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The effect of prolonged intubation on ventilator associated pneumonia: endotracheal tube cuff is really steril or not?

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ABSTRACT

Aims: Endotracheal tube (ETT) design, size, cuff material, cuff pressure and intubation duration are critical in preventing nosocomial pneumonia. We aimed to evaluate the possible infection focus potential of ETT cuff and pilot balloon, particularly in prolonged intubated patients.

Methods: A total number of 66 patients who underwent orotracheal intubation and received conventional mechanical ventilation more than 48 hours in the intensive care unit (ICU), were included in this prospective cohort study.

Results: The mean duration of intubation was 10.36±4.82 days. Bacteriologically confirmed positive tracheal aspirate culture was 18.2% (n=12). The most frequent positive culture was detected inside of ETT lumen with a percentage of 83.3% (n=55) and followed by cuff (27.3%, n=18), pilot balloon (13.6%, n=9), respectively. It was documented that rates of lung infections were significantly increased after 14 days (p=0.017) and rates of cuff positive cultures were significantly increased after 10 and 14 days of incubation (p= 0.001, p=0.004). The same type of bacteriological strains was identified from both pilot balloon (n=9) and ETT cuff (n=9), simultaneously. In the remaining 9-cuff positive patients pilot balloons were sterile and ETT lumens were positive culture with the same strains as identified from the cuff. There was a statistically significant positive correlation between the intubation duration and the number of infected ETT parts (p<0.001).

Conclusion: ETT cuff was demonstrated to be a potential infection focus in the present study. In addition, it was observed that ETT cuff colonization increased in proportion to the intubation duration. We suggest changing ETT at appropriate time intervals in order to reduce ventilator-associated pneumonia in intubated patients.

Keywords: Endotracheal tube, patient care, critical care, ventilator associated pneumonia

INTRODUCTION

Nosocomial infections are a global problem that significantly increases mortality, hospital stay, labor loss, antimicrobial resistance, antibiotic consumption and hospitalization costs. According to World Health Organization (WHO) reports, approximately 15% of inpatients are affected by these infections.[1] More than half of nosocomial infections are associated with intensive care units (ICUs). In addition, ventilator-associated pneumonia (VAP) is the most common cause of the ICU originated nosocomial infections (60%) ve nosocomial pneumonia (86%). VAP typically affects 9-27% of patients under mechanical ventilation for at least 48 hours.[2]

Microaspiration of subglottic and oropharyngeal secretions plays a prominent role in the pathophysiology of VAP by causing bacterial translocation.[3] The tracheal cuff is critical in preventing the progression of infection to the lower respiratory tract. Bacterial colonization begins within a few hours of intubation and contaminated subglottic secretions accumulate on the surface of the endotracheal tube (ETT) cuff.[4] To confirm VAP and initiate appropriate antimicrobial therapy, examination of respiratory tract specimens with culture and antibiogram should be performed as soon as possible. Although many bacteriological methods are still controversial based on distinguishing between colonization and infection, tracheal aspirate culture (TAC) and ETT culture is the most used ones.[5]

ETT design, size, cuff material, cuff pressure and intubation duration are critical in preventing intubation-related infections.[6] Therefore, we aimed to evaluate the possible infection focus potential of the ETT cuff and pilot balloon, which are expected to be sterile, particularly in prolonged intubated patients.

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METHODS

This prospective cohort study was performed with the approval of the Samsun Ondokuz Mayıs University Clinical Researches Ethics Committee (Date: 29.05.2019, Decision No: 2019/191), department of intensive care, between May 2020 - October 2020. A total number of 66 patients (aged between 18-80 years old) who underwent orotracheal intubation and received conventional mechanical ventilation more than 48 hours in the ICU unit, were included in this prospective study. Patients with any possible immunodeficiency status (oncology patients receiving radio-chemotherapy, HIV positivity, immunosuppressed treatment), pregnant patients, patients with a history of neck surgery restricting neck movement were excluded from our study. All procedures were carried out in accordance with the ethical rules and the principles of the Declaration of Helsinki.

