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Voice Disorders after Intubation: The Importance of Intra-Operative Monitoring and Controlling of Endo-Tracheal Tube Cuff Pressure in Reducing Intubation-Related Complications

NEFISSA AMR, M.D.*; AZZA SAMY, M.D.** and AZZA ABD EL-AZIZ AZZAM, M.D.**

The Departments of Anaesthesia and Phoniatrics**, Hearing & Speech Institute (HSI), General Organization for Teaching Hospitals & Institutes (GOTHI), Egypt*

Abstract

Background: The importance of monitoring and controlling endotracheal tube cuff (ETTc) pressure in reducing laryngeotracheal injuries and intubation-related respiratory complications has been previously investigated by several authors. However, little is known about the role of controlling ETT cuff pressure in minimizing transient voice changes following endotracheal intubation.

Aim of the Study: The aim of this study was to investigate the importance of monitoring and controlling ETTc pressure in reducing voice disorders after endotracheal intubation.

Patients and Methods: Fifty patients in the age between 18-50 years, undergoing middle ear surgery were enrolled into the study. Patients were randomized by means of individually prepared envelopes to either the control group (n=25), without measuring ETTc pressure, or the study group (n=25), with ETTc pressure measurement. All patients were examined pre-operatively to determine baseline values, 24 hours after surgery and 1 week post-operatively. Phoniatric examination included auditory perceptual assessment, videolaryngoscopy and acoustic analysis of voice. Statistical analysis included the arithmetic mean, Standard Deviation (SD), standard error, hypothesis student's "*t*" and Spearman's rank-order correlation tests. *p*-values <0.05 were chosen as the level of significance.

Results: Auditory perceptual assessment of voice performed one day after extubation indicated the presence of post-intubation dysphonia which was of a mild to moderate grade, an irregular quality, a low pitch and fluctuating loudness. These changes were more pronounced and occurred more frequently in patients of the control group in whom the cuff pressure was adjusted by pilot balloon palpation according to the experience of the anaesthesiologist. One week after surgery, all patients belonging to the study group, in whom a hand-held cuff pressure monitor was used to adjust the cuff pressure, showed improvement in all the perceived parameters, whereas persistent dysphonia was still perceived in two patients of the control group. Videolaryngoscopy performed before intubation showed that all patients were free from any laryngeal lesions. One day after extubation, there was evidence of traumatic laryngeal lesions in the form of vocal fold congestion in 5 patients (20%) of the control group and 3 patients (12%) of the study group. One week after extubation, residual lesions were still present in 3 patients (12%) of the control group in the form of mild vocal fold edema in one patient and vocal fold congestion in two other patients. Acoustic analysis of voice performed 24 hours after extubation showed a highly significant increase in fundamental frequency F_0 in both male and female patients of the control group. These changes were accompanied by a significant increase in jitter in only the female patients. By contrast, acoustic analysis of voice recorded both 24 hours and one week after extubation in patients belonging to the study group did not show any significant changes in any of the measured parameters when compared to their corresponding baseline values. An inter-group comparison of the post-operative parameters recorded by acoustic analysis of voice one day after extubation showed a statistically highly significant (p=0.013) reduction in fundamental frequency F_0 by 75% among male patients, and a statistically significant (p=0.05) reduction in jitter by 74% in females belonging to the study group when compared to those of the control group. Shimmer and NHR increased to 78% and 47%, respectively, in male patients belonging to the study group, and decreased in females, but these changes were statistically not significant.

Correlation performed between the changes in parameters obtained by acoustic analysis of voice and the duration of intubation showed a statistically significant (p-value=0.023) positive correlation between the changes in fundamental frequency F0 and the duration of intubation. Likewise, a significant (p-value=0.016) positive correlation was found between the changes in jitter and the duration of intubation.

Conclusion and Future Recommendations: General anaesthesia has multisystem effects, some of which can disturb the fine harmony necessary for voice production. Even short-term intubation is usually followed by a period of dysphonia that may extend after extubation anywhere from 12 hours to more than five days. Proper control of endotracheal tube cuff (ETTc) pressure by a manometer helps reduce ETT-related postprocedural complications. Acoustic analysis may be used to identify and monitor even minor laryngeal trauma resulting from the procedure. Jitter and shimmer are the best indicators of post-intubation phonation changes. For medicolegal reasons, patients scheduled for general anesthesia should be informed about the possible post-operative voice changes that could

Correspondence to: Dr. Nefissa Amr,
E-Mail: nefissa_amr@hotmail.com

last longer than one day. We further recommend routine intraoperative monitoring of endotracheal tube cuff pressure, in addition to post-operative phoniatric assessment and follow-up of the patients for early post-operative diagnosis and treatment of dysphonia.

Key Words: *Endotracheal intubation – Dysphonia – Cuff pressure monitoring – Acoustic analysis.*

Introduction

EACH year, millions of patients undergo instrumentation of the airway as part of routine anaesthetic care [1]. The indications for intubation are twofold: Primarily to protect the airway against inundation with aspirate from the upper gastrointestinal tract and secondarily to establish and maintain the airway and facilitate positive pressure ventilation of the lungs [2]. To ensure the effect of ventilation, leakage of air and inhalational anaesthetics is prevented by inflation of the endotracheal tube cuff (ETTc) immediately after intubation [3].

However, tissue damage and other problems attributable to endotracheal intubation frequently occur in mechanically ventilated patients, originating in most cases at the cuff site of the endotracheal tube. Despite the use of high-volume low-pressure cuffed tubes, some degree of laryngeal or tracheal damage is still reported [4]. While severe over-inflation of the ETTc affects the blood supply to the tracheal mucosa, resulting in tracheal mucosal ichaemia, ulceration, necrosis, tracheo-oesophageal fistula, or even tracheal rupture, under-inflation is frequently associated with micro-aspiration of oropharyngeal and gastric secretions, which is the most important risk factor for ventilator-associated pneumonia. This goes primarily for patients with prolonged (days) endotracheal intubation [3,5].

