DOI: 10.14744/cm.2024.65265
Comprehensive Medicine 2024;16(3):136-141

RESEARCH ARTICLE

Clinical Evaluation of Reproducing Microorganisms and Antibiotic Susceptibility in Patients with Tracheostomy: Five-Year Study

Leyla Kazancıoğlu[1], İlkay Bahçeci[2]

[1]Department of Anesthesiology and Reanimation, Recep Tayyip Erdoğan University Faculty of Medicine, Rize, Türkiye
[2]Department of Medical Microbiology and Clinical Microbiology, Recep Tayyip Erdoğan University Faculty of Medicine, Rize, Türkiye

ABSTRACT

Objective: Tracheostomy is essential for long-term ventilator patients, but can lead to serious infections like ventilator-associated pneumonia, increasing morbidity and mortality. This study examines microorganisms in endotracheal aspirates from ICU patients with tracheostomies, assessing antibiotic susceptibility and clinical outcomes.

Materials and Methods: Endotracheal aspirate samples taken from 149 patients treated in Anesthesia and Surgical Intensive Care Units between January 15, 2017 and December 15, 2021 were included in this retrospective study. Endotracheal aspirate samples of 50 patients before tracheostomy, patients' age, gender, body mass index, admission diagnosis, length of stay in the Intensive Care Unit, Glasgow coma score, Acute Physiology and Chronic Health Evaluation II score, and risk factors for colonization were recorded.

Results: Before tracheostomy, colonization was detected in 42% of patients. The most common microorganisms were *Acinetobacter baumannii* (40.5%), *Pseudomonas aeruginosa* (19%), and others (40.5%). A total of 184 pathogens were identified. Colonization with 4 pathogens was observed in 2 patients, 3 pathogens in 8 patients, 2 pathogens in 43 patients, and a single pathogen in 72 patients. Additionally, 13 different microorganisms were isolated from endotracheal aspirate cultures, with *Acinetobacter baumannii* (38.6%), *Pseudomonas aeruginosa* (18.5%), and *Serratia marcescens* (8.1%) being the most frequent, while other microorganisms accounted for 34.8%. The overall mortality rate of patients with colonization was 60.5%, with the highest mortality observed in the group with *Acinetobacter baumannii* detected in endotracheal aspirate cultures (41.2%). This group also had a higher incidence of ischemic or hemorrhagic cerebral damage (62.3%).

Conclusion: The prevalent microorganisms in our tracheostomy patients were *Acinetobacter baumannii* and Pseudomonas aeruginosa, which were found to be 100% sensitive to colistin upon examination of their antibiotic susceptibility. The group of patients affected by *Acinetobacter baumannii* had the highest mortality rate compared to other groups, and the diagnosis of ischemic/hemorrhagic brain disease occurred in this group with the highest mortality rates. Further comprehensive studies are warranted to explore the impact of expanding tracheostomy with a ventilator on mortality in intensive care patients, and we anticipate that our research can guide the selection of targeted antibiotics.

Keywords: Antimicrobial susceptibility, mechanical ventilation, tracheostomy, ventilator associated pneumonia

How to cite this article: Kazancıoğlu L, Bahçeci İ. Clinical Evaluation of Reproducing Microorganisms and Antibiotic Susceptibility in Patients with Tracheostomy: Five-Year Study. CM 2024;16(3):136-141

INTRODUCTION

Tracheostomy applications are necessary for long-term ventilator-dependent patients in the intensive care unit (ICU). However, serious infection and colonization may occur after tracheostomy. As a result, ventilator-associated pneumonia may develop in patients.[1] This may cause increased morbidity and mortality in patients.

The length of stay in the ICU is prolonged with the increase in chronic respiratory diseases, malignancies, use of immunosuppressive agents and broad-spectrum antibiotics. It

Address for Correspondence: Leyla Kazancıoğlu, Department of Anesthesiology and Reanimation, Recep Tayyip Erdoğan University Faculty of Medicine, Rize, Türkiye
E-mail: leyla.kazancioglu@erdogan.edu.tr **ORCID ID:** 0000-0002-3833-0692

Received date: 17.04.2024
Revised date: 25.04.2024
Accepted date: 30.04.2024
Online date: 29.07.2024

causes infections caused by opportunistic pathogens to occur more frequently in ICUs.[2–4] These infections, which occur through multidrug-resistant microorganisms, require a comprehensive diagnosis. And, additional costs increase in the treatment of these infections.[5] The frequency and resistance characteristics of infectious agents in ICUs may differ even in different ICUs of the same hospital. Bacteria isolated from long-term tracheostomized patients and their antibiotic susceptibility are important for clinicians.

