Otologic Changes in Tracheostomized, Mechanically Ventilated Patients

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ABSTRACT

Background: One of the most often used procedures in intensive care units for patients on mechanical ventilation is tracheostomy. In order to provide a safe and secure airway for individuals with traumatic brain damage, it is done. Patients with tracheostomies exhibit both transient and permanent alterations. Numerous investigations indicated that tracheostomies had an increased incidence of middle ear illness. Tympanostomy is necessary for about 20% of children who have had tracheostomies. **Objective:** To evaluate the otologic changes based on clinical, audiological, and radiological findings in tracheostomized, mechanically ventilated patients.

Patients and Methods: This retrospective study of 43 tracheostomized, mechanically ventilated selected from intensive and long-term care units from January 2020 to January 2023. Fifty individuals with unilateral sensorineural hearing loss or tinnitus, with no previous history of ear surgery or other complaints were selected as a control group.

Results: The study included a total of 86 ears and 100 ears as controls. The studied groups were comparable regarding age, gender, and laterality. Patients' ears showed significantly higher middle ear effusion (62.8% vs. 0%, $P < 0.001$) and tympanic membrane retraction (14% vs. 0%, $P < 0.001$). Tympanometry results significantly differed between the studied groups ($P < 0.001$). Type B was the most frequent type in the patients' group (62.8%), followed by types A (22.1%), C (11.6%), Ad (2.3%), and As (1.2%). Radiologically, patients' ears showed significantly higher eustachian tube obliteration (68.6% vs. 0%, $P < 0.001$), middle ear cavity effusion (62.8% vs. 0%, $P < 0.001$), mastoid air cells effusion (55.8% vs. 0%, $p < 0.001$), and petrous apex effusion (5.8% vs. 0%, $P = 0.02$).

Conclusion: Prolonged tracheostomized and mechanically ventilated patients exhibit a significant incidence of middle ear changes as determined by clinical, audiological, and radiological assessments.

Keywords: Tracheostomized, Mechanically ventilated patients, Otologic changes, Middle ear effusion.

INTRODUCTION

Tracheostomy is one of the ancient surgical procedures performed three thousand years ago in Egypt and India. The epidemics of diphtheria in the middle 19th century increased the performance of tracheostomy, which improved the outcome of patients with upper airway obstruction [1].

About 10% of mechanically ventilated patients are tracheostomized. The prevalence of tracheostomy is increasing with the higher performance of percutaneous bedside tracheostomy. However, the indication and timing of decannulation are still controversial [2].

Tracheostomy is one of the most common procedures performed for mechanically ventilated patients in intensive care units. It is primarily indicated for patients with respiratory failure who require mechanical ventilation. It is performed for post-traumatic brain injury patients aiming for a safe and secure airway. The main goals for tracheostomy include airway protection and access to suction the lower airway secretions. Tracheostomy decreases the incidence of well-recognized complications from prolonged endotracheal intubation, including injury to the oropharynx, larynx, and trachea and patient discomfort. In addition, systemic sedation is administrated mainly for all patients with endotracheal intubation, with its possible adverse effects [3].

In long-term dependent ventilated patients, tracheostomy facilitates the early weaning process from mechanical ventilation by reducing the dead space of upper airway passage, shortening mechanical ventilation duration and the length of stay in the intensive care unit, resulting in better utilization of ICU resources, and lowering the cost [4].

Additionally, tracheostomy decreases the incidence of ventilator-associated pneumonia, which is more prevalent with longer mechanical ventilation duration. This complication carries a significant risk of morbidity and even mortality [5].

Tracheostomy is frequently recommended in post-traumatic brain injury patients. Many studies suggest early tracheostomy to avoid the above-mentioned possible complications. However, few studies were conducted to evaluate the importance and post-procedure sequelae in this group of patients [6].

The timing and selection of patients who might benefit from tracheostomy is still a challenging and complex medical decision. It depends on the medical condition and variable comorbidities of the patient. Patients with a single organ failure, such as head injury or respiratory failure, have different management from those having multiple organ injuries [7].

