics, nursing quality, and credentialing plays an important role in increasing the knowledge and skills of nurses.[10]

On the indicator of organizational structure, that some respondents are in a good category. The organizational structure here is how an organization applies rules and policies, how tasks are clearly described and communicated to subordinates. Organizational structure is the way a group is formed, lines of communication and authority relations, and decision making.[11] This means that a good organizational structure will support staff to be more obedient in carrying out their work, especially in the implementation of nursing care documentation. This organizational structure contains a line of command and a good communication system to provide information to each other regarding the field of work of each division.[12]

The organizational system at the hospital is well structured so that the line of command and coordination lines between each field can be carried out quite well. With this good organizational structure, it can support nurses' compliance in implementing

VAP prevention. At the hospital, there is already support from the organization for the implementation of VAP prevention. To facilitate the implementation of good VAP prevention, it requires budget support from management for education and training activities, provision of program support facilities, monitoring and evaluation, regular reports and meetings, incentives/allowances for obedient nurses in carrying out actions by the existing standard operational procedure.

The work characteristics consists of objectives performance and feedback. Objectives performance is a domain factor related to nursing compliance in implementing nursing care documentation. One of the factors that affect performance is job characteristics consisting of job descriptions, job designs, and work schedules.[13] A work characteristic is an approach to work that is specified into 5 dimensions of core characteristics, namely skill variety, task identity, task significance, autonomy, and feedback. Feedback refers to information that informs employees about how well their work performance has been achieved while working. Feedback arises from the job itself, supervisors, or other employees.[14] At the hospital, the job design is submitted at the beginning of the orientation when the nurse is declared accepted as a nurse. Nurses are oriented towards the responsibilities, rights, and obligations of being a nurse in the hospital. This activity is closely related to the work performance and supervision carried out by the hospital, but this activity has not been carried out optimally. Hospitals should be able to carry out evaluation activities and efforts to improve their work performance. In the work characteristic sub variable: Objectives performance, all respondents are in a good category.[13]

Performance objectives include job orientation, which is the task and responsibility of the organization when the nurse is oriented to work at the time the nurse starts working.[13,15] Job descriptions or job designs are one of the organizational variables that affect individual behavior and performance. Job design is a managerial decision and action that specifies the depth, scope and objective job relationships to meet the needs of the organization as well as the social and individual needs of the job holder.[13,16] Job design describes the scope, depth, and purpose of each job that differentiates between one job and another. Job objectives are carried out through job analysis where managers describe the work according to the activities required to produce results.[17] Job design refers to the process applied to managers to decide on job assignments and authority. Job design is an attempt by a manager to classify the duties and responsibilities of each individual. A well-designed job will increase motivation which is a determining factor for both productivity and organization. Job satisfaction is influenced by job demands and the extent to which the job demands are by one's abilities. Supervision is an effort to evaluate the nurse's actions.[18]

The job design can be applied well so that it will further increase nurse compliance in filling out nursing care documentation. This study found that if nurses have a good perception of performance objectives, the job design is a list of jobs regarding the worker's obligations and includes qualifications, meaning that it details the minimum education and experience needed by a worker to carry out obligations and a good job design will affect one's performance achievement. Job descriptions are used as standards for conducting performance appraisals. [19]

The implementation of VAP prevention in this hospital has SOP with several innovations and adjustments. *Permenkes RI* (Regulation of the Minister of Health of the Republic of Indonesia) Number 27/2017 states that oral hygiene in patients with ventilators is carried out every 2-4 h using 0.02% chlorhexidine antiseptic and brushing teeth every 12 h,[20] but in the SOP VAP Bundle at Lavalette Hospital Malang, oral hygiene is carried out. Once every 8 h or every picket keep with antiseptic base 0.02% chlorhexidine and brushing teeth 3 times per day. This adjustment was made because the ICU was unable to perform oral hygiene every 2-4 h. One of the obstacles is the number of nurses, especially in the afternoon and evening duty, where one nurse has to treat 2-3 patients. Ideally, one nurse supports 1 patient on a ventilator. Information was also obtained that some patients refuse to have oral hygiene, especially at night because they feel their resting time is disturbed. Other information from the executive in the room also found that oral hygiene is done every 8 h.