In this study, the microorganisms grown in the endotracheal aspirate (ETA) samples of the patients followed in the tracheostomized state in the Anesthesiology and Surgery ICU and the investigation of the antibiotic susceptibility of these microorganisms; in addition, it was aimed to evaluate the antibiotic susceptibility of microorganisms with the clinical course of the patients.

MATERIALS and METHODS

This retrospective descriptive, cross-sectional study was conducted with the approval of the Non-Invasive Clinical Research Ethics Committee (Decision no: 2021/140). ETA samples sent to the Medical Microbiology Laboratory of 149 patients who were followed up as tracheostomized in Anesthesia ICU and Surgical ICUs between 15 January 2017 and 15 December 2021 were included in the study. ETA cultures of the patients, if any, were recorded before tracheostomy. ETA cultures were taken from the tracheostomy cannula with the help of an aspiration tube. Clinical specimens were cultivated on media by counting and dilution methods. The media were incubated aerobically in an incubator at standard temperature (36±1°C) for 1–2 days. After Gram-staining, bacteria were identified by conventional microbiological methods and VITEK 2 compact automated system (BioMerieux, France). The European Committee for Antimicrobial Susceptibility Tests (EUCAST, 2017) was referenced for the evaluation of antibiotic resistance profiles of strains.

Age, gender, body mass index, hospitalization diagnosis, ICU length of stay, Glasgow coma score, Acute Physiology and Chronic Health Evaluation (APACHE) II score, and risk factors for colonization of the patients included in the study were examined and recorded. As risk factors; trauma, immunosuppressive status, use of broad-spectrum antibiotics, hemodialysis, blood transfusion, presence of neutropenia, previous abdominal surgery, nutritional status with total parenteral nutrition, and presence of invasive intervention (mechanical ventilation, central catheter, bladder catheter, surgical resistance) were investigated. Patients with a hospitalization period of fewer than seven days in the ICU, patients with a history of recurrent ICU stays in the last two months, patients younger than 18 years of age, patients with a diagnosis of fungal infection at the time of admission to the ICU, and strains detected in re-cultures of the same patient were excluded from the study.

The necessary patient consents were acquired upon their admission to the intensive care unit. The data analyzed in this retrospective study originated from cultures routinely procured from patients and subjected to bacterial growth control testing at the Medical Microbiology and Clinical Microbiology Laboratory.

Statistical Analysis

IBM SPSS v21 (SPSS Inc., Chicago, IL, USA) software was used for statistical evaluation. Categorical variables were expressed as numbers and percentages, and descriptive data for continuous variables were expressed as mean and standard deviation. Z test was used to compare the ratios.

Since the study was conducted retrospectively, a post-hoc power analysis was carried out using the G*Power 3.1.9.7 program (Heinrich Heine Universitat, Düsseldorf, Germany).[6] This analysis revealed that the sample size of 140 individuals yielded a power value of 1.0, assuming an effect size of 0.9 and a type 1 error value of 0.05.

All stages of our study were conducted in accordance with the Declaration of Helsinki.

RESULTS

The data of 202 patients who underwent percutaneous dilatational tracheostomy (PDT) in our ICUs between 2017 and 2021 were analyzed retrospectively. While the mean age of the patients was 72.5±10.2 years, 96 (64.4%) were male and 53 (35.5%) were female. A total of 149 patients had ETA cultures. The mean Acute Physiology and Chronic Health Evaluation: APACHE II scores at the time of collection of ETA cultures were 27.3±8.1 and the Glasgow Coma Score mean was 7.5±3.5. The population of the study consisted of patients who were admitted to the ICU with 33.7% from the second-line ICU, 28.8% from the emergency services and 37.5% from other services. The comorbid diseases of the patients are mostly diabetes mellitus (51.2%), hypertension (28.1%), and chronic obstructive pulmonary disease (20.7%). Mortality of all patients with growth detected in the study was found to be 60.5%. Among this group, the group with the highest mortality was *Acinetobacter Baumannii* in ETA culture (41.2%). The diagnosis of ischemic or hemorrhagic cerebral injury was higher in this group with *Acinetobacter Baumannii* (62.3%). Mean days of stay in ICU mechanical

ventilation for these patients were 57.2±31.2 days. The mean total days spent in the ICU were determined to be 62.2±15.5 days. It was determined that the tracheostomy opening time of the patients was 12.3±6.8 days compared to the day they were admitted to the ICU. PDT was applied to 37.2% of the patients in the early (≤10 days) and 62.8% of the patients in the late (>10 days) period.

