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 (ES) is used to clean the airways of secretions in patients under mechanical ventilation (MV). The objective of this study was to compare the effects of an open endotracheal suction system (OESS) versus a closed endotracheal suction system (CESS) on the incidence of ventilator-associated pneumonia (VAP).
Study Design: 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 December2019.
Methodology: Age, gender, and length of stay in the intensive care unit and under mechanical ventilation (MV), mortality and isolated microorganism status of 73 (35.6%) patients with VAP were analyzed retrospectively. These features were compared according to the ES type applied. Sample: The study was conducted among 205 patients who were connected to a mechanical ventilator for more than 48 h in the reanimation intensive care unit (RICU) of a tertiary care hospital.
Results: There was no difference between OESS and CESS groups in terms of mortality rates, length of stay in the RICU, and duration of MV. There was a significant difference in terms of incidence of VAP between the OESS group and the CESS group (41.8% and 29%, respectively; *P* = .045) *Acinetobacter baumanii* was the most frequently isolated microorganism in both groups.
Conclusion: CESS treatment was associated with a lower incidence of VAP in patients of the RICU.

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

1. INTRODUCTION (ARIAL, BOLD, 11 FONT, LEFT ALIGNED, CAPS)

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 MV 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 its 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 an 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 a CESS, an additional instrument is utilized to insert the suction catheter through the endotracheal tube without disconnecting the patient from MV. This approach is aimed at preventing hypoxia, minimizing loss in lung volume, and reducing 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 an OESS to a CESS.

2. MATERIAL AND METHODS

The study was conducted using retrospective data analysis from patients in a 20-bed reanimation intensive care unit (RICU) of a tertiary hospital.

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 203 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 a CESS in February 2019, 110 patients connected to MV underwent OESS treatment. CESS treatment was applied to 93 patients after the transition.

During the ES, nurses routinely implemented barrier precautions, including handwashing and the use of gloves and masks. In the 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. A system manufactured by TUORen, MedNet, China, was selected for endotracheal aspiration in the 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, in addition to at least

two of the microbiological and clinical criteria (body temperature > 38 °C or < 36 °C; white blood cell count > 10,000 mm3 or < 5,000 mm3; 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 underwent MV and were 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 (percentages), and continuous variables are represented as a mean ± standard deviation (SD) for normal scattering data and a median (interquartile range, IQR) for normal nonscattering data. For the categorical variables, the statistical difference among the groups was determined using chi-square tests. For the continuous variables, the statistical difference among the groups was determined using the Mann–Whitney U test. Statistical significance was accepted as $p < 0.05$. RStudio version 3.6.3 was employed for the statistical analysis of research data.

3. RESULTS AND DISCUSSION

A total of 203 patients were mechanically ventilated in the RICU between January 2018 and December 2019.

An 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, a CESS was applied to 93 patients who were mechanically ventilated. VAP was detected in 27 (29%) of these patients. There was a significant difference in the detection of VAP between the two groups that underwent OESS and CESS treatment ($P = 0.045$) (Table 1).

Patient characteristics such as age, gender, and APACHE II scores at the time of MV 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 VAP between patient groups that underwent by OESS and CESS treatment

Ventilator Associated Pneumonia	OESS n(%)	CESS n(%)	*P*
Yes	46 (41.8%)	27 (28.4%)	.045
No	64 (58.2%)	68 (71.6%)	

Total	110 (100%)	95 (100%)

Table 2. Comparison of patient characteristics between patient groups diagnosed with VAP

	Open Endotracheal Suction System	Closed Endotracheal Suction System	*P*
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:I nter Quantile Range

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

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

The most important causes of pneumonia in patients receiving MV 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 treatment 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 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 a 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 MV 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] In contrast to expectations, some studies show that CESS does not change VAP frequency, whereas some studies report a higher incidence of VAP in patients who underwent OESS treatment.[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 recommend the use of CESS in intensive care units, if possible.[26] Our study supports these results.

Table 3. Comparison of hospital stay, MV duration, and mortality rate between the patient groups diagnosed with VAP

	Open Endotracheal Suction System median(IQR)	Closed Endotracheal Suction System median(IQR)	*P*
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:I nter Quantile Range

Table 4. Comparison of microorganism distribution between patient groups diagnosed with VAP

	Open Endotracheal Suction System n(%)	Closed Endotracheal Suction System n(%)	*P*
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 factors may be healthcare professionals, who are a significant cause of contamination in intensive care units. 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 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, MV duration, and mortality rates are expected to be negatively affected due to the possible increase in the frequency of VAP and changes in vital signs. However, no significant results could be found in the literature to demonstrate the distinct superiority of CESS in this regard. Sayed et al. reported no difference in mortality rates, although they observed that vital signs were more impaired in patients who underwent OESS treatment 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 baumanii 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 Tamura et al. also reported Acinetobacter species (72.7% and 97.6%, respectively) as the most common causative agent.[17, 33] In other studies, Acinetobacter species may be lag 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 limitation 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 large 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, or their reasons for receiving MV therapy. These factors can affect patient mortality rates. By examining the changes in patients' vital signs, the effect of ES type on vital signs could also be evaluated.