For brief procedures lasting only a few hours, most clinicians give little attention to inflation pressure of the ETTc, and simply determine the pressure by pilot balloon palpation according to their experience. Studies by faculty anaesthesiologists, anaesthesia residents, and critical care unit staff have demonstrated a prevalent inability of these clinicians to accurately determine ETTc pressure by pilot balloon palpation [3,4,6]. In a multicenter study, Liu et al., investigated the short-term (hours) impact of measuring and controlling ETTc pressure on post-procedural complications. Selected patients were examined by fiberoptic bronchoscopy immediately after removing the endotracheal tube [3]. However, to our knowledge, the impact of ETTc pressure on voice has not yet been investigated.

Aim of the study:

By using auditory perceptual assessment, videolaryngoscopy, as well as acoustic analysis of voice, the aim of this study was to investigate the importance of monitoring and controlling ETTc pressure in reducing voice disorders after endotracheal intubation.

Material and Methods

This was a randomized, comparative, single-blind, prospective, observational study of the correlation between endotracheal tube cuff (ETTc) pressure control and postprocedural complications that was conducted at the Hearing and Speech Institute during the time period extending from September 2016 to November 2017.

After approval by the Local Ethics Committee of the General Organization for Teaching Hospitals and Institutes, written informed consent of all patients entering the trial was obtained.

Fifty patients of either sex, ASA physical status I or II, in the age between 18-50 years, undergoing middle ear surgery were enrolled into the study. Exclusion criteria included an ASA physical status other than I or II, age outside the range (18-50 years), pregnant females, patients with cough and sore throat before operation, patients with laryngeal pathology, patients with a known history of voice disorder, vocal fold immobility, thyroid surgery, those who experienced double-lumen endobronchial intubation, difficult and/or repeated endotracheal intubation, neck trauma, and those who were scheduled to undergo oral or laryngopharyngeal surgery.

Anaesthesia methods:

Upon arrival at the operating theatre and prior to induction of anaesthesia, all patients received an intravenous sedative dose of midazolam (0.03mg /kg). Xylocaine 2% in a dose of 1mg/kg was injected intravenously immediately before induction of anaesthesia, both for attenuating the hypertensive response to laryngoscopy and intubation and to diminish the pain associated with injection of propofol. Anaesthesia was then induced with intravenous propofol (2.5mg/kg). To achieve optimum intubating conditions, rapid-sequence-intubation using intravenous succinylcholine (1mg/kg) was performed by an experienced anaesthesiologist. Before use, the low-pressure cuff of the endotracheal tube was checked for leaks. All patients were then intubated orally with a sterile oral/nasal cuffed Murphy eye tracheal tube with a high-volume low-pressure cuff (inner diameter 7.0-8.0mm, manufactured in Thailand by Mallinckrodt/Covidien) the

size of which was selected individually for each patient (males 7.5-8.0, females 7.0-7.5). Manual assisted ventilation was performed till regain of spontaneous breathing. After intravenous administration of atracurium (0.5mg/kg) and fentanyl (0.005mg/kg), controlled mechanical ventilation of the lungs was initiated using a rebreathing anaesthetic circuit and oxygen as a carrier gas. To avoid significant changes of cuff pressure, nitrous oxide was not used during this study. Tidal volume and frequency of ventilation were adjusted to maintain the end-expiratory carbon dioxide pressure ($ETCO_2$) between 30-35mmHg. Anaesthesia was maintained with 0.8 end-tidal vol% of isoflurane and intermittent bolus doses of atracurium and fentanyl as deemed necessary. ECG, noninvasive arterial blood pressure, and peripheral oxygen saturation were continuously monitored during anaesthesia by means of the INVIVO M1 2TM 3550 vital signs monitor. At the end of surgery, the effect of the non-depolarizing muscle relaxant was reversed with a combination of neostigmine (0.08mg/kg) and atropine (0.01mg/kg).

Cuff pressure monitoring:

Patients were randomized by means of individually prepared envelopes to either the control or study group. The main researcher was not blinded to the group assignment; however, all of the other participants including anaesthesiologists, follow-up residents, ENT surgeons, and phoniatricians were not aware of the assignment. The ETTc in the control group was inflated by the anaesthesiologist according to his/her experience using the pilot balloon palpation method without any other instrumentation, whereas that in the study group was inflated first by the anaesthesiologist and then adjusted once by the researcher with a manual manometer (Endotest, RUSCH, Kernen, Germany) within the range of 15-25mmHg. For the low-pressure cuff to unfold and attach itself evenly to the tracheal mucosa, the manufacturer recommended to first inflate the cuff until a pressure of 100 cmH_2O was reached before adjusting it to the desired value. To minimize the risk of aspiration and pneumonia, cuff pressure was chosen high enough for the trachea to be securely sealed off by the inflated cuff, which is normally achieved with a cuff pressure of at least 25cmH_2O. At the same time, to prevent damage of the mucosa, the cuff pressure was not allowed to exceed the capillary perfusion pressure of the tracheal mucosa (max. 30cmH_2O) for a prolonged period of time. Air leakage was monitored with a stethoscope. In all patients, airway pressure was continuously monitored. Duration of surgery, as well as that of endotracheal intubation was recorded in both groups. For patients belonging to the study group, ETTc pressure was measured soon after initial inflation of the cuff and again after adjustment. At the end of surgery and just before extubation, the oral cavity was carefully suctioned, the cuff was deflated and tracheal suction was repeated. In the study group, complete cuff deflation was first checked by the cuff pressure gauge and confirmed when the needle of the manometer showed a negative pressure by moving counter-clockwise. After ensuring complete recovery of neuromuscular function and regain of spontaneous respiration, the ETT was removed at the end of expiration without suction to avoid laryngeal lesions that might be induced by suction catheters. Finally, the mouth was once again carefully suctioned.

