

Original Research Article

Comparison of the Effects of Open and Closed Endotracheal Suction Systems on Ventilator-Associated Pneumonia and Mortality

ABSTRACT

Aims: Nosocomial pneumonia is a prevalent complication in patients admitted to intensive care units. Endotracheal suction is used in cleaning the airways of secretions in patients under mechanical ventilation. The objection of this study was to compare the effects of open versus closed endotracheal suction (OESS vs CESS) on the incidence of ventilator-associated pneumonia (VAP).

Study Design: Study designed by retrospective examination of hospital records

Place and Duration of Study: Reanimation Intensive Care Unit, Van Training and Research Hospital, Van, Turkey, between January 2018 and December 2019.

Methodology: Age, gender, length of stay in intensive care unit and mechanical ventilation, mortality and isolated microorganism status of 73 (35.6%) patients with VAP were analyzed retrospectively. These features were compared according to the endotracheal suction type applied. Sample: The study was conducted among 205 patients who are on mechanical ventilator for more than 48h in the reanimation intensive care unit (RICU) in tertiary care hospital.

Results: There was no difference between the groups in terms of mortality rates, length of RICU stay and duration of mechanical ventilation. There was a significant difference in terms of incidence of VAP between OESS and CESS group (41.8% and 28.4%, respectively). ($P = .045$) *Acinetobacter baumannii* was the most frequently isolated microorganism in both groups.

Conclusion: Closed endotracheal suction compared to the open method was associated with lower incidence of VAP in patients of RICU.

Keywords: ventilator-associated pneumonia; intensive care unit; suction; mechanical ventilation

1. INTRODUCTION

Nosocomial pneumonia (NP) is one of the most common complications in intensive care units.[1-3] Mechanical ventilation (MV) and endotracheal suction (ES) are accepted as predisposing factors for NP, and the clinical condition of NP patients is defined as ventilator-associated pneumonia (VAP).[4] Patients who are intubated and treated with mechanical ventilation are almost 10 times more likely to develop NP than patients with spontaneous breathing.[5] Additionally, VAP is associated with high morbidity and mortality due to the challenges in diagnosis and treatment.[6]

The endotracheal tube disrupts tissue integrity in the respiratory tract, increases secretion, and eliminates the cough reflex. In patients with weakened natural defense mechanisms, the

lower respiratory tract is susceptible to infection through aspiration of nasopharyngeal bacterial colonies.[7, 8] Therefore, one of the most important methods to reduce the incidence of VAP during MV is tracheal aspiration. Adequate oxygenation is also ensured while using ES to remove secretions, which are the main source of infection in the respiratory tract.[9, 10]

Endotracheal suction is performed using two main types of systems: open and closed. In the open endotracheal suction system (OESS), ES is typically performed after the patient has been disconnected from MV. However, this disconnection can lead to hypoxia, decreased humidity, and reduced positive end-expiratory pressure. Consequently, a closed endotracheal suction system (CESS) has been introduced to minimize these effects. In the CESS, an additional instrument is utilized to insert the suction catheter through the endotracheal tube without disconnecting the patient from MV. This approach aims to prevent hypoxia, minimize loss in lung volume, and reduce environmental and personnel-related contamination.[11]

While the goal is to minimize the risk of contamination, the literature reports varying results regarding which suction method achieves lower infection rates and reduced morbidity and mortality.[7, 10, 12] In this study, we aimed to compare the incidence of VAP in our intensive care patients who transitioned from the OESS system to the CESS system.

2. MATERIAL AND METHODS

The study was conducted through retrospective analysis of data from patients in the Reanimation Intensive Care Unit (RICU), which contains 20 of our tertiary hospital's 1,400 beds.

In this study, we analyzed data from patients who received MV in the intensive care unit for at least 48 hours between January 2018 and December 2019. A total of 205 patients were included in the study after we identified and excluded those with known chronic respiratory diseases, terminal malignancies, and previous diagnoses of NP.

Prior to the RICU's transition to the CESS in February 2019, 110 patients connected to MV underwent OESS. CESS was applied to 95 patients after the transition.

During the ES, nurses routinely implemented barrier precautions, including handwashing and the use of gloves and masks. In OESS, the connection between the tracheal tube and the mechanical ventilator was disconnected, and suction was performed using an aspiration catheter passed through the tracheal tube. A different aspiration catheter was used for each suction. TUORen, MedNet, China system was used for endotracheal aspiration in CESS. Before the patient was disconnected from the mechanical ventilator, one end of the closed suction catheter was connected to the mechanical ventilator and tracheal tube, and the other end was connected to the suction tube. After the catheter valve was opened, suction was performed using a Nelaton catheter placed in the tracheal tube.

The diagnostic criteria for VAP were determined as follows: the presence of new or persistent infiltrations, cavitations, or consolidations on chest X-rays, along with at least two of the microbiological and clinical criteria (body temperature $> 38\text{ }^{\circ}\text{C}$ or $< 36\text{ }^{\circ}\text{C}$; white blood cell count $> 10,000\text{ mm}^3$ or $< 5,000\text{ mm}^3$; and purulent tracheobronchial secretions and gas degradation).[13] After VAP was diagnosed, appropriate antibiotic treatments were determined based on the growth in endotracheal aspirate cultures from the patients.