ETA cultures of 50 patients were analyzed before tracheostomy. Bacterial growth was detected in 42 of them. The most common microorganisms found to reproduce were *Acinetobacter baumannii* (40.5%), *Pseudomonas aeruginosa* (19%) and others (40.5%), respectively. ETA cultures were collected from 149 patients; growth was detected in 125 of them, normal flora agents were found in 12, and contamination was found in the remaining 12. A total of 184 agents were identified. While 4 factors were determined in 2 patients, 3 agents were found in 8 patients, 2 agents were found in 43 patients, and single agent growth was found in 72 patients. In addition, 13 different microorganisms were isolated in ETA cultures. The most common microorganisms were *Acinetobacter baumannii* (38.6%), *Pseudomonas aeruginosa* (18.5%) and *Serratia marcescens* (8.1%), while 34.8% were other microorganisms (Table 1).

In terms of antibiograms, 100% of *Acinetobacter baumannii* was resistant to Ceftazidime, Levofloxacin, Meropenem, Piperacillin-Tazobactam, Piperacillin, Ciprofloxacin, Imipenem, Tigecycline. While it was resistant to Amikacin at a rate of 88.7%, to Gentamicin at a rate of 94.4%, it was 100% sensitive to Colistin. *Pseudomonas aeruginosa* was resistant to Amikacin, Ceftazidime, Levofloxacin, Meropenem, Piperacillin-Tazobactam, Piperacillin, Ciprofloxacin, Imipenem by 11.8%, 50%, 44.1%, 47.1%, 57.6%, 58.8%, %32.4 and %44.1 respectively. However, it was 100% sensitive to Colistin. Antibiotic resistances of other microorganisms are listed in Table 2.

Table 1. Isolated bacterias

Bacteria	Frequency	Ratio (%)
Pseudomonas Aeruginosa	34	18.48
Acinetobacter Baumannii	71	38.59
Stenotrophomonas Maltophilia	4	2.17
Klebsiella Oxytoca	3	1.63
Burkholderia Cepacia	13	7.07
Serratia Marcescens	15	8.15
Staphylococcus Aureus	10	5.43
E. Coli	9	4.89
Klebsiella Pneumonia	11	5.98
Proteus spp.	3	1.63
Candida Albicans	2	1.09
Enterobacter spp.	8	4.35
Haemophilus influenzae	1	0.54
Total	184	100.00

DISCUSSION

The most commonly grown microorganisms in ETA cultures were *Acinetobacter baumanii* (38.6%), *Pseudomonas aeruginosa* (18.5%) and *Serratia marcescens* (8.1%). It was determined that *Acinetobacter baumanii* and *Pseudomonas aeruginosa* were 100 % sensitive to colistin but highly resistant to other antibiotics. Mortality was highest in the patient group

Table 2. Antibiotic resistance rates in gram-negative bacteria (%)

Antibiotic	*Acinetobacter Baumannii* (n=71)	*Pseudomonas Aeruginosa* (n=34)	*Serratia Marcescens* (n=15)	*E. Coli (n=9)*	*Klebsiella Pneumonia* (n=11)	*Enterobacter spp.* (n=8)
Amikacin	88.7	11.8	0	0	7.1	0
Ceftazidime	100	50	13.3	33.3	64.3	50
Cefepime	–	39.4	0	33.3	50	25
Gentamicin	94.4	32.4	0	0	7.1	0
Colistin	0	0		0	7.1	0
Levofloxacin	100	44.1	0	44.4	57.1	0
Meropenem	100	47.1	0	0	21.4	0
Piperacillin-Tazobactam	100	57.6	–	33.3	64.3	37.5
Ciprofloxacin	100	32.4	0	44.4	57.1	12.5
Imipenem	100	44.1	7.1	0	14.3	0
Tigecycline	8.5	–	–	–	–	–