Tracheostomized patients show evidence of short and long-term changes. One of these changes is an alteration of nasal physiological function due to the discontinuity of inhaled air and its connection with the nasal mucosal lining [8]. Generally speaking, functional changes mirror structural changes and vice versa. The nasal airflow is essential to maintain normal nasal mucosal epithelium. Subsequently, the absence of nasal airflow may result in pathological changes in the nasal mucosal lining and alter nasal function [9]. Patients who have had a complete laryngectomy are not allowed to breathe via their noses. As a result, the nose stops functioning physiologically. Furthermore, nasal

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histopathological mucosal atrophy increases as a long-term effect of airflow deprivation on the nasal mucosa [10]. The relationship between the middle ear mucosa, eustachian tube, and nasal cavities has been investigated in many studies. Most of them confirmed that impaired eustachian tube function due to nasal, paranasal, or nasopharyngeal pathologies leads to inadequate middle ear cavity ventilation, which is believed to be an important reason for middle ear inflammatory diseases [11]. Patients with isolated severely deviated nasal septum have poor eustachian tube functions due to inadequate nasal airflow at the side of deviation. This insufficient airflow results in lower middle ear pressure. Correction of deviated septum improves the airflow, resulting in better eustachian tube functions. Hence, the middle ear ventilation is improved [12].

Due to persistent middle ear effusion, pediatric tracheostomy patients are more susceptible to hearing loss and developmental delays, putting them at risk for unfavourable developmental outcomes [13]. **McAfee *et al.*** investigated the debate about whether tracheostomy itself increases the risk of middle ear disease. They reported that approximately 20% of children undergoing tracheostomy require tympanostomy tube placement. However, the presence of a tracheostomy tube is an independent risk factor for developing middle ear disease, which requires further evaluation [14].

In this study, we aimed to clarify the relationship between risk factors associated with prolonged mechanical ventilation via tracheostomy tubes and otologic changes that may increase the risk of middle ear disease, given the medical complexity of tracheotomized patients. We assessed these patients' radiological and tympanometric changes in the middle ear and mastoid.

PATIENTS AND METHODS

This retrospective cross-sectional study was conducted on 43 tracheostomized, mechanically ventilated patients (35 males and 8 females) from January 2020 to January 2023. Those patients were selected from the ICU and long-term care units of Benha University Hospital and NMC Royal Hospital, Khalifa City, Abu Dhabi, UAE. Fifty individuals were selected as a control group from the Audiology Unit of Benha University Hospital. They had unilateral sensorineural hearing loss or tinnitus, with no previous history of ear trauma, surgery, or any other ENT complaints.

Inclusion criteria

The inclusion criteria were patients aged between 18 and 40 years, including tracheostomized and mechanically ventilated post-traumatic head injury patients for a duration of 3 to 6 months. Furthermore, eligible patients had to be nourished through gastrostomy tubes.

Exclusion criteria: The exclusion criteria encompassed patients who were mechanically ventilated due to non-traumatic reasons, those with a prior history of ear or nose surgery, individuals with acute upper respiratory infections during the study period, and patients with neuromuscular disease or any syndromic or craniofacial anomalies.

Methods

All the selected patients underwent a comprehensive medical history obtained from the patient's relatives, including detailed pre-injury medical and surgical history. A thorough ENT examination was conducted, which included an otoscopic examination and fiberoptic nasal and nasopharyngeal endoscopic examination. Middle ear compliance was assessed through impedance audiometry.

All selected patients underwent CT scans of the temporal bone (axial and coronal views). Collected patients' data were recorded. Impedance audiological results of all patients were obtained. A radiologist studied the CT temporal bone of each patient for evaluation and analysis of the radiological changes of the middle ear cleft, including eustachian tube status (patency), tympanic membrane (intact, retraction), middle ear cavity status (pneumatization, atelectasis, effusion), ossicular chain status (integrity, discontinuity, necrosis), mastoid air cells status (pneumatization, effusion, sclerosis), and petrous apex (pneumatized or not).