4. CONCLUSION

Our results showed that CESS treatment decreased the incidence of VAP but that neither system is superior in reducing mortality rates and 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 larger sample sizes

COMPETING INTERESTS

Authors have declared that no competing interests exist.

AUTHORS' CONTRIBUTIONS

'Author A' designed the study, performed the statistical analysis, wrote the protocol, and wrote the first draft of the manuscript. 'Author B' managed the analyses of the study and the literature searches. All authors read and approved the final manuscript.

ETHICAL APPROVAL

All authors hereby declare that all experiments have been examined and approved by the 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 enacted in the 1964 Declaration of Helsinki.

REFERENCES

1. Alipour N, Manouchehrian N, Sanatkar M, Anvari HMP, Jahromi MSS. Evaluation of the effect of open and closed tracheal suction on the incidence of ventilator associated pneumonia in patients admitted in the intensive care unit. Archives of Anesthesiology and Critical Care. 2016;2(2):193-6.

2. Gadani H, Vyas A, Kar AK. A study of ventilator-associated pneumonia: Incidence, outcome, risk factors and measures to be taken for prevention. Indian journal of anaesthesia. 2010;54(6):535.

3. Vanhems P, Bénet T, Voirin N, Januel J-M, Lepape A, Allaouchiche B, et al. Early-onset ventilator-associated pneumonia incidence in intensive care units: a surveillance-based study. BMC infectious diseases. 2011;11:1-6.

4. Kózka M, Sega A, Wojnar-Gruszka K, Tarnawska A, Gniadek A. Risk factors of pneumonia associated with mechanical ventilation. International Journal of Environmental Research and Public Health. 2020;17(2):656.

5. Juneja D, Javeri Y, Singh O, Nasa P, Pandey R, Uniyal B. Comparing influence of intermittent subglottic secretions drainage with/without closed suction systems on the incidence of ventilator associated pneumonia. Indian Journal of Critical Care Medicine: Peer-reviewed, Official Publication of Indian Society of Critical Care Medicine. 2011;15(3):168.

6. Kandeel N, Tantawy N. Current nursing practice for prevention of ventilator associated pneumonia in ICUs. Life Science Journal. 2012;9(3):966-73.

7. Pagotto IM, Oliveira LRdC, Araújo FC, Carvalho NAAd, Chiavone P. Comparison between open and closed suction systems: a systematic review. Revista Brasileira de terapia intensiva. 2008;20:331-8.

8. Makhnevich A, Feldhamer KH, Kast CL, Sinvani L. Aspiration pneumonia in older adults. Journal of Hospital Medicine. 2019;14(7):429-35.

9. Coelho L, Moniz P, Guerreiro G, Póvoa P. Airway and Respiratory Devices in the Prevention of Ventilator-Associated Pneumonia. Medicina. 2023;59(2):199.

10. Jongerden IP, Rovers MM, Grypdonck MH, Bonten MJ. Open and closed endotracheal suction systems in mechanically ventilated intensive care patients: a meta-analysis. Critical care medicine. 2007;35(1):260-70.

11. Siempos I, Vardakas K, Falagas M. Closed tracheal suction systems for prevention of ventilator-associated pneumonia. British journal of anaesthesia. 2008;100(3):299-306.

12. Dodek P, Keenan S, Cook D, Heyland D, Jacka M, Hand L, et al. Evidence-based clinical practice guideline for the prevention of ventilator-associated pneumonia. Annals of Internal Medicine. 2004;141(4):305-13.

13. Society AT, America IDSo. Guidelines for the management of adults with hospital-acquired, ventilator-associated, and healthcare-associated pneumonia. American journal of respiratory and critical care medicine. 2005;171(4):388.

14. Mahmoodpoor A, Peyrovi-far A, Hamishehkar H, Bakhtyiari Z, Mirinezhad MM, Hamidi M, et al. Comparison of prophylactic effects of polyurethane cylindrical or tapered cuff and polyvinyl chloride cuff endotracheal tubes on ventilator-associated pneumonia. Acta Medica Iranica. 2013:461-6.

15. Hamishekar H, Shadvar K, Taghizadeh M, Golzari SE, Mojtahedzadeh M, Soleimanpour H, et al. Ventilator-associated pneumonia in patients admitted to intensive

care units, using open or closed endotracheal suctioning. Anesthesiology and pain medicine. 2014;4(5).

16. Topeli A, Harmanci A, Cetinkaya Y, Akdeniz S, Unal S. Comparison of the effect of closed versus open endotracheal suction systems on the development of ventilator-associated pneumonia. Journal of Hospital Infection. 2004;58(1):14-9.