Post-operatively, a resident physician was assigned to follow-up the patients with a structured questionnaire and record any endotracheal intubation-related respiratory complications including cough, sore throat, hoarseness, and blood-streaked expectoration 24 hours postextubation, as well as one week after surgery.

Phoniatric methods:

Each patient was subjected pre-operatively and post-operatively to the following procedures:

I- *Elementary diagnostic procedures:*

- Detailed history taking to avoid any of the exclusion criteria.
- General examination.
- Full ENT examination.
- Vocal tract examination.

II- *Clinical diagnostic aids:*

- Voice evaluation.
- Speech evaluation.

III- *Additional instrumental measures:*

- Computerized tomography scanning (CT) when indicated.

Evaluation of vocal functions was carried out in the Phoniatrics Department at the Hearing and Speech Institute using a standardized pre-and post-operative assessment protocol which was applied to all patients enrolled into this study. All patients were subjected to voice evaluation by:

- Auditory perceptual assessment.
- Videolaryngoscopy and
- Quantitative acoustic analysis.

Auditory perceptual assessment:

The subjective impression (perceptual judgment) of the patient's voice was assessed by three expert phoniatricians using a modified GRBAS scale [overall grade or severity (G), voice roughness (R), breathiness (B), asthenia (A), and strain (S)] (7). The degree of dysphonia was graded according to a 0-3 scale, where 0 is normal, 1 is mild dysphonia, 2 indicates moderate dysphonia, and 3 indicates severe dysphonia. Voice recording was done to document the auditory perceptual assessment, which was carried out in a sound-treated room using a high-fidelity computerized audio recording system.

Videolaryngoscopy:

Laryngeal visualization was carried out by Videolaryngoscopy which consists of:

1- A KayPENTAX 70 degrees rigid oral endoscope.

2- A coloured camera (Toshiba IK-M43A, model 9211 PHL).

3- A constant halogen light source for illumination 9100B with a 150 Watt halogen lamp.

4- A videorecorder (model 9221, Kay Corp., New Jersey, USA) and a screen.

Quantitative acoustic analysis:

Acoustic analysis of voice was performed using a Multidimensional Voice Program (MDVP) Model 5105. This analysis is based on selecting a particular segment from a voice sample and analyzing it using defined acoustic algorithms: The percentage of jitter, shimmer, and noise to harmonic ratio (NHR). The percentage of jitter gives an indication of the variability of the pitch period within the analyzed voice sample. It represents the relative period-to period variability. The percentage of shimmer gives an indication of the period-to-period variability of the peak-to-peak amplitude. The evaluation of the noise present in the signal is expressed as noise to harmonic ratio, which is the average ratio of energy of the inharmonic components in the 1500-to-4500-Hz range to the harmonic components' energy in the 70-t0-4500-Hz range. For reliable scoring of both visuoperceptual and audioperceptual outcome variables for vocal cord injuries and dysphonia, the raters were blinded to the patient's assignment. Fig. (1). Is a diagram illustrating the various acoustic parameters included in the MDVP program.

Statistical analysis:

The statistical analysis was performed using "SPSS 20 for windows" software statistics version (SPSS Inc., USA). The obtained data were tabulated and statistically analyzed to evaluate the differences within and between the groups under study. Correlations between the essential studied parameters were determined. The statistical analysis included the arithmetic mean, Standard Deviation (SD), standard error, hypothesis student's " *t*" and Pearson's correlation tests. *p*-values <0.05 were chosen as the level of significance. All results are presented as mean ± standard deviation. The correlation between nonparametric variables was determined using the Spearman rank correlation coefficient.

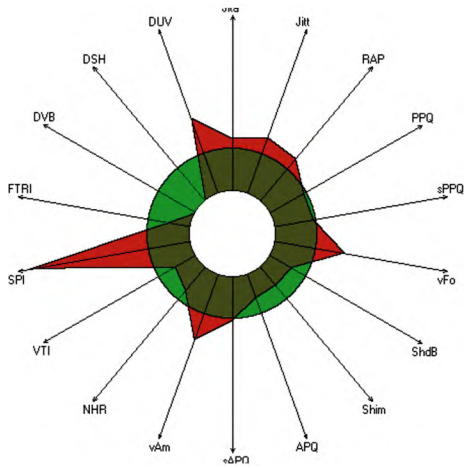


Fig. (1): Acoustic parameters diagram.

Results

The objective of this study was to examine the vocal symptoms and acoustic changes of voice perceived in the short period following endotracheal intubation. Demographic data are presented in (Table 1). A total number of 50 patients participated in our study, 25 in each group. There were no significant differences among the patients regarding age, sex, height, body weight, ASA physical status, duration of intubation, type and duration of surgery, or clinical procedures. All patients were examined pre-operatively to determine baseline values, 24 hours after surgery and 1 week post-operatively. Phoniatric examination included auditory perceptual assessment, videolaryngoscopy and acoustic analysis of voice, mainly the average fundamental frequency (F_0), Relative Average Perturbation (RAP), shimmer and Noise to Harmonic Ratio (NHR).

Auditory perceptual assessment:

One day after extubation, there were mild voice changes in 6 patients of the control group (24%) and 7 patients of study group (28%). A strained and leaky voice quality was perceived in four patients of the study group (16%), and in three patients of the control group (12%), whereas a

breathy voice quality was perceived in one patient of the control group (4%) and none of the study group. Irregular quality of voice was perceived in six patients of the control group (24%) and in two patients only of the study group (8%). The pitch decreased in 5 patients of the control group (20%) and increased in two patients of the study group (8%). The loudness was fluctuating in 7 patients of the control group (28%) and decreased in four patients of the study group (16%). One week after surgery, all patients belonging to the study group showed improvement in all the perceived parameters. On the other hand, persistent dysphonia was perceived in two patients of the control group (8%), being mild in one patient (4%) and moderate in the other (4%).