caused by *Acinetobacter baumanni* compared to the groups with other factors. There was a diagnosis of ischemic/hemorrhagic cerebral injury hospitalization in this patient group. The causative microorganisms of patients with tracheostomy are examined in ICUs. Cader et al.[7] conducted a study in order to determine the bacterial species colonizing the tracheostomy tube, antibiotic susceptibility and resistance in patients with tracheostomy. The most common microorganism isolated from the tracheostomy tube in the study was *Pseudomonas aeruginosa*. Bacteria were most resistant to ciprofloxacin, while most bacteria were susceptible to imipenem and piperacillin-tazobactam. Acharya et al.[8] collected tracheal swab samples from 30 adult tracheostomized patients and reported that these samples were heavily colonized by *Pseudomonas aeruginosa*, *Acinetobacter anitratus*, and *Staphylococcus aureus*. A study evaluating 20 patients under 18 who were tracheostomized patients reported that 90 % of the patients had a positive microbiological culture and the most common microorganisms were *Pseudomonas aeruginosa* (55.5%) and *Staphylococcus aureus* (27.7%). It was also concluded that routine access to tracheal secretion cultures by Brazilian children and adolescents may help guide antibiotic use.[9] Another study evaluated tracheostomy-dependent pediatric patients with a positive respiratory culture for *Stenotrophomonas maltophilia*. The patients were divided into 2 groups those who received antibiotic treatment for this agent and those who did not. However, there was no significant difference in terms of hospital stay in both groups.[10] In our study, the most commonly grown microorganisms in the tracheal aspirates of our patients with tracheostomy were *Acinetobacter baumanii*, *Pseudomonas aeruginosa* and *Serratia marcescens*. In patients with tracheostomy who stay in ICUs for a long time, more appropriate antibiotics can be preferred by evaluating the reproducing factors. Length of hospital stay and mortality rates can be reduced. In addition, tracheal swab aspirates of our patients can be taken to determine the profile of microorganisms that may be causative. Ultimately, this agent profile may contribute to the selection of appropriate antibiotics.

Tracheostomy is a surgical procedure that is generally performed in ICUs to avoid complications of prolonged mechanical ventilation. It has advantages such as easy removal of tracheobronchial secretions, facilitating weaning from the mechanical ventilator, and early oral feeding.[11,12] However, ventilator-associated pneumonia (VAP) (hospital-acquired pneumonia without pneumonia during intubation but occurring 48 hours after endotracheal intubation) is an important cause of morbidity and mortality in ICUs.[13,14] The effect of tracheostomy time on the development of VAP remains unclear. While there are studies suggesting that it may increase the development of VAP.[15,16] there are also studies stating the opposite.[17,18] In our study, the mortality rate was highest in the patient group in which *Acinetobacter baumanni*n was the causative agent, compared to the groups with other causative agents. There was a diagnosis of ischemic/hemorrhagic cerebral injury hospitalization in this patient group.

The incidence of VAP in patients with tracheostomy in ICUs is reported to be between 6% and 26%.[13] Studies have shown that the time between tracheostomy and VAP formation differs from each other. According to the research carried out by Nseir et al.,[19] which involved 177 individuals, tracheostomy was executed on 72% (128/177) of the patients after 7 days of commencing mechanical ventilation (MV). 178 VAP episodes were observed in 124 patients (84% of which were late-onset VAP). VAP occurred in 69 patients after tracheostomy was opened. In this study, neurological disorders and antibiotic use during the stay in the intensive care unit were found to be independent risk factors that increase VAP.

In addition, it has been reported that tracheostomy is an independent risk factor that reduces the risk of VAP. On the other hand, Kim et al.[20] investigated the effects of early and late tracheostomy in patients undergoing decompressive surgery and reported that early tracheostomy in patients with severe brain injury reduced the recommended antibiotic dose for the treatment of VAP. In a prospective study in which 62 patients with severe head trauma were divided into 2 groups early tracheostomy and prolonged endotracheal intubation, no difference was found between pneumonia and mortality rates.[21] Perez-Losada et al.[22] prospectively collected 127 tracheal aspirates from 20 acute respiratory tract infections and 20 healthy patients at four consecutive times to compare the diversity and temporal dynamics of microbiota sampled directly from the trachea via tracheostomy in patients with and without lower respiratory tract infection. They found that the structure of the tracheal microbiota and the normalized distribution of *Haemophilus, Pseudomonas, Corynebacterium*, and *Acinetobacter* differed significantly depending on whether individuals developed lower respiratory tract infections. They also showed that the tracheal microbiota diversity did not change significantly during the meteorological seasons. Yıldırım et al.[23] stated that despite the known advantages of tracheostomy applications, the risk and timing of VAP are still controversial today. However, they reported that early tracheostomy is recommended for patients who are expected to be intubated for more than 2 weeks. Microorganisms grown in ETAs of our patients before and after