Ethical approval:

Benha Medical Ethics Committee of the Faculty of Medicine gave its approval to this study, which approved the study protocol with the approval number RC-7-6-2023, All participants gave written consent after receiving all information. The Helsinki Declaration was followed throughout the study's conduct.

Statistical methods

SPSS version 28.0 was used for statistical analysis and data management. Utilising direct data visualisation techniques and the Kolmogorov-Smirnov test, the lone quantitative variable—age—was evaluated for normalcy. Age was summed up as mean and standard deviation based on normalcy. Numbers and percentages were used to summarise the categorical data. The independent t-test was used to compare ages among the groups under study. Both Fisher's exact test and the Chi-square test were used to compare categorical data. Each and every statistical test has two sides. Significant P values were those with a value of < 0.05.

RESULTS

General characteristics

This study was conducted on 43 patients (35 males and 8 females) with a total of 86 ears and 50 controls (34 males and 16 females) with a total of 100 ears. The studied groups were comparable regarding age, gender, and laterality **(Table 1).**

Table (1): General characteristics of the studied groups

		Patients (n = 86 ears)	Controls (n = 100 ears)	P-value
Age (years)	Mean ±SD	31 ±8	31 ±8	1
Gender				
Males	n (%)	35 (81.4)	34 (68)	0.141
Females	n (%)	8 (18.6)	16 (32)	
Laterality				
Right	n (%)	43 (50)	50 (50)	1.0
Left	n (%)	43 (50)	50 (50)	

Otoscopic and audiological findings

On otoscopic examination, the ears of the studied patients demonstrated significantly higher middle ear effusion and tympanic membrane retraction, with no significant difference regarding tympanic membrane perforation **(Table 2, Figure 1).**

On audiological assessment, tympanometry results significantly differed between the studied groups and controls. Type B was the most frequent type in patients' ears (62.8%). In contrast, most control ears revealed type A (95%) **(Table 2).**

Table (2): Otoscopic and audiological findings in the studied groups

		Patients (n = 86 ears)	Controls (n = 100 ears)	P-value
Otoscopic examination				
Middle ear effusion	n (%)	54 (62.8)	0 (0)	**<0.001***
Tympanic membrane				
Retraction	n (%)	12 (14)	0 (0)	**<0.001***
Perforation	n (%)	2 (2.3)	0 (0)	0.212
Audiological assessment				
Tympanometry				
Type A	n (%)	19 (22.1)	95 (95)	**<0.001***
Type Ad	n (%)	2 (2.3)	1 (1)	
Type As	n (%)	1 (1.2)	0 (0)	
Type B	n (%)	54 (62.8)	0 (0)	
Type C	n (%)	10 (11.6)	4 (4)	

*Significant P-value.