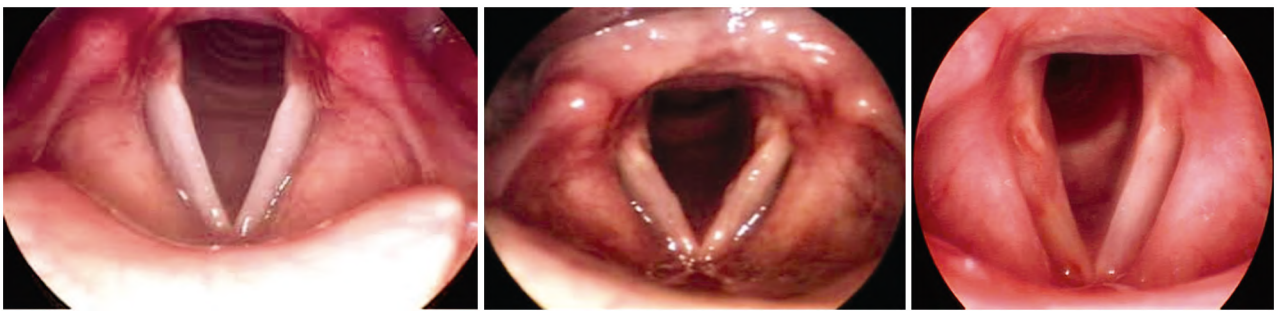
Table (1): Patients and procedures.

	Control group	Study group	*p*-value
Number of patients (n)	25	25	
Male/female	11/14	12/13	0.201
Age (years)	27±13.3	25.15±10.83	0.120
Body height (cm)	164.5±9.15	161.76±9.65	0.168
Body weight (kg)	63.5±11.84	62.07±16.25	0.325
Duration of intubation (min)	113.67±38.66	121.54±51.33	0.770
Duration of surgery (min)	87.5±33.27	100±49.95	0.140
Type of surgery:	(n)	(n)	
Tympanoplasty	5	10	
Cholesteatoma	17	14	
Stapedectomy	2	1	
Meatal atresia	1		

(n): Number of patients.

Videolaryngoscopy:

Videolaryngoscopy before intubation showed that all patients were free from any laryngeal lesions. One day after extubation, 5 patients (20%) of the control group and 3 patients (12%) of the study group showed evidence of traumatic laryngeal lesions in the form of vocal fold congestion (in all of the 8 patients). Increased vascular markings were observed in 4 patients of the control group. Two patients in the control group and 2 in the study group showed vocal fold edema Fig. (2). One week after extubation, residual lesions were still present in 3 patients (12%) of the control group in the form of mild vocal fold edema in one patient and vocal fold congestion in two other patients.



Normal vocal fold before intubation | After extubation in the control group | After extubation in the study group

Fig. (2): Vocal folds before intubation and 1 day after extubation in the control and study groups.

Acoustic analysis of voice:

Intra-group changes in the parameters recorded by acoustic analysis of voice are illustrated in (Table 2). For patients belonging to the control group and in (Table 3). For patients belonging to the study group.

Control group:

Acoustic analysis of voice performed 24 hours after extubation showed a highly significant (p<0.05) increase in fundamental frequency F 0 in both male and female patients belonging to the control group, reaching 34% of the pre-operative

values in males and 19% in females. These changes were accompanied by a significant (p=0.05) increase in jitter in only the female patients belonging to the same group, reaching 70% of the pre-operative values. Changes in fundamental frequency, jitter, shimmer and NHR recorded one week after extubation were statistically not significant when compared to their corresponding baseline measurements.

Study group:

Acoustic analysis of voice recorded both 24 hours and one week after extubation in patients belonging to the study group did not show any significant changes in any of the measured parameters when compared to their corresponding baseline values.

Inter-group comparison of the pre-operative (baseline) parameters recorded by acoustic analysis of voice, are illustrated in (Table 4), while the postoperative differences between the two groups are depicted in (Table 5).

Pre-operatively, no statistically significant differences were found between patients of the control group and those of the study group in any of the baseline parameters recorded by acoustic analysis of voice.

Post-operatively, one day after extubation, there was a statistically highly significant (p=0.013) reduction in fundamental frequency F 0 by 75% among male patients, and a statistically significant (p=0.05) reduction in jitter by 74% in females belonging to the study group when compared to those of the control group. Shimmer and NHR increased to 78% and 47%, respectively, in male patients belonging to the study group, and decreased in females, but these changes were statistically not significant.

Correlation between the changes in parameters obtained by acoustic analysis of voice and the duration of intubation.

Table (6) summarizes the correlation between the changes in parameters obtained by acoustic analysis of voice, and the duration of intubation. A statistically significant (p-value=0.023) positive correlation was found between the changes in fundamental frequency F 0 and the duration of intubation. Likewise, a significant (p-value=0.016) positive correlation was found between the changes in jitter and the duration of intubation.

Table (2): Intra-group changes in the parameters recorded by acoustic analysis of voice within the control group.

	Pre-operative	1st post-operative day	p-value	1 week post-operative day	p-value
F0:					
Male	168.24±42.7	226±25.86	0.036*	215.5±27.57	0.219
Female	233.25±14.4	277.6±29.8	0.04*	239±16.5	0.718
Jitter:					
Male	56.08±14.7	80.14±41.59	0.249	57.5±20.5	0.920
Female	49.35±13.22	83.9±19.66	0.05*	47.3±15.69	0.892
Shimmer:					
Male	0.29±0.26	0.246±0.05	0.636	0.27±0.08	0.908
Female	0.193±0.09	0.473±0.35	0.318	0.336±16.5	0.244
NHR:					
Male	0.156±0.07	0.121±0.02	0.292	0.138±0.27	0.778
Female	0.130±0.02	0.237±0.16	0.409	0.118±0.013	0.549

All data are presented as mean ± standard deviation. On the first post-operative day, there was a significant increase in F0 in both male and females and a significant increase in jitter in female patients only within the control group. Changes recorded one week after extubation were statistically non-significant. A p-value <0.05 was considered statistically significant.
F0 : Fundamental frequency.
NHR: Noise to Harmonic Ratio.