tracheostomy were similar. Many predisposing factors, such as the differences in tracheostomy application times and the length of stay in MV for patients with high co-morbidity, may be effective in this result. In addition, as a result of our study, we would like to state that tracheostomy applications did not cause any improvement in infection rates.

The microorganisms responsible for causing infections can vary depending on factors such as the patient population in ICUs, the duration of their stay in the ICU, and comorbid diseases. It was reported that the most frequently detected microorganisms were *Pseudomonas aeruginosa, Staphylococcus aureus, Enterobacteriaceae* and *Acinetobacter baumanii* in our country.[24] In a study in which a tracheostomy-associated *Acinetobacter baumannii* outbreak was reported, it was stated that a procedure such as tracheostomy, which aims to reduce the risk of nosocomial infection, may predispose to infection due to non-compliance with basic infection control practices.[25] In a study investigating bacterial biofilms in tracheostomy tubes, biofilm positivity was reported in 57% of the isolates, while in other studies more than 60% bacterial biofilm formation was found at similar rates.[26] On the other hand, there are studies reporting that biofilm formation rates are 73%, 90% and 95% in medical prostheses.[27–30] Raveendra et al.[31] stated that they identified *Acinetobacter baumannii* (45%) as the most common biofilm-forming organism. Likewise, Gil-Perotin et al.[30] reported that most of the bacteria isolated in their study were *Acinetobacter baumannii* and *Pseudomonas aeruginosa*. They have commonly isolated these agents from tracheostomy tubes and ventilator filters. Of these microorganisms, *Acinetobacter baumannii* was the most common multidrug-resistant organism and was susceptible to carbapenem and colistin. Pseudomonas aureginosa was sensitive to imipenem and amikacin[32–34] Consistent with the literature, the most common reproducing agent in our study was *Acinetobacter baumannii*. It was only sensitive to colistin. Regional differences, factors in ICUs with different patient populations, and antibiotic resistance mechanisms should be considered. The lack of personnel in ICUs and the inadequate implementation of the recommendations of the infection control committee may have caused this result.

We have the capability to diagnose VAP by utilizing the Clinical Pulmonary Infection Score in our patients who have shown signs of growth. Additionally, we have the ability to detect the microorganisms that are responsible for causing VAP. Moreover, we can conduct research to examine the correlation between the timing of tracheostomy (early or late) and VAP occurrence in our patients.

CONCLUSION

The most commonly grown microorganisms in our patients with tracheostomy were *Acinetobacter baumannii* and *Pseudomonas aeruginosa*. These agents, whose antibiotic susceptibilities were examined, were found to be 100% sensitive to colistin. Mortality was highest in the patient group in which *Acinetobacter baumannii* was the causative agent, compared to the groups with other causative agents. There was a diagnosis of ischemic/hemorrhagic cerebral injury hospitalization in this patient group. However, more comprehensive studies can be conducted to investigate the effects of tracheostomy on VAP and mortality in intensive care patients. We believe that our study can be a guide for the selection of targeted antibiotics.

Disclosures

Ethics Committee Approval: The study was approved by the Recep Tayyip Erdogan University Faculty of Medicine Non-Interventional Clinical Research Ethics Committee (No: 2021/140, Date: 17/08/2021).

Authorship Contributions: Concept: L.K., İ.B.; Design: L.K., İ.B.; Supervision: L.K., İ.B.; Funding: L.K., İ.B.; Materials: L.K., İ.B.; Data Collection or Processing: L.K., İ.B.; Analysis or Interpretation: L.K., İ.B.; Literature Search: L.K., İ.B.; Writing: L.K., İ.B.; Critical review: L.K., İ.B.

Conflict of Interest: No conflict of interest was declared by the authors.

Informed Consent: Written informed consent was obtained from all patients.

Use of AI for Writing Assistance: Not declared.