Information recorded for patients in the intensive care unit who were connected to MV and diagnosed with VAP included age, gender, Chronic Health Evaluation II (APACHE II) scores at the time of MV initiation, length of stay in the intensive care unit, MV duration, and mortality status. Microorganisms identified in endotracheal aspirate cultures from VAP patients were also recorded.

This study was conducted with approval from the ethics committee of Van Research and Training Hospital on 10/09/2020 (Approval Number: 2020/18).

2.1 Statistical Analysis

We utilized analytical methods to evaluate the normal distribution of continuous variables. In the descriptive findings, categorical variables are given as numbers (percent), and continuous variables are presented with a mean \pm standard deviation (SD) for normal scattering data and a median (IQR) for normal nonscattering data. For the categorical variables, the statistical difference among groups was determined using chi-square tests. For the continuous variables, the statistical difference among groups was determined using the Mann–Whitney U test. Statistical significance was accepted as $p < 0.05$. RStudio version 3.6.3 was used for the statistical analysis of research data.

3. RESULTS AND DISCUSSION

A total of 203 patients were mechanically ventilated in the reanimation intensive care unit between January 2018 and December 2019.

OESS was applied to 110 patients who were mechanically ventilated between January 2018 and February 2019. VAP was detected in 46 (41.8%) of these patients. Between February 2019 and December 2019, CESS was applied to 95 patients who were mechanically ventilated. VAP was detected in 27 (28.4%) of these patients. There was a significant difference in the detection of VAP between the two groups that underwent OESS and CESS ($P = 0.045$)(Table 1)

Patient characteristics such as age, gender, and APACHE II scores at the time of mechanical ventilation were evaluated. The results of the two groups were compared. There was no significant difference between the two groups in terms of patient characteristics (Table 2).

Table 1. Comparison of the incidence of ventilation-associated pneumonia between patient groups applied open endotracheal suction system and closed endotracheal suction system

	Open Endotracheal Suction System	Closed Endotracheal Suction System	<i>P</i>
Age median(IQR)	74.5 (60.5-81.75)	70 (55-79)	.148
Gender			.290
Female n(%)	18 (39.1%)	14 (51.9%)	
Male n(%)	28 (60.9%)	13 (48.1%)	
APACHE II mean (SD)	23.78 (5,1)	25.67 (6.31)	.129

Table 2. Comparison of patient characteristics between patient groups diagnosed with ventilator-associated pneumonia

	Open Endotracheal Suction System	Closed Endotracheal Suction System	<i>P</i>
Age median(IQR)	74.5 (60.5-81.75)	70 (55-79)	.148
Gender			.290
Female n(%)	18 (39.1%)	14 (51.9%)	
Male n(%)	28 (60.9%)	13 (48.1%)	
APACHE II mean (SD)	23.78 (5,1)	25.67 (6.31)	.129

APACHE II: Chronic Health Evaluation II scores

SD: Standard deviation

IQR: Inter Quantile Range

The two groups of patients who were diagnosed with VAP and underwent OESS or CESS were evaluated according to the stay in the intensive care unit, the duration of the mechanical ventilation treatment, and the mortality status, and the two groups were compared. There was no significant difference between the two groups in terms of the stay in the intensive care unit, the duration of mechanical ventilation treatment, or the mortality status (Table 3).

Microorganisms grown in endotracheal aspirate cultures from patients diagnosed with VAP were recorded. *Acinetobacter baumannii* was the most isolated in both groups. It was isolated in 31 (67.4%) patients in the OESS group and 13 (48.2%) patients in the CESS group. The two groups were compared in terms of microorganism distribution as *Acinetobacter baumannii* and the others (Table 4).

The most important causes of pneumonia in patients receiving mechanical ventilation are contamination of the lower respiratory tract from the pharynx and intestine through the endotracheal tube cuff or direct cross-contamination from nurses and other healthcare professionals.[14] Theoretically, CESS should reduce the incidence of VAP because it minimizes personnel-related contamination and prevents open contact of the endotracheal tube, which creates a direct passageway between the lower respiratory tract and the environment. However, there are notably different results in the literature regarding the effects of the OESS and the CESS on VAP. [1, 15, 16]

Ardehalli et al. reported that the ES type had no effect on the incidence of VAP.[17] Similarly, a prospective study with relatively high participation of patients from four centers revealed that the type of ES did not affect gram-negative bacteria grown in endotracheal aspirate cultures.[18] Based on the theory that the ES type can change the incidence of VAP in different age groups, this difference could not be demonstrated in another study conducted in pediatric intensive care patients.[19] Meta-analysis studies were also conducted because strong assessments could not be formed from the number of patient groups receiving mechanical ventilation therapy at the centers between certain dates. In their systematic review, which included 16 clinical studies, Subirana et al. concluded that the incidence of VAP did not change with these two systems.[20] There are additional meta-analyses supporting that study.[21, 22] Contrary to expectations, there are studies showing that CESS does not change VAP frequency and studies reporting a higher incidence of VAP in patients who underwent OESS.[17, 23] In a prospective randomized study of 200 patients, David et al. found that CESS significantly reduced the incidence of VAP, as the authors expected.[24] In a study conducted on a specific group of patients, the authors found that CESS in head trauma patients minimized the contamination of the patients' lower airways, thus reducing the incidence of VAP.[25] Furthermore, Sanaie et al. reported that OESS increased the

frequency of VAP in their meta-analysis, which included 10 studies, and they recommend the use of CESS in intensive care units, if possible.[26] Our study supports these results.