17. Ardehali SH, Fatemi A, Rezaei SF, Forouzanfar MM, Zolghadr Z. The effects of open and closed suction methods on occurrence of ventilator associated pneumonia; A comparative study. Archives of academic emergency medicine. 2020;8(1).

18. Jongerden IP, Buiting AG, Leverstein-van Hall MA, Speelberg B, Zeidler S, Kesecioglu J, et al. Effect of open and closed endotracheal suctioning on cross-transmission with Gram-negative bacteria: a prospective crossover study. Critical care medicine. 2011;39(6):1313-21.

19. Morrow BM, Mowzer R, Pitcher R, Argent AC. Investigation into the effect of closed-system suctioning on the frequency of pediatric ventilator-associated pneumonia in a developing country. Pediatric Critical Care Medicine. 2012;13(1):e25-e32.

20. Subirana M, Solà I, Benito S. Closed tracheal suction systems versus open tracheal suction systems for mechanically ventilated adult patients. Anesthesia and analgesia. 2008;106(4):1326-.

21. Overend TJ, Anderson CM, Brooks D, Cicutto L, Keim M, McAuslan D, et al. Updating the evidence base for suctioning adult patients: A systematic review. Canadian respiratory journal. 2009;16:e6-e17.

22. Niel-Weise B, Snoeren R, Van den Broek P. Policies for endotracheal suctioning of patients receiving mechanical ventilation: a systematic review of randomized controlled trials. Infection Control & Hospital Epidemiology. 2007;28(5):531-6.

23. Ebrahimi Fakhar HR, Rezaie K. Effect of closed endotracheal suction on incidence of ventilator-associated pneumonia. Scientific Journal of Kurdistan University of Medical Sciences. 2010;15(2):79-87.

24. David D, Samuel P, David T, Keshava SN, Irodi A, Peter JV. An open-labelled randomized controlled trial comparing costs and clinical outcomes of open endotracheal suctioning with closed endotracheal suctioning in mechanically ventilated medical intensive care patients. Journal of critical care. 2011;26(5):482-8.

25. Alipour N, Toulabi T, Manouchehrian N, Anbari K, Rahimi Bashar F. A comparison of the effect of open and closed endotracheal suctioning on hemodynamic status of patients in the ICU. Evidence Based Care. 2014;3(4):65-74.

26. Sanaie S, Rahnemayan S, Javan S, Shadvar K, Saghaleini S-H, Mahmoodpoor A. Comparison of Closed vs Open Suction in Prevention of Ventilator-associated Pneumonia: A Systematic Review and Meta-analysis. Indian Journal of Critical Care Medicine: Peer-reviewed, Official Publication of Indian Society of Critical Care Medicine. 2022;26(7):839.

27. Mulla RJ, Mohite VR. Efficacy of closed and open endotracheal suction on prevention of ventilator-associated pneumonia on patients admitted to critical care unit at

tertiary care hospital. Journal of Datta Meghe Institute of Medical Sciences University. 2023;18(2):192-8.

28. Restrepo R, Brown J, Hughes J. AARC Clinical Practice Guidelines. Endotracheal suctioning of mechanically ventilated patients with artificial airways 2010. 2010.

29. Muscedere J, Dodek P, Keenan S, Fowler R, Cook D, Heyland D, et al. Comprehensive evidence-based clinical practice guidelines for ventilator-associated pneumonia: prevention. Journal of critical care. 2008;23(1):126-37.

30. Ahmed Sayed Z. Effect of open versus closed suction system on cardiorespiratory parameters and suction duration among critically ill mechanically ventilated patients. Egyptian Journal of Health Care. 2019;10(2):409-18.

31. Combes P, Fauvage B, Oleyer C. Nosocomial pneumonia in mechanically ventilated patients, a prospective randomised evaluation of the Stericath closed suctioning system. Intensive care medicine. 2000;26:878-82.

32. Ozcan MS, Bonett SW, Martin AD, Gabrielli A, Layon AJ, Banner MJ. Abnormally increased power of breathing as a complication of closed endotracheal suction catheter systems. Respiratory care. 2006;51(4):423-5.

33. Tamura Y, Kumamaru H, Abe K, Satoh T, Miyata H, Ogawa A, et al. Microorganisms and clinical outcomes of early-and late-onset ventilator-associated pneumonia at Srinagarind Hospital, a tertiary center in Northeastern Thailand. 2020.

34. Giamarellou H, Antoniadou A, Kanellakopoulou K. Acinetobacter baumannii: a universal threat to public health? International journal of antimicrobial agents. 2008;32(2):106-19.

35. Mishra DR, Shah DS, Shah N, Prasad JN, Gupta PP, Agrawaal KK. Study of microbiological and antibiotic sensitivity pattern of ventilator associated pneumonia (VAP) in ICU of a tertiary care hospital in Nepal. Journal of family medicine and primary care. 2020;9(12):6171.

36. Peleg AY, Seifert H, Paterson DL. Acinetobacter baumannii: emergence of a successful pathogen. Clinical microbiology reviews. 2008;21(3):538-82.