ETTs (Bıçakçılar™ medical devices, Istanbul, Turkey) obtained during tracheotomy and transported to the microbiology laboratory. Duration of mechanical ventilation and presence of lung infection was recorded in all patients. Bacteriological data obtained from tracheal aspirate culture (TAC), as well as culture from the inside of ETT lumen, cuff and pilot balloon sections, were evaluated in association with intubation duration.

Microbiological Methods

Tracheal aspirate samples were obtained during endotracheal intubation and ETT samples were obtained immediately after extubation under sterile conditions. Each ETT was cut separately from the lumen, cuff and pilot balloon sections, subsequently inserted into sterile tubes in the microbiology laboratory. Samples were incubated into thioglycollate broth for 18 hours at 37°C and then cultures were performed using the single-colony method on eosin methylene blue (EMB), blood and chocolate agars. After incubation of the culture plates at 37°C for 24 to 48 hours, gram staining was performed from the positive cultures; colony morphology, gram staining features and shapes of the isolated bacteria were recorded. Bacteriological identification was performed using conventional microbiological methods and/or VITEC 2 Automated Identification System (Biomerieux, France).

Statistical Analysis

The data were analyzed via SPSS (Statistical Package for the Social Sciences) software (v21.0; IBM, Armonk, NY, USA). Individual and aggregate data were expressed using descriptive statistics including mean, standard deviations, medians (min-max), frequency distributions and percentages. Data distribution was screened by the Kolmogorov-Smirnov test. Normally distributed data were compared by Student T-Test and non-normal distributed data was evaluated by Mann Whitney test. Evaluation of categorical variables was performed by Chi-Square test. The presence of correlation was analyzed with Spearman's Rho tests. P-values of <0.05 were considered statistically significant.

RESULTS

The 66 orotracheally intubated patients enrolled in this study were 35 (53.0%) male and 31 (47.0%) female and the mean age of all patients was 70.64±13.46 (Ranged: 37-95) years. In addition, mean age was significantly higher in female patients (76.97±11.62) than male patients (65.03±12.59) (p<0.001). The mean duration of intubation was 10.36±4.82 (ranged=4-23) days. It was documented that 37.9% (n=25) of our sample group had a lung infection. Bacteriologically confirmed positive TAC prevalence was 18.2% (n=12); *Acinetobacter baumanni* was the most frequently isolated strain from TAC samples (6.1%), followed by Pseudomonas aeroginosa (6.1%), *Corynebacterium* spp. (4.5%) and *Haemophilus* spp. (1.5%) (**Table 1**).

Table 1. Culture results of TAC and ETT parts.

Clinical Variables	TAC n (%)	ETT Lumen n (%)	ETT Cuff n (%)	Pilot balloon n (%)
Culture result				
Negative	54 (81.8)	11 (16.7)	48 (72.7)	57 (86.4)
Positive	12 (18.2)	55 (83.3)	18 (27.3)	9 (13.6)
Identified strain				
Klebsiella pneumoniae	0 (0.0)	11 (16.7)	4 (6.1)	4 (6.1)
Acinetobacter spp.	4 (6.1)	8 (12.1)	1 (1.5)	0 (0.0)
Enterobacter aerogenes	0 (0.0)	7 (10.6)	2 (3.0)	2 (3.0)
Escherichia coli	0 (0.0)	6 (9.1)	2 (3.0)	0 (0.0)
Cornebacterium spp.	3 (4.5)	6 (9.1)	2 (3.0)	0 (0.0)
Pseudomonas aeruginosa	4 (6.1)	7 (10.6)	4 (6.1)	1 (1.5)
Enterococcus spp.	0 (0.0)	1 (1.5)	1 (1.5)	1 (1.5)
Coagulase negative *Staphylococcus*	0 (0.0)	5 (7.6)	1 (1.5)	0 (0.0)
Diphtheroid bacilli	0 (0.0)	0 (0.0)	1 (1.5)	1 (1.5)
Mixt type	0 (0.0)	4 (6.1)	0 (0.0)	0 (0.0)
Haemophilus spp.	1 (1.5)	0 (0.0)	0 (0.0)	0 (0.0)