Table 3. Comparison of hospital stay, mechanical ventilation duration and mortality rate between between patient groups diagnosed with ventilator-associated pneumonia

	Open Endotracheal Suction System median(IQR)	Closed Endotracheal Suction System median(IQR)	<i>P</i>
Length of Hospital Stay	31 (12.75-50.5)	34 (16-84)	.192
Length of Mechanical Ventilation	24 (12-49.75)	33 (13-80)	.293
Mortality n(%)	22 (47.8%)	12 (44.4%)	.524

IQR: Inter Quantile Range

Table 4. Comparison of microorganisms distribution between between patient groups diagnosed with ventilator-associated pneumonia

	Open Endotracheal Suction System n(%)	Closed Endotracheal Suction System n(%)	<i>P</i>
Acinetobacter species	31 (67.4%)	13 (48.2%)	.169
Others			
E. Coli	2 (4.3%)	2 (7.4%)	
Klebsiella spp.	8 (17.4%)	5 (18.5%)	
Pseudomonas spp.	3 (6.6%)	5 (18.5%)	
Staphylococcus aureus	2 (4.3%)	0	
Serratia marcescens	0	2 (7.4%)	

The varying results and interpretations in the literature can be attributed to several factors. One of these may be healthcare professionals, who are a significant cause of contamination in intensive care. The educational backgrounds of nurses, especially aspirants, may differ across clinics. There may be nurses with insufficient knowledge of the principles of CESS practice.[17] In addition, preexisting lower respiratory tract diseases in patients, insufficient or small sample sizes, and inappropriate inclusion or exclusion criteria in study design may result in different findings. The authors of other studies attributed the inconsistent results to several factors: the VAP diagnosis criteria differed across the studies; the studies were composed of patients in different intensive care units (surgical, medical, neurosurgical, and trauma); the patient groups were not homogeneous in terms of underlying diseases; it was not known whether the CESS system was changed, even though companies recommended it; and the empirical treatments were not known.[17, 26, 27] Since the advantage of the CESS in VAP development has not been clearly demonstrated, its use is not yet recommended for VAP. However, some guidelines recommend CESS use for cost and safety reasons.[12, 28, 29]

During OESS use, a short-term hypoxia is expected, and vital values will deteriorate due to the patient's disconnection from the mechanical ventilator. Additionally, the intensive care unit stay, the MV duration, and the mortality rates are expected to be negatively affected due to the possible increase in the frequency of VAP and vital changes. However, no significant results could be found in the literature to demonstrate the clear superiority of CESS in this regard. Sayed et al. reported no difference in mortality rates, although they observed that the vitals were more impaired in patients who underwent OESS in their study.[30] Furthermore,

Combes et al., Topeli et al., Ozcan et al., and Hamishkar et al. found that the MV duration and mortality rates of the two systems were similar in their respective studies.[15, 16, 31, 32] In addition, two studies, one of which was a meta-analysis, showed that the two systems had no impact on the length of stay in intensive care nor the mortality rate.[17, 26]

Acinetobacter baumannii was found to be the most common agent isolated in endotracheal aspirate cultures from patients diagnosed with VAP in our study. Ardehali et al. and Dey et al. also reported *Acinetobacter* species (72.7% and 48.9%, respectively) as the most common causative agent.[17, 33] In other studies, *Acinetobacter* species may be far behind in terms of incidence.[34-36] Different microbiota in hospitals, the faster spread of some bacterial species, and different methods of sample collection for microbiological testing may produce different microbiological results.

There were several important limitations to our study. The most important of these is that the study included biases arising from its retrospective nature. In addition, because it is a single-center study, it does not include the high number of patients found in most other studies. The study design did not include patients' reasons for admission to the intensive care unit, their additional comorbidities, nor their reasons for receiving MV therapy. These factors can affect patient mortality rates. By examining the changes in patients' vital signs, the effect of the ES type on vital signs could also be evaluated.

4. CONCLUSION

Our results showed that the CESS decreased the incidence of VAP, but neither system is superior at reducing mortality rates and the duration of treatment. Selection can be made considering intensive care conditions, the individual patient's disease, and cost. To obtain stronger conclusions, we recommend high-quality prospective and multicenter trials with a larger sample size.

ETHICAL APPROVAL

All authors hereby declare that all experiments have been examined and approved by ethics committee of Van Research and Training Hospital on 10/09/2020 (Approval Number: 2020/18) and have therefore been performed in accordance with the ethical standards laid down in the 1964 Declaration of Helsinki.

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