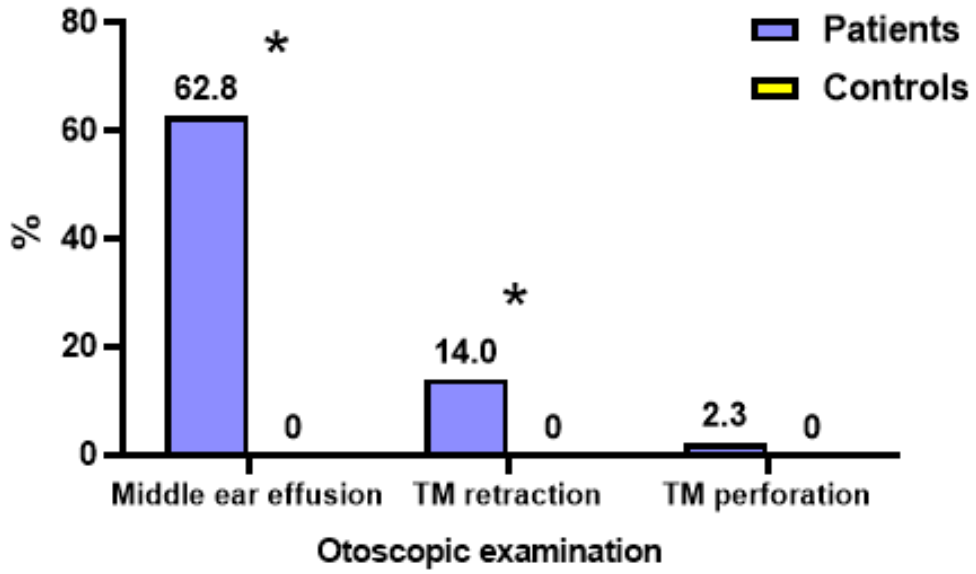

Figure (1): Otoscopic examination findings in the studied groups

Radiological findings

On radiological examinations, patients' ears showed significantly higher eustachian tube obliteration, middle ear cavity effusion, mastoid air cells effusion, and petrous apex effusion. No significant differences were observed regarding ossicular chain discontinuity, mastoid air cell sclerosis, and pneumatized petrous apex **(Table 3, figure 2).**

Table (3): Radiological findings in the studied groups

Radiological findings		Patients (n = 86 ears)	Controls (n = 100 ear)	P-value
Eustachian tube obliteration	n (%)	59 (68.6)	0 (0)	**<0.001***
Middle ear cavity effusion	n (%)	54 (62.8)	0 (0)	**<0.001***
Ossicular chain discontinuity	n (%)	2 (2.3)	0 (0)	0.212
Mastoid air cells				
Effusion	n (%)	48 (55.8)	0 (0)	**<0.001***
Sclerosis	n (%)	11 (12.8)	21 (21)	0.139
Petrous apex				
Pneumatized	n (%)	13 (15.1)	17 (17)	0.728
Effusion	n (%)	5 (5.8)	0 (0)	**0.02***