TAC: Tracheal aspirate culture, ETT: Endotracheal tube

According to the bacteriological results of ETT parts; the most frequent positive culture was detected inside of ETT lumen with a percentage of 83.3% (n=55) and followed by cuff (27.3%, n=18), pilot balloon (13.6%, n=9), respectively. *Klebsiella pneumonia* was the most frequently isolated strain from all ETT parts (lumen 16.7%, cuff 6.1%, pilot balloon 6.1%) (**Table 1**). Moreover, it was documented that rates of lung infections were significantly increased after 14 days (p=0.017) and rates of cuff positive cultures were significantly increased after 10 and 14 days of incubation (p-values=0.001 and 0.004, respectively). It was also observed that positive culture rates inside of ETT lumen and pilot balloon were not significantly related to the intubation duration (p>0.05) (**Table 2**).

Of the patients, 37 (56.1%) had positive culture only from the inside of ETT lumen, 9 (13.6%) had positive culture from ETT lumen + cuff and 9 patients (13.6%) had positive culture from all parts of ETT (ETT lumen + cuff + pilot balloon). In addition, there was a statistically significant positive correlation between the intubation duration and a number of contaminated ETT parts (r:0.429, p< 0.001).

Table 1. Distribution of the general demographic data of the patients

Duration	TAC		p- value	ETT LUMEN		p- value	ETT Cuff		p- value	Pilot balloon		p- value
	- n (%)	+ n (%)		- n (%)	+ n (%)		- n (%)	+ n (%)		- n (%)	+ n (%)	
<10 days	24 (58.5)	9 (36.0)	.076	8 (72.7)	25 (45.5)	.099	30 (62.5)	3 (16.7)	.001*	30 (52.6)	3 (33.3)	475
>10 days	17 (41.5)	16 (64.0)		3 (27.3)	30 (54.5)		18 (37.5)	15 (83.3)		27 (47.4)	6 (66.7)	
<14 days	34 (82.9)	14 (56.0)	.017*	10 (90.9)	38 (69.1)	.131	40 (83.3)	8 (44.4)	.004*	42 (73.7)	6 (66.7)	696
>14 days	7 (17.1)	11 (44.0)		1 (9.1)	17 (30.9)		8 (16.7)	10 (55.6)		15 (26.3)	3 (33.3)	

TAC: Tracheal aspirate culture, ETT: Endotracheal tube

In the present study, it was documented that the same type of bacteriological strains was identified from both pilot balloon (n=9) and ETT cuff (n=9), simultaneously. In the remaining 9-cuff positive patients pilot balloons were sterile and ETT lumens were positive culture with the same strains as identified from the cuff.

DISCUSSION

Despite advances in mechanical ventilation and antimicrobial therapy strategies, VAP enhances the mortality rate by 5.8%.[7] The previous studies have shown that accurate, rapid and reliable bacteriological identification reduces the mortality rate. Since there are conflicting published data on the distinction between infection and colonization with TAC, it was recommended to confirm culture-antibiogram with ETT.[8] In a study conducted by McCauley et al.[9] consisting of 2011 patients diagnosed with active pneumonia, 94 of the patients were intubated and a TAC culture antibiogram was performed from 84 of them. A positive culture was reported in only 39% (n=32) of these patients. Awasthi et al.[10] documented VAP in approximately 1/3 of the 105 pediatric patients and ETT culture was positive in 19.05% (n=20) of them. In the same study, *Klebsiella* spp. and *S. aureus* were the most frequently isolated bacteriological strains. Additionally, researchers have been significantly associated VAP with mechanical ventilation over 4 days. Similarly in our study, the mean duration of intubation was 10.36±4, days. Of the patients, 37.9% (n=25) had lung infection and bacteriologically confirmed positive TAC prevalence was 18.2% (n=12). In addition, the most frequent positive culture was detected inside of ETT lumen with a percentage of 83.3% (n=55) and followed by cuff (27.3%, n=18), pilot balloon (13.6%, n=9), respectively. *A. baumanni* was the most frequently isolated strain from TAC samples (6.1%) and *K. pneumonia* was the most frequently isolated strain from all ETT parts.