The findings on the implementation of VAP prevention and control in the ICU of this hospital are in line with other study. This study points out that systematic and scheduled oral care cannot significantly reduce the incidence of VAP in critical patients but improve oral health and reduce plaque buildup.[21] These results are also in line with a research which states that comprehensive oral care such as brushing, suction, and rinsing with antiseptics can prevent VAP.[22] Further discussion is needed on how best to implement oral care in the ICU room at Lavalette Hospital. The VAP Bundle SOP at Lavalette Hospital added four bundles in addition to seven VAP prevention and control bundles which refer to *Permenkes RI* Number 27/2017, namely the implementation of chest physiotherapy, use of closed suction, replacement of ETT every 14 days, and monitoring of the use of endotracheal type esophageal tubes.[20] Chest physiotherapy is carried out so that there is no accumulation of secretions in patients on a ventilator.

The implementation of chest physiotherapy is in line with other finding that chest physiotherapy has a significant positive effect on reducing the incidence of VAP.[23] The use of closed suction is carried out to

reduce the incidence of VAP. This is supported by the results of a research which states that the use of closed suction can reduce the incidence of VAP, including reducing the risk of contaminant transfer from health workers and medical devices.[24] Patients who use closed suction have a shorter length of stay than patients who use open suction.[25]

The shorter length of stay is possible due to the lower risk of exposure to germs in the hospital, and from an economic point of view, the costs incurred by patients will be lower. Another VAP bundle that is being added is the replacement of the ETT every 14 days. The replacement of ETT for a maximum duration of 30 days can reduce the incidence of VAP, but the replacement of ETT must consider the risk of airway trauma in the invasive procedure performed.[26] The addition of the next bundle is monitoring the use of endotracheal type esophageal tubes. This monitoring is carried out because the use of an endotracheal type esophageal tube is usually done during a difficult intubation process, pre-hospital intubation, or during emergency intubation.[3] There are several risks of developing VAP, one of which is the process in the hospital.[27-30]

Emergency intubation is included in the hospital process using an endotracheal type esophageal tube which is at risk of VAP, so monitoring is necessary. The transmission aspect in the form of the delivery of the SOP VAP Bundle as a guideline for VAP prevention and control has reached the executive level in the ICU room at Lavalette Hospital. ICU executives know, understand, and implement the SOP VAP Bundle. Communication from the Infection Prevention Control Link Nurse (IPCLN) and IPCN to the head of the room and the service coordinator and service quality of the ICU was running effectively. Communication from the head of the room and the service coordinator and service quality of ICU to the executives in the room runs smoothly.

5. CONCLUSION

Keeping the research results in view, a VAP prevention model based on Six Sigma and VAP bundle was successfully built in the ICU, which involved organizational factors, work characteristics and individual factors.

The application of this VAP prevention can be done by the nurses in the hospital wards. The qualified nursing care implementing VAP prevention will increase the quality of nursing care to support the achievement of the optimum healthcare service.

6. Strength and weakness

Strength: this research produces a model of nurse behavior in VAP prevention, which is very important for patient safety in the ICU. Weakness: this model is only applied to nurses in the ICU, even though it can still be developed for other care units.

7. Data availability

Data presented in this study will be available on a fair request to the corresponding author.

8. Acknowledgment

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9. Conflict of interest

All authors declare no conflict of interest.

10. Author's contribution

TJAY: Conception; data collection; data management; data analysis; draft writing

manuscript development; submission

NE, FKS: Conception; data collection; data management; data analysis; manuscript writing

HSWN: data analysis; draft writing; manuscript development; review; editing; submission

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