***Significant P-value**

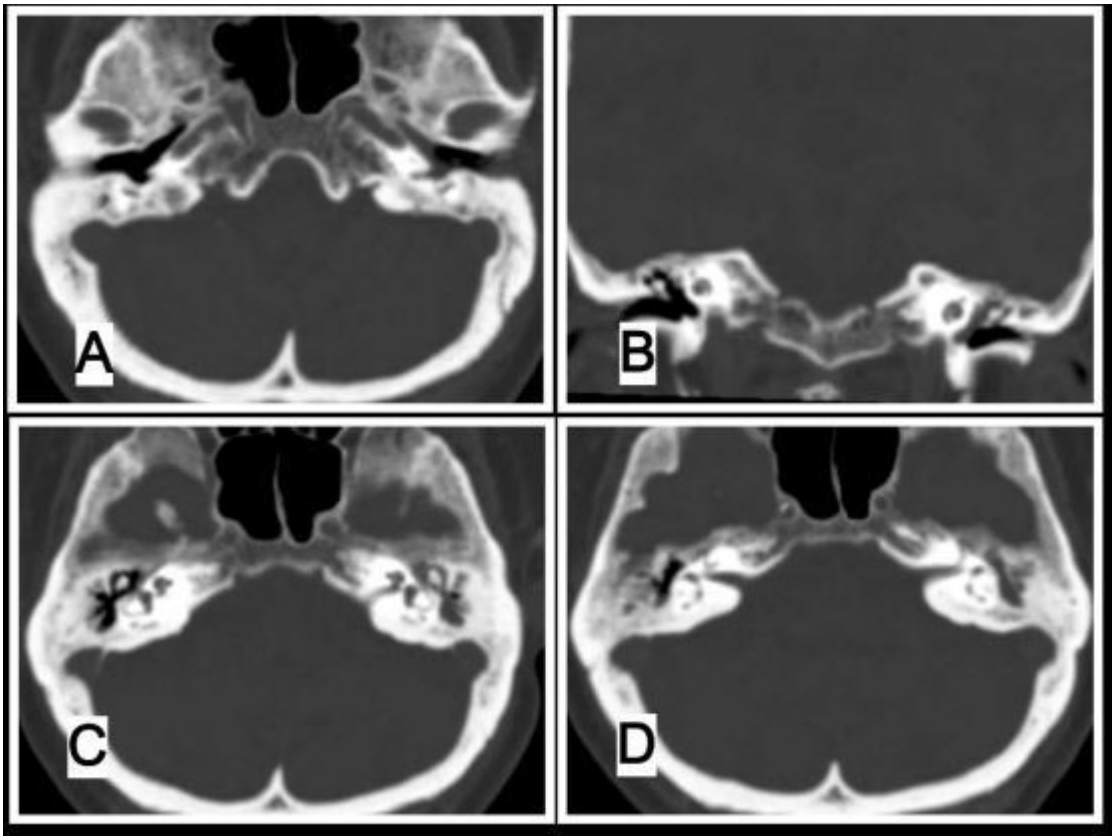

Figure (2): Radiological findings in the studied groups: CT of the temporal bones in axial (a, b, and c) and coronal (d) planes showing: (A) Obliterated bony part of left eustachian tube with patent right one. (B) Diminished pneumatization of bilateral mastoid air cells. (C and D) Obliterated left middle ear cavity with clear right one.

DISCUSSION

Although ENT problems are not the first-line concern for the ICU team, some of these problems might rebound into unpredictable critical illnesses, leading to severe or even catastrophic complications. More attention and regular ENT screening and follow-up examinations are recommended to avoid any serious ENT issues [15].

The inability to equalise the pressure inside the eustachian tube during prolonged mechanical ventilation is linked to the incidence of chronic middle ear effusion for a variety of reasons, including extended hospital stays, bacterial colonisation, recurrent respiratory tract infections, or a high rate of gastroesophageal reflux. However, we believe that bypassing nasal breathing in tracheostomized mechanically ventilated patients results in the alteration of eustachian tube function and, subsequently, middle ear effusion. Our study focused on evaluating otologic changes among those patients using clinical otoscopic assessment, audiological tympanometry findings, and radiological CT findings of middle ear cleft.

Lin *et al.* [16] assessed 20 ICU patients with prolonged endotracheal intubation to identify the conditions related to developing middle ear effusion (MEE). They used the otoscopic examination and the tympanometry to detect middle ear effusion, but they did not use the radiological CT changes. In agreement with our results, they found that among the 40 examined ears, 20 had MEE (50%), 6 had negative pressure in the middle ear (15%), and 14 were normal (35%). Additionally, they added that the poor conscious level and the longer time of intubation (14 days) had a significant contribution to the development of MEE.

Mechanical ventilation increases the chance of developing eustachian tube dysfunction and, consequently, MEE because it alters the dynamics of airflow in the upper airway and/or causes the upper airway to get colonised with bacteria [17].

In their study, **Christensen *et al.*** [17] examined 67 adult patients who underwent intubation following head trauma. They investigated the incidence of acute middle ear infections that developed three or more days after intubation, relying on clinical otoscopic examination to detect otitis media. Among these 67 patients, 11 had acute otitis media and concurrent purulent paranasal sinusitis at the time of examination. As a result, the authors concluded that it is advisable to clinically assess all intubated patients following head trauma for the presence of otitis media.

A prospective study conducted by **Wynings *et al.*** [13] on tracheostomized children under 2 years of age aimed to determine the incidence of MEE in tracheostomy-dependent children and its relation to ventilatory support. They found that mechanically ventilated children frequently developed MEE compared to those not mechanically ventilated. Their results showed that within 2 years after tracheostomy, 56.5% of patients developed at least one MEE. Among those, 74.0 % were dependent on mechanical ventilation, compared to 31.2% who were not on mechanical ventilation. They recommended that physicians should consider this risk factor for early MME evaluation and management in those patients to avoid delay in speech and language development. These results support our findings.