Table (3): Intra-group changes in the parameters recorded by acoustic analysis of voice within the study group.

	Pre-operative	1st post-operative day	*p*-value	1 week post-operative day	*p*-value
F0:					
Male	182.81±55.32	170.3±49.49	0.549	180.1±37.1	0.522
Female	249.3±23.4	254.6±37.13	0.704	230.6±16.2	0.221
Jitter:					
Male	73.32±44.7	59.50±11.38	0.292	51.5±5.4	0.426
Female	55.43±10.35	62.39±17.11	0.285	56.3±15.37	0.901
Shimmer:					
Male	0.536±0.38	0.439±0.26	0.462	0.536±0.38	0.388
Female	0.39±0.24	0.378±0.21	0.910	0.45±0.31	0.726
NHR:					
Male	0.167±0.03	0.15±0.04	0.504	0.167±0.03	0.221
Female	0.132±0.04	0.142±0.02	0.512	0.175±0.046	0.110

All data are presented as mean ± standard deviation. There were no significant differences in any of the recorded parameters 24 hours and 1 week after extubation within the study group when compared to the corresponding baseline values. A *p*-value <0.05 was considered statistically significant.
F0 : Fundamental frequency.
NHR: Noise to Harmonic Ratio.

Table (4): Inter-group comparison of the pre-operative parameters recorded by acoustic analysis of voice.

	Control group	Study group	*p*-value
F0:			
Male	168.24±42.7	182.81±55.32	0.605
Female	233.25±14.4	249.3±23.4	0.379
Jitter:			
Male	56.08±14.7	73.32±44.7	0.419
Female	49.35±13.22	55.43±10.35	0.473
Shimmer:			
Male	0.29±0.26	0.536±0.38	0.212
Female	0.193±0.09	0.39±0.24	0.293
NHR:			
Male	0.156±0.07	0.167±0.03	0.692
Female	0.130±0.02	0.132±0.04	0.941

All data are presented as mean ± standard deviation. No statistically significant differences were found between patients of the control group and those of the study group in any of the baseline parameters recorded pre-operatively by acoustic analysis of voice.

Table (5): Inter-group comparison of post-operative parameters recorded by acoustic analysis of voice one day after extubation.

	Control group	Study group	*p*-value
F0:			
Male	226±25.86	170.3±49.49	0.013 *
Female	277.6±29.8	254.6±37.13	0.193
Jitter:			
Male	80.14±41.59	59.50±11.38	0.105
Female	83.9±19.66	62.39±17.11	0.05*
Shimmer:			
Male	0.246±0.05	0.439±0.26	0.08
Female	0.473±0.35	0.378±0.21	0.525
NHR:			
Male	0.121±0.02	0.178±0.04	0.06
Female	0.237±0.16	0.142±0.02	0.154

All data are presented as mean ± standard deviation. Post-operatively, there was a statistically highly significant (p=0.013) reduction in fundamental frequency F0 in male patients and a statistically significant (p=0.05) reduction in jitter in female patients belonging to the study group when compared to those of the control group. Shimmer and NHR increased in male patients belonging to the study group, and decreased in females, but these changes were statistically not significant.

Table (6): Correlation between the changes in parameters obtained by acoustic analysis of voice and the duration of intubation.

	F0	Jitter	Shimmer	NHR
• Correlation coefficient (r_s)	0.395*	0.457*	0.088	0.232
• *p*-value	0.023	0.016	0.624	0.192

Numbers represent the Spearman's correlation coefficient (r_s) for each of the measured variables in relation to the duration of intubation.
*: Denotes the presence of a statistically significant correlation.

Discussion

The importance of monitoring and controlling ETT cuff pressure in reducing laryngeotracheal injuries and intubation-related respiratory complications has been previously investigated by several authors [3,4]. However, little is known about the role of controlling ETT cuff pressure in minimizing transient voice changes associated with endotracheal intubation. In fact, dysphonia or change in voice quality reported by the patient following

surgery is very often overlooked by the anesthesiologist and the treating physician. The results of the present study confirm the importance of cuff pressure monitoring in minimizing postintubation changes in vocal function and support our hypothesis that the reliability of subjective finger estimation of cuff pressure is very low and could easily misjudge the appropriate inflation pressure due to variations in elasticity and distensibility of ETT cuffs used by the different manufacturers, thus reemphasizing the importance of using objective systems for controlling ETT cuff pressure to reduce postintubation sequelae.

Auditory perceptual assessment of voice:

In the current study, auditory perceptual assessment of voice performed one day after extubation indicated the presence of post-intubation dysphonia which was of a mild to moderate grade, an irregular quality, a low pitch and fluctuating loudness. These changes were more pronounced and occurred more frequently in patients of the control group in whom the cuff pressure was adjusted by pilot balloon palpation according to the experience of the anaesthesiologist.

One week after surgery, all patients belonging to the study group, in whom a hand-held cuff pressure monitor was used to adjust the cuff pressure, showed improvement in all the perceived parameters, whereas persistent dysphonia was still perceived in two patients of the control group (8%), being mild in one patient (4%) and moderate in the other (4%).

Videolaryngoscopy:

Video-laryngoscopy performed one day after extubation showed evidence of traumatic laryngeal lesions in the form of vocal fold congestion in 5 patients (20%) of the control group and 3 patients (12%) of the study group.

One week after extubation, residual lesions were still present in 3 patients (12%) of the control group in the form of mild vocal fold edema in one patient and vocal fold congestion in two other patients.