Financial Disclosure: The authors declared that this study received no financial support.

Peer-review: Externally peer reviewed.

REFERENCES

1. Turković, TM, Obraz M, Zlatić Glogoški M, Juranić I, Bodulica B, Kovačić J. Incidence, etiology and outcome of ventilator-associated pneumonia in patients with percutaneous tracheotomy. Acta Clinica Croatica 2017;56:99–109. [CrossRef]
2. Bahçeci İ, Kostakoğlu U, Duran ÖF, Yıldız İE, Dilek AZ. Distribution and antimicrobial susceptibilities of *stenotrophomonas maltophilia* strains isolated from various clinical samples: an 8-year study. Dicle Med J [Article in Turkish] 2021;48:147–52. [CrossRef]
3. Batçık Ş, Bahçeci İ, Kazancıoğlu L, Kazdal H, Özcan M. Candida species and antifungal susceptibility isolated in intensive care units: a three-year study. Van Med J [Article in Turkish] 2021;28:459–65. [CrossRef]
4. Şanlı K, Kömürcü SZM, Şahin AS. Investigation of candida epidemiology and antifungal resistance change in intensive care unit patients produced in blood cultures, 2015-2019. Dicle Med J [Article in Turkish] 2021;48:796–805. [CrossRef]

5. Núñez SA, Roveda G, Zárate MS, Emmerich M, Verón MT. Ventilator-associated pneumonia in patients on prolonged mechanical ventilation: description, risk factors for mortality, and performance of the SOFA score. J Bras Pneumol 2021;47:e20200569. [CrossRef]
6. Faul F, Erdfelder E, Lang AG, BUchner A. G*Power 3: a flexible statistical power analysis program for the social, behavioral, and biomedical sciences. Behav Res Methods 2007;39:175–91. [CrossRef]
7. Cader SHA, Shah FA, Nair SKGR. Tracheostomy colonisation and microbiological isolates of patients in intensive care units-a retrospective study. World J Otorhinolaryngol Head Neck Surg 2020;6:49–52. [CrossRef]
8. Acharya R, Wakode PT, Bhandary S, Khanal B, Khatiwada S. Colonization and infection in tracheostomized patients at tertiary care hospital in Eastern Nepal. Health Renaissance 2014;12:68–73. [CrossRef]
9. Cheikh MRE, Barbosa JM, Caixêta JA, Avelino MA. Microbiology of tracheal secretions: what to expect with children and adolescents with tracheostomies. Int Arch Otorhinolaryngol 2018;22:50–4. [CrossRef]
10. Tillman EM, Firmani SE, Ackerman VL, Slaven JE, Cristea AI. Evaluation of the treatment of *stenotrophomonas maltophilia* in tracheostomy-dependent pediatric patients. J Pediatr Pharmacol Ther 2019;24:510–6. [CrossRef]
11. Batçık Ş, Koyuncu T. Percutaneous dilatational tracheostomy applications in our intensive care units: a 10-year retrospective study. J Cardiovasc Thorac Anaest Intensive Care Society 2022;28:158–63. [CrossRef]
12. Kaya C, Köksal E, Üstün FE. Tracheostomy in the practice of anesthesia and intensive care. J Harran University Med Fac [Article in Turkish] 2014;11:172–83.
13. Nair GB, Niederman MS. Ventilator-associated pneumonia: present understanding and ongoing debates. Intensive Care Med 2015;41:34–48. [CrossRef]
14. Lewis SC, Li L, Murphy MV, Klompas M; CDC Prevention Epicenters. Risk factors for ventilator-associated events: a case-control multivariable analysis. Crit Care Med 2014;42:1839–48. [CrossRef]
15. Veelo DP, Binnekade JM, Schultz MJ. Tracheostomy-causative or preventive for ventilator-associated pneumonia? Curr Respir Med Rev 2010;6:52–7. [CrossRef]
16. Zheng Y, Sui F, Chen XK, Zhang GC, Wang XW, Zhao S, et al. Early versus late percutaneous dilational tracheostomy in critically ill patients anticipated requiring prolonged mechanical ventilation. Chin Med J 2012;125:1925–30.
17. Turković TM, Lukić A, Perić M. Early versus late percutaneous tracheotomy in ciritically ill patients: a retrospective single center observational study. Acta Clin Croat 2016;55(Suppl 1):33–40. [CrossRef]