In agreement with our study, a retrospective study by **Palmisano *et al.*** [18] evaluated the tracheostomized, ventilator-dependent children to determine the incidence of chronic otitis media with effusion requiring myringotomy with tympanostomy tube insertion. They conducted their study on the pediatric age group, and they used only an otoscopic examination for assessing the middle ear. In contrast, our study was conducted on adult patients and used different tools (otoscopic examination, tympanometry, and CT temporal bone). They stated that tracheostomized children who are dependent on mechanical ventilation should be closely monitored for MEE. However, they believed that many other conditions are responsible for developing MEE by interfering with normal eustachian tube function. These conditions include prolonged and or frequent hospitalization, which carries a higher risk of acquiring nosocomial respiratory infections and bacterial colonization. Moreover, long stay bedridden in a supine position, prematurity, craniofacial abnormalities, neuromuscular disease, immunodeficiency, medications, or a high incidence of gastroesophageal reflux are other conditions.

Another retrospective cohort study conducted by **Kloosterman *et al.*** [19] examined the prevalence of myringotomy and tympanostomy tubes in 214 pediatric patients under the age of 18 who underwent tracheostomy. The study investigated various comorbid risk factors, including genetic syndromes, craniofacial abnormalities, cleft palate, airway abnormalities, and the presence of a gastrostomy tube. They found statistical significance of comorbid risk factors among patients who required tympanostomy tubes compared with those who did not. In disagreement with our study, they found that the tracheostomy alone was not a statistically significant independent risk factor. Additionally, they examined middle effusion fluid at the time of tympanostomy, and they found that it was non-purulent in 80%, purulent in 6%, and clear in 14% of operated patients' ears.

McAfee *et al.* [14] reviewed 181 cases from 1999 to 2010 to determine the prevalence of myringotomy and tympanostomy tube procedures among children with tracheostomy tubes and to identify the comorbid risk factors. Thirty-seven patients out of 181 required myringotomy and tympanostomy tube placement, with a prevalence of 20%. They studied the average time between tracheostomy and tympanostomy tube placement, in addition to the comorbid risk factors. They found that only 27% of the operated patients were premature at birth. Moreover, they studied the incidence of craniofacial anomalies, neurologic disorders,

cardiopulmonary diseases, and airway abnormalities. They found that patients with craniofacial comorbidities had a three times higher risk of myringotomy than patients without. They stated that neurologic disorders, airway abnormalities, or cardiopulmonary comorbidities did not have a statistical significance in relation to myringotomy.

To our knowledge, this study is the first to report an association between prolonged mechanical ventilation through tracheostomy tubes and middle ear disease based on clinical, audiological, and radiological characteristics.

In prolonged tracheostomized, mechanically ventilated patients, where comorbidities often hinder effective communication and interaction with loved ones and caregivers, preserving hearing and enhancing the overall quality of life (QOL) is of paramount importance. Vigilance in monitoring for otitis media with effusion in these patients is essential to ensure a higher quality of care.

Limitations of our study comprise its retrospective design, variations in institutional practices regarding follow-up visit frequency and tracheostomy care, and the limited sample size. Additionally, the records lacked differentiation between serous and mucoid effusions in all cases, potentially reflecting different chronicity or underlying pathophysiology of ear diseases.

CONCLUSION

Middle ear effusion was highly prevalent, affecting 62.8% of studied ears based on clinical and radiological assessments and 74.4% of studied ears according to tympanometry in tracheostomized, mechanically-ventilated patients. Prolonged tracheostomized, mechanically ventilated patients should be closely monitored for the development of middle ear effusions. Effective screening can offer timely treatment in a group that is often unable to express symptoms.