Acoustic analysis of voice:

In the control group, acoustic analysis of voice performed 24 hours after extubation showed a highly significant ($p<0.05$) increase in fundamental frequency F_0 in both male and female patients, reaching 34% of the pre-operative values in males and 19% in females. These changes were accompanied by a significant ($p=0.05$) increase in jitter in only the female patients belonging to the same group, reaching 70% of the pre-operative values. By contrast, acoustic analysis of voice recorded both 24 hours and one week after extubation in patients belonging to the study group did not show any significant changes in any of the measured parameters when compared to their corresponding baseline values.

An inter-group comparison of the post-operative parameters recorded by acoustic analysis of voice one day after extubation showed a statistically highly significant ($p=0.013$) reduction in fundamental frequency F_0 by 75% among male patients, and a statistically significant ($p=0.05$) reduction in jitter by 74% in females belonging to the study group when compared to those of the control group. Shimmer and NHR increased to 78% and 47%, respectively, in male patients belonging to the study group, and decreased in females, but these changes were statistically not significant.

Correlation performed between the changes in parameters obtained by acoustic analysis of voice and the duration of intubation showed a statistically significant (p-value=0.023) positive correlation between the changes in fundamental frequency F_0 and the duration of intubation. Likewise, a significant (p-value=0.016) positive correlation was found between the changes in jitter and the duration of intubation.

A possible explanation of these findings could be the changes affecting the vibratory properties of vocal folds caused by edema of the mucosa. Baken reported that any change in the acoustic characteristics of the speech signal must represent a change in the status of the vocal folds, and Yonick et al., suggested that even subtle changes indicative of laryngeal trauma after short-term intubation can be detected by acoustic analysis of voice **[8,9]**. Overinflation of the ETT cuff is one of the leading causes for edema of the vocal folds and mucosal ischemia, with the areas of folds vocal cord that are nearest to cartilage being especially sensitive to ischemia **[10]**. Ischemia of the tracheal mucosa originating at the interface between the tube cuff and the tracheal epithelium is widely recognized as the major determinant of tracheal injury in mechanically ventilated patients, with the ischemia being proportional to cuff pressures exceeding 25 cmH_2O, which is the perfusion pressure of the tracheal mucosa and submucosa **[4]**. In a prospective long-term evaluation of patients who were endotracheally intubated for varying periods of time in an intensive care unit, a ring-shaped tracheitis at the level of the ETT cuff was found in 31% of studied patients **[11]**. The precise pressure at which capillary

perfusion is impaired certainly will vary from patient to patient and depends upon numerous factors, most importantly the patient's blood pressure, but it is reported that 25cmH_2O is the maximal safe pressure and that at pressures of 30cmH_2O, tracheal mucosal blood flow may be impaired, and at 45cmH_2O, tracheal mucosal blood flow is completely obstructed. However, the volume of cuff inflation should preferably not be fixed. To allow effective ventilation, the cuff should be inflated just until it prevents an air leak. In all of our patients, the mean arterial blood pressure was kept around 65±5mmHg throughout the operation.

Likewise, the duration of time that an ETT cuff is overly inflated is almost certainly another determinant of tracheal hypoperfusion injury. It is unknown how much time, if any, is a safe duration during which excess ETT cuff pressure may be tolerated without injury **[6]**. In the current study, the mean duration of intubation was 113.67±38.66 min for patients of the control group, and 121.54 ±51.33min for those belonging to the study group, but this difference was not statistically significant (p=0.77). However, despite the fact that the mean duration of intubation in the study group exceeded that of the control group by a few minutes, post-intubation dysphonia secondary to vocal fold congestion occurred more frequently in patients of the control group in whom the cuff pressure was adjusted by pilot balloon palpation according to the experience of the anaesthesiologist, thus further emphasizing the importance of controlling ETT cuff pressure in reducing adverse post-intubation sequelae on voice. These observations suggest that pressure and time are both important variables determining the degree of laryngeotracheal morbidity following endotracheal intubation. Despite the use of low-pressure, high-volume cuffed endotracheal tubes, some degree of laryngeal or tracheal injuries is still continuously reported in all patients after endotracheal intubation **[4]**. This can be explained by the fact that although the cuff may be easily distensible in open air, yet when confined within the trachea, small increments in the inflation volume may produce a high pressure.

Our findings are in agreement with those of Liu et al., who found a significantly higher incidence of hoarseness in patients of the control group than in those belonging to the study group **[3]**. Previous studies also reported that hoarseness was related to increased cuff pressure, but the actual reason for this could not be determined **[12]**.

One could argue that the ETT cuff is below the glottis, and thus should not affect voice changes significantly. However, irritation of the posterior glottis and arytenoids resulting from the continuous to-and-fro movement of the ETT with each ventilator cycle could be one of the major contributing factors to vocal fold edema and mucosal damage, especially if the ETT cuff is overly inflated. An equally important possible contributing factor to vocal fold edema observed in our patients is the frequent manual rotation of the head by the surgeon with the ETT in situ to adjust his field of vision during microscopic surgery of the middle ear.

In terms of acoustic analysis of voice, the results of the present study confirm previous findings that all of those symptoms usually decrease to insignificant values 24 hours following extubation, especially in patients belonging to the study group in whom the cuff pressure was controlled, and they are in keeping with those of Horii and Fuller who reported a significant decrease in F0 after extubation **[13]**. Likewise, Gleeson and Fourcin reported that the change in F0 contours following short-term intubation returned to normal within 24 hours, while Iqbal & Zuleika reported that short-term intubation is usually followed by a period of dysphonia that may extend after extubation anywhere from 12 hours to more than five days **[14,15]**. Similarly, Yonick et al., found that F0 measures returned to normal within 72 hours **[9]**. They concluded that acoustic analysis may be used to identify and monitor even minor laryngeal trauma resulting from the procedure. They analyzed F0 and found that jitter and shimmer were the best indicators of post-intubation phonation changes **[9]**. Their findings are in concordance with the significant changes in jitter occurring in our patients. However, in the current study, the changes in shimmer were statistically not significant. Further findings of the present study were the persistent acoustic changes in the mucosal wave occurring in two patients of the control group who had a mild to moderate degree of dysphonia after extubation. Consequently, a time period of not less than one week is required for the return of vocal functions to normal, especially in patients in whom the cuff pressure was not adjusted.