In the present study, it was remarkable that the same type of bacteriological strains was identified from both pilot balloon (n=9) and ETT cuff (n=9), simultaneously. This was interpreted to be a consequence of contamination due to the care providers particularly while regulating the cuff pressure or constant contact to environmental surfaces of the pilot balloon.

VAP has been noted to increase the duration of mechanical ventilation and ICU stay by approximately 5-7 days.11 Therefore, in order to prevent infections caused by intubation; numerous methods and products have been utilized, including control of cuff pressure, aspiration of subglottic secretions, decontamination of subglottic area, antiseptic impregnated ETTs and prevention of ETT biofilm formation. However, most of these methods are either controversial or do not contribute to mortality rates and length of hospital stay.[12,13] For instance, aspiration of subglottic secretions was found to be effective in cases that underwent intubation for more than 72 hours. On the other hand, it is well known that ETT cuff colonization and biofilm formation are prominent mechanisms in the pathogenesis of VAP. Thus, some researchers have focused on cuff material, shape and pressure to prevent biofilm formation. Although promising studies (silver coated ETT) have been published, the majority of them are still controversial and not found cost-effective.[14] Moreover, it is well-known that the risk of VAP increases cumulatively with a duration of MV, especially during the first 5 days of ventilation VAP increases by 3% per day. Furthermore, as the intubation duration and ETT size increase, the damage on the posterior aspect of the larynx progresses and paves the way for infection.[13,15] Poelaert et al.[16] reported VAP in 32% of 136 patients who underwent cardiac surgery and MV more than an average of 16.6 hours was significantly associated with an increased risk of postoperative pneumonia. Wilson et al.[17] documented VAP in half of the 32 ETT patients during an average of 13 hours in ICU. On the contrary, researchers concluded that biofilm stages were not significantly associated with intubation duration. In accordance with these data, lung infections were significantly increased after 14 days and cuff positive cultures were significantly increased after 10 and 14 days of incubation in our study. Moreover, 37 (56.1%) patients had positive culture only from the inside of ETT lumen, 9 (13.6%) had positive culture from ETT lumen + cuff and 9 patients (13.6%) had positive culture from all parts of ETT (ETT lumen + cuff + pilot balloon). In addition, there was a statistically significant positive correlation between the intubation duration and the number of contaminated ETT parts. In the remaining 9-cuff positive patients, accept mentioned 9 patients with the contaminated pilot balloons, pilot balloons were sterile and ETT lumens were positive culture with the same strains as identified from the cuff. It is also well known that the biofilm formation on the surface of the endotracheal tube and the subglottic secretions accumulated above the cuff contain a high burden of bacteria. Biofilms are 3-dimensional complex structures involving polysaccharides, nucleic acids and protein-rich extracellular matrix. After bacterial adhesion, this structure becomes continuous via aggregation and microcolony formation.[18] As a result of the possible alteration in the permeability of the cuff surface with the help of bacterial and biochemical microenvironment formed by prolonged intubation above the cuff, intra-cuff colonization may become possible. Bacterial colonization inside the ETT cuff without any contamination in the pilot balloon was interpreted to be a potential infection focus in the present study.

CONCLUSION

Increased intubation duration has been demonstrated to be a major risk factor for VAP. Bacterial colonization inside the ETT cuff without any contamination in the pilot balloon proved the migration of microorganisms from the ETT lumen or respiratory tract. Thus, the ETT cuff was demonstrated to be a potential infection focus on the present study. In addition, it was observed that ETT cuff colonization increased in proportion to the intubation duration. Therefore, we suggest changing ETT at appropriate time intervals to reduce VAP, mortality, ICU stays, antibiotic consumption and patient care costs in intubated patients.

ETHICAL DECLARATIONS

Ethics Committee Approval: The study was approved by the Samsun Ondokuz Mayıs University Clinical Researches Ethics Committee (Date: 29.05.2019, Decision No: 2019/191).

Informed Consent: Written informed consent was obtained from the patient participating in this study.

Referee Evaluation Process: Externally peer-reviewed.

Conflict of Interest Statement: The authors have no conflicts of interest to declare.

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