18. Wang F, Wu Y, Bo L, Lou J, Zhu J, Chen F, et al. The timing of tracheotomy in critically ill patients undergoing mechanical ventilation: a systematic review and meta-analysis of randomized controlled trials. Chest 2011;140:1456–65. [CrossRef]
19. Nseir S, Di Pompeo C, Jozefowicz E, Cavestri B, Brisson H, Nyunga M, et al. Relationship between tracheotomy and ventilator-associated pneumonia: a case control study. Eur Respir J 2007;30:314–20. [CrossRef]
20. Kim TH, Kim HS, Yang SH, Kim IS, Hong JT, Sung JH, et al. Early and late tracheostomy after decompressive craniectomy for Severe Traumatic Brain Injury. J Korean Neurotraumatol Society 2009;5:89–92. [CrossRef]
21. Bouderka MA, Fakhir B, Bouaggad A, Hmamouchi B, Hamoudi D, Harti A. Early tracheostomy versus prolonged endotracheal intubation in severe head injury. J Trauma 2004;57:251–4. [CrossRef]
22. Perez-Losada M, Graham RJ, Coquillette M, Jafarey A, Castro-Nallar E, Aira M, et al. The temporal dynamics of the tracheal microbiome in tracheostomised patients with and without lower respiratory infections. PLoS One 2017;12:e0182520. [CrossRef]
23. Yıldırım F, Tahir E. Relationship between tracheostomy and ventilator-associated pneumonia in intensive care. Yoğun Bakım Derg [Article in Turkish] 2017;8:19–24. [CrossRef]
24. Savaş L, Onlen Y, Duran N, Savaş N. Causes of nosocomial pneumonia and evaluation of risk factors in a university hospital in Turkey. Saudi Med J 2007;28:114–20.
25. Mah MW, Memish ZA, Cunningham G, Bannatyne RM. Outbreak of *Acinetobacter baumannii* in an intensive care unit associated with tracheostomy. Am J Infect Control 2001;29:284–8. [CrossRef]
26. Treter J, Macedo AJ. Catheters: a suitable surface for biofilm formation. In: Méndez-Vilas A, ed. Science Against Microbial Pathogens: Communicating Current Research and Technological Advances. FORMATEX Microbiology Series Nº 3 Vol. 1. Badajoz, Spain: FORMATEX; 2011. p. 835–42.
27. Donlan RM, Costerton JW. Biofilms: survival mechanisms of clinically relevant microorganisms. Clinic Microbio Rev 2002;15:167–93. [CrossRef]
28. Solomon DH, Wobb J, Buttaro BA, Truant A, Soliman AM. Characterization of bacterial biofilms on tracheostomy tubes. Laryngoscope 2009;119:1633–8. [CrossRef]
29. Inglis TJ, Millar MR, Jones JG, Robinson DA Tracheal tube biofilm as a source of bacterial colonization of the lung. J Clinic Microbiol 1989;27:2014–8. [CrossRef]
30. Gil-Perotin S, Ramirez P, Marti V, Sahuquillo JM, Gonzalez E, Calleja I, et al. Implications of endotracheal tube biofilm in ventilator-associated pneumonia response: a state of concept. Crit Care 2012;16:R93. [CrossRef]
31. Raveendra N, Rathnakara SH, Haswani N, Subramaniam V. Bacterial biofilms on tracheostomy tubes. Indian J Otolaryngol Head Neck Surg 2022;74(Suppl 3):4995–9. [CrossRef]
32. Mahendra M, Jayaraj BS, Lokesh KS, Chaya SK, Veerapaneni VV, Limaye S, et al. Antibiotic prescription, organisms and its resistance pattern in patients admitted to respiratory ICU with respiratory infection in Mysuru. Indian J Critic Care Med 2018;22:223–230. [CrossRef]
33. Radji M, Fauziah S, Aribinuko N. Antibiotic sensitivity pattern of bacterial pathogens in the intensive care unit of Fatmawati Hospital, Indonesia. Asian Pac J Trop Biomed 2011;1:39–42. [CrossRef]
34. Arslan K, Şahin AS. Clinical characteristics, antibiotic resistance profiles, and factors affecting mortality in patients isolated *Acinetobacter baumannii* in intensive care unit: retrospective tertiary center analysis. CM 2024;16:51–7. [CrossRef]