On the contrary, in another study conducted by Hamdan et al., no significant changes affecting any of the parameters measured by acoustic analysis of voice could be detected **[16]**. In a similar study evaluating the temporary effect of short-term endotacheal intubation on vocal function, Paulauskiene et al., attributed these differences in results to the type of surgical operations performed **[10]**. While 46% of patients in the Hamdan study underwent major thoracic or abdominal operations, the

patients included in the Paulauskiene study, as well as those included in our study underwent ear surgery; so, possibly the patients in the Hamdan study had much more serious general complaints after operation when compared to those undergoing ear surgery who could better concentrate on the symptoms of throat and voice.

In order to understand these paradoxical findings, it is important to know, that general anaesthesia has multisystem effects that can disturb the fine harmony necessary for normal voice production. Since voice is a function of the coordinated interaction of the respiratory system, glottic larynx, and supraglottic vocal tract (supraglottic larynx, pharynx, and oral cavity), neuromuscular system, as well as central higher nervous system functions, even the slightest changes affecting the input of any of these systems can affect the vocal function to varying degrees [17]. Pulmonary function is an important factor in the regulation of important parameters of speech such as intensity, fundamental frequency (pitch), lingual stress, and the division of speech into syllables, words, and phrases. Restricted ventilation after general anaesthesia resulting from splinting of the diaphragm secondary to pain, especially after abdominal or chest procedures, or residual paralysis, or musculoskeletal tenderness frequently encountered after the use of paralyzing agents can affect the process of voice production. Impaired gas exchange resulting from atelectasis in dependent lung regions during mechanical ventilation can alter respiratory function in the immediate postoperative period. These changes can be reduced by the use of intraoperative Positive End-Expiratory Pressure (PEEP), especially with increased duration of surgery. Clinically relevant depression of ventilation may persist for significant periods after intraoperative administration of barbiturates or narcotic analgesics. Likewise, administration of postoperative analgesics can also be associated with decrease in respiratory function. Changes in cortical function associated with the administration of anaesthetic agents may also affect the fine vocal tract neuromuscular activity necessary to coordinate normal speech production. For all of the above reasons, it seems advisable to postpone performing the first post-operative phoniatric evaluation of patients for 24 hours after extubation until the effects of anaesthesia have worn off.

The statistically significant increase in jitter occurring one day after extubation in female patients belonging to the control group can be a result of alteration of the intrinsic vibratory characteristics of the vocal fold mucosa or associated vocal tract systems. The use of unhumidified oxygen and inhalational anaesthetics could possibly cause dessication of the laryngeal mucosa and impair regular vocal fold vibration. Inadequate fluid replacement, together with the administration of atropine and the preoperative use of diuretics are additional contributing factors to vocal fold dessication. Therefore, in view of all of the above factors, developing a study design that would control for all the variables that may influence vocal fold vibration would be most difficult. Thus, it cannot be unequivocally stated, whether the postintubation changes in vocal function are a result of extrinsic forces affecting the vocal folds or due to morphologic changes in the folds themselves causing alteration of the intrinsic vibratory characteristics of the vocal fold mucosa or the associated vocal tract systems participating in voice production. However, since vocal fold trauma caused by overinflated ETT cuffs probably stimulates a reactive edema that may result in greater vocal fold contact during the glottic cycle, cuff pressure monitoring should be routinely applied during everyday practice to minimize postintubation changes in vocal function, as confirmed by the results of the present study.

Methodologic shortcomings:

This study has got some limitations. First, it would have been valuable to measure ETT cuff pressure in the control group before extubation and compare this value with that in the study group. Another limitation is that even though in many studies audioperceptual evaluation is considered the criterion standard for voice evaluation, it is a less reliable assessment technique because of its subjective nature. Audioperceptual evaluation involves problems such as the unstable internal standards for comparing speech stimuli and the lack of universally accepted definitions of perceptual concepts. Furthermore, despite the fact that instrumental analysis is considered to be more objective, it also has limitations, including imperfection in acoustic analysis. For that reason, no measurement alone can diagnose or characterize dysphonia, and multidimensional assessment is recommended.

Conclusion and Future Recommendations:

Change of voice, postintubation dysphonia and vocal cord injuries seem to be clinically relevant complications related to the use of an endotracheal tube for general anaesthesia, with the ETT cuff pressure being one of the important risk factors contributing to these complications. This study demonstrated that proper control of ETT cuff pres-

sure by a manometer, even in procedures lasting only a few hours, helps to reduce postprocedural endotracheal intubation-related complications that affect voice production. For medicolegal aspects, patients scheduled for general anaesthesia should be informed about the possible post-operative voice changes that could last for more than one day. Furthermore, the use of a pre-operative and post-operative standardized measurement protocol combining acoustic analysis together with the voice Handicap index is advised. In this context, it is important to know the proper time of the post-operative evaluation, which should preferably be performed within one day after surgery. If more time elapses between the end of anaesthesia and the first measurement, more factors will interfere and affect the results. In addition, a uniform nomenclature or definition of vocal cord injury is necessary to compare the outcomes of future studies. A classification of the type of injury can be made according to the impairment of the vibratory movement and movement disorders of the vocal cords as suggested by the Phonosurgery Committee of the European Laryngological Society.