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REFERENCES

1. **Heffner J (1989):** Medical indications for tracheotomy. Chest, 96(1):186-190.
2. **Marchese S, Corrado A, Scala R *et al.* (2010):** Tracheostomy in patients with long-term mechanical ventilation: a survey. Respiratory Medicine, 104(5):749-753.
3. **Raimondi N, Vial M, Calleja J *et al.* (2017):** Evidence-based guidelines for the use of tracheostomy in critically ill patients. Journal of Critical Care, 38: 304-318.
4. **Tobin A, Santamaria J (2008):** An intensivist-led tracheostomy review team is associated with shorter decannulation time and length of stay: a prospective cohort study. Critical Care, 12: 1-8.
5. **Papazian L, Klompas M, Luyt C (2020):** Ventilator-associated pneumonia in adults: a narrative review. Intensive Care Medicine, 46(5): 888-906.
6. **Khanna J, Singh J, Kulshreshtha P *et al.* (2005):** Early tracheostomy in closed head injuries: experience at a tertiary center in a developing country–a prospective study. BMC Emergency Medicine, 5: 1-8.
7. **Holevar M, Dunham J, Brautigan R *et al.* (2009):** Practice management guidelines for timing of tracheostomy: the EAST Practice Management Guidelines Work Group. Journal of Trauma and Acute Care Surgery, 67(4): 870-874.
8. **Karaoglu D, Kocyigit M, Ortekin S *et al.* (2017):** Late-term effects of surgery on nasal functions in patients who underwent total laryngectomy surgery. International Archives of Otorhinolaryngology, 21(03): 270-275.
9. **Tsikoudas A, Barnes M, White P (2011):** The impact of tracheostomy on the nose. European Archives of Oto-rhino-laryngology, 268: 1005-1008.
10. **El-Sharnouby M, Khalil Y, El-Shafy I *et al.* (2018):** Evaluation of nasal mucosal changes of tracheastomized patients. Menoufia Medical Journal, 31(1):254-61.
11. **Akyildiz M, Özmen Ö, Demir U *et al.* (2017): I**mpact of septoplasty on Eustachian tube functions. Journal of Craniofacial Surgery, 28(8):1929-1932.
12. **Kaya M, Dağlı E, Kırat S (2018):** Does nasal Septal deviation affect the Eustachian tube function and middle ear ventilation? Turkish Archives of Otorhinolaryngology, 56(2):102-5.
13. **Wynings E, Jaffal H, John R *et al.* (2022):** Mechanical ventilation and middle ear effusions among tracheostomy-dependent children. International Journal of Pediatric Otorhinolaryngology, 155:111062. doi: 10.1016/j.ijporl.2022.111062.
14. **McAfee J, Demarcantonio M, Fine B *et al.* (2013):** Prevalence of ventilation tubes in children with a tracheostomy tube. International Journal of Pediatric Otorhinolaryngology, 77(1):65-68.
15. **Roth Y, Sokolov M, Adler M *et al.* (2003):** Otorhinolaryngological problems occurring within the intensive care unit. Intensive Care Medicine, 29: 884-889.
16. **Lin C, Lin C, Cheng Y *et al.* (2006):** Middle ear effusion in intensive care unit patients with prolonged endotracheal intubation. American journal of Otolaryngology, 27(2):109-111.
17. **Christensen L, Schaffer S, Ross S (1991):** Otitis media in adult trauma patients: incidence and clinical significance. Journal of Trauma and Acute Care Surgery, 31(11):1543-1545.
18. **Palmisano J, Moler F, Revesz S *et al.* (1994):** Chronic otitis media requiring ventilation tubes in tracheotomized ventilator dependent children. International Journal of Pediatric Otorhinolaryngology, 30(3):177-182.
19. **Kloosterman N, Donnell N, Somers E *et al.* (2021):** Middle ear disease requiring myringotomy in the first two years after tracheotomy in the pediatric population. International Journal of Pediatric Otorhinolaryngology, 150:110864. doi: 10.1016/j.ijporl.2021.110864.