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الإضطرابات الصوتية الناجمة عن إستخدام الآنبوبة الحنجرية للتخدير: آهمية متابعة قياس وضبط حجم الهواء داخل بالونة الآنبوبة الحنجرية آثناء التخدير فى تقليل المضاعفات المرتبطة بذلك

الخلفية العلمية للبحث: شق الموضوع المتعلق بآهمية متابعة قياس وضبط حجم الهواء داخل الآنبوبة الحنجرية آثناء التخدير فى الحد من إحداث خدوش وجروح وإحتقان بالحنجرة والقصبة الهوائية وتخفيف مضاعفات الجهاز التنفسى سبق وآن تعرض له العديد من الباحثين فى هذا المجال، ولكن المعلومات المتوفرة عن دور ضبط حجم الهواء داخل بالونة الآنبوبة الحنجرية آثناء التخدير فى تخفيف الإضطرابات الصوتية المصاحبة لذلك تكاد تكون منعدمة.

الهدف من البحث: دراسة الآعراض الجانبية الناجمة عن إستخدام الآنبوبة الحنجرية فى التخدير العمومى على الممرات الهوائية العلوية بعد التدخلات الجراحية القصيرة والإضطرابات الصوتية المصاحبة لذلك ومدى علاقتها بحجم الهواء داخل بالونة الآنبوبة الحنجرية للتخدير.

المواد والطريقة: للإجابة عن هذا السؤال، تم إجراء هذا البحث على خمسين مريضا من الآصحاء تتراوح آعمارهم ما بين ١٨ إلى ٥٠ عاما ممن خضعوا لجراحات فى الآذن الوسطى، حيث تم تقسيم المرضى بصفة عشوائية إلى مجموعتين تشمل كل منهما ٢٥ مريضا، إحداهما– وهى المجموعة الحاكمة آو مجموعة الإختبار الضابط - control group - لم يتم قياس ضغط الهواء داخل بالونة الآنبوبة الحنجرية بإستخدام الآداة المخصصة لذلك، بل تم ذلك بالطريقة اليدوية التقليدية التى تعتمد على حس وخبرة طبيب التخدير، آما المجموعة الآخرى من المرضى– وهى مجموعة البحث study group - فقد إستخدمت فيها الآداة المخصصة لقياس ضغط الغازات داخل بالونة الآنبوبة الحنجرية، علما بآن جميع المرضى فى المجموعتين سبق إجراء الفحوصات والإختبارات اللازمة لهم بقسم التخاطب قبل الخضوع للتدخلات الجراحية وذلك لتقييم حالتهم قبل التخدير، كما تمت معاودة فحصهم بعد إنقضاء ٢٤ ساعة، ثم بعد مرور إسبوع من تاريخ إجراء العملية الجراحية، وقد شملت الفحوصات التى تم إجراؤها لجميع المرضى إختبار التقييم الإدراكى السمعى، والتصوير الحنجرى، بالإضافة للتحليل الصوتى.

النتائج: وقد آسفرت إختبارات التقييم الإدراكى الصوتى التى آجريت للمرضى بعد إنقضاء يوم واحد من إخراج الآنبوبة الحنجرية عن وجود تغيير فى الصوت يتراوح فى شدته ما بين التغيير البسيط إلى المتوسط مع عدم إستقرار شدة الصوت وإنخفاض فى درجة الصوت، وقد ظهرت التغييرات بصورة آكثر وضوحا فى المجموعة الحاكمة، آما فيما يتعلق بالمرضى المندرجين تحت مجموعة البحث، فقد آظهرت الإختبارات المستخدمة إختفاء جميع الآعراض الناتجة عن الآنبوبة الحنجرية بالكامل بعد مرور إسبوع من تاريخ إجراء العملية الجراحية، بينما إستمرت البحة الصوتية فى إثنين من المرضى بالمجموعة الحاكمة. آما فيما يتعلق بنتائج التصوير الحنجرى، فقد آظهرت وجود إحتقان بالثنايا الصوتية بعد مرور ٢٤ ساعة على إخراج الآنبوبة الحنجرية فى ٥ حالات (٢٠٪) من المجموعة الحاكمة مقابل ٣ حالات (١٢٪) فقط من مجموعة البحث، وقد إستمر وجود الإحتقان فى ٣ حالات من المجموعة الحاكمة عند إعادة التصوير الحنجرى بعد إسبوع من التخدير. وبمقارنة نتائج إختبار التحليل الصوتى للمجموعتين بعد مرور ٢٤ ساعة على إخراج الآنبوبة الحنجرية، لوحظ إنخفاض التردد الآساسى Fundamental frequency بنسبة ٧٥٪ فى المرضى الذكور، وإنخفاض فى الآهتياج الصوتى Jitter بنسبة ٧٤٪ فى المرضى الإناث بالمجموعة الحاكمة. كما زاد الوميض الصوتى Shimmer بنسبة ٧٨٪، وزادت كذلك نسبة التشويش إلى الصوت التوافقى المتآلف NHR بنسبة ٤٧٪ فى المرضى الذكور وإنخفضت فى الإناث فى مجموعة البحث، ولكن هذه التغييرات لم تكن ذات دلالة من الناحية الإحصائية. وقد وجدت علاقة إيجابية بين التغييرات التى تحدث فى قياسات التحليل الصوتى ومدة العملية الجراحية، فكلما زادت مدة وجود الآنبوبة الحنجرية داخل القصبة الهوائية، كلما زادت التغييرات الصوتية بعد العملية.

الإستنتاج والتوصيات: التخدير العمومى بإستخدام الآنبوبة الحنجرية له تآثير سلبى على مراحل تكوين الصوت وإحدى هذه المضاعفات "البحة الصوتية" التى قد تستمر حتى إسبوع آو آكثر بعد العملية الجراحية، ولذلك ينبغى توعية المرضى قبل العملية بإمكانية حدوث هذه المضاعفات. متابعة قياس ضغط الهواء داخل بالونة الآنبوبة الحنجرية بإستخدام الآداة المخصصة لذلك يقلل من حدوث هذه المضاعفات.