Assessment of the short-term effects of endotracheal intubation on vocal functions

Hassan H. Ghandour[a], Rasha M. Shoeib[a], Jilan F. Nassar[a] and Mohammed M. El-Shafei[b]

[a]Unit of Phoniatrics, Department of Otorhinolaryngology and [b]Department of Anesthesiology, Faculty of Medicine, Ain Shams University, Cairo, Egypt

Correspondence to Hassan H. Ghandour, MD, Unit of Phoniatrics, Department of Otorhinolaryngology, Faculty of Medicine, Ain Shams University, Cairo, Egypt
Tel: +20 224 702 825; fax: +20 106 454 5465;
e-mail: hhghandour@yahoo.com

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Background
Transient voice change associated with endotracheal intubation has generally been attributed to vocal fold trauma.

Aim
The aim of this study was to examine the effects of short-term endotracheal intubation on the vocal fold vibratory pattern using videokymography in order to aid the early detection and prevention of these changes.

Participants and methods
This study was carried out on 40 patients who were scheduled for a variety of elective surgical procedures under general anesthesia. They were 26 males, ranging in age from 17 to 61 years, mean age of 36.4 ± 4.2 years, and 14 females ranging in age from 16 to 54 years, mean age of 34.6 ± 5.3 years. Evaluation of vocal functions was carried out at three intervals, 1 day before intubation, 1 day after extubation, and 1 week later. All patients were subjected to analysis of their complaints, auditory perceptual assessment of their voice, and assessment of vocal fold vibration using videokymography.

Results
Sixteen patients complained of postoperative voice change, ranging in severity from good in 11, moderate in four, and bad in one patient. After 1 week, five patients were still complaining of voice change, ranging from good in four to moderate in one. There was a positive significant correlation between the degree of voice change and both the duration of anesthesia and tube size. There was postextubation mild to moderate voice change in 12 patients. The pitch was decreased in nine patients, increased in two patients, and there was diplophonia in one patient. The loudness was fluctuating in eight patients and was decreased in four patients; after 1 week, there was an improvement in all the perceived parameters; however, persistent dysphonia was perceived in three patients. There was a positive significant correlation between the degree of dysphonia and both the duration of anesthesia and the tube size. The normal video mode of videokymography, performed 1 day after extubation, indicated evidence of traumatic laryngeal lesions in 15 patients. In the high-speed mode of videokymography performed before intubation, 1 day after extubation, and 1 week after extubation, a significant difference was found in most of the parameters when comparing before intubation and 1 day after extubation; also, a significant difference in all the parameters was found 1 day after extubation and 1 week after extubation, whereas a nonsignificant difference was found when comparing before intubation and 1 week after extubation. There was a significant positive correlation between both the duration of intubation and the tube size with the severity of voice complaint and grade of dysphonia. Also, there was a significant positive correlation between the aperiodicity in both the amplitude of mucosal wave and the glottal cycle time, and both the duration of intubation and the tube size in the dysphonic group.

Conclusion
Traumatic lesions of the laryngeal structures that occur during intubation, in addition to possible subepithelial changes, are the most common causes of postoperative dysphonia, with a tendency toward a regressive course of the resulting dysphonia. As such, it is important to establish an early diagnosis and adopt preventive measures.

Keywords:
dysphonia, endotracheal intubation, videokymography

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Introduction

Voice production is a complex process that involves more than one system and the human phonatory behavior requires more than simple oscillation of the vocal folds. Adequate breathing support and control are important to initiate the vocal signal, and resonance is required for proper amplification and projection of the sound. The power supply for vocal production may be affected in chest or abdominal surgery; yet, most causes of dysphonia are attributed to disturbances in the laryngeal structure and little attention is paid to extralaryngeal factors [1].

Patients often complain of transient dysphonia and dysphagia after undergoing procedures requiring endotracheal intubation; indeed, this complaint is so common, which may occur in anywhere from 14.4 to 50% of patients who have undergone tracheal intubation, that it is often considered part of the surgical experience. These symptoms are completely unpredictable and usually resolve within 12–72 h. Vocal changes associated with endotracheal intubation are generally assumed to be a result of vocal fold trauma [2].

Dysphonia or change in voice quality reported by patients following surgery is very often overlooked by the anesthesiologist and the treating physician. In view of its transient nature, no investigation for the causes of dysphonia is warranted despite the frequency of this condition. The diagnosis is always late and the etiology is invariably attributed to factors related to anesthesia [3].

The hazards of intubation have been well documented since the beginning of endotracheal anesthesia. Endotracheal intubation as a mode of administration of anesthetics for a surgical operation is associated with a significant rate of laryngeal damage and subsequent vocal pathology [4,5].

The postintubation voice change is generally assumed to be the result of laryngeal damage. Endotracheal intubation may produce various degrees of temporary and sometimes permanent damage to the laryngeal mechanism, ranging from microscopic alterations of the mucosal surfaces to gross tissue damage of the mucosa, connective tissues and muscles, to dislocation of the laryngeal joints and vocal fold paralysis [6].

In many cases, dysphonia after intubation may be accompanied by a larynx that, on examination, appears normal in structure. However, such dysphonia may result from altered biomechanical properties of the vocal folds and subepithelial histopathological changes [7].

Research has begun to delineate the extent to which the vocal waveform characteristics are altered by endotracheal intubation by Horii and Fuller [8], and Yonick *et al.* [9].

Special methods are necessary to facilitate observation of the vocal fold vibration; one of these methods is videokymography, which is a high-speed imaging technique for the investigation of vocal fold vibration. This system uses a special modified video camera that is able to work in two modes: normal-speed and high-speed modes. In the normal mode, the system functions as a normal commercial video camera providing 50 images/s, whereas in the high-speed mode, the camera selects just a single line from the entire image and monitors it at a rate of 7812.5 images/s. This rate allows the examination of all kinds of vocal folds' vibratory patterns [10].

Aim of the work

The aim of this study was to examine the effects of short-term endotracheal intubation on the vocal fold vibratory pattern using videokymography in order to aid the early detection and prevention of these changes.

Participants and methods

This study was carried out on 40 patients who were scheduled for a variety of elective surgical procedures under general anesthesia. They were 26 males, ranging in age from 17 to 61 years, mean age 36.4 ± 4.2 years, and 14 females, ranging in age from 16 to 54 years, mean age 34.6 ± 5.3 years. The patients were selected according to the following criteria:

(1) Free from any current or previous voice complaints.
(2) Did not undergo head and neck surgery during the last year.
(3) Current surgery is selected from those categories that would not affect the vocal tract or the abdominal breath support such as otologic, ocular, or plastic surgery.

The patients had undergone general anesthesia with endotracheal intubation, of the (Rusch) type, with a size ranging from 6.5 to 8.5 mm. The duration of intubation ranged from 25 min to 5 h (average intubation time 1 h, 50 min; SD = 0.88). A variety of anesthetic techniques were used and a variety of endotracheal tube sizes and materials were used. The anesthetist involved in each case was required to fill a form involving the premedication agents, anesthetic agents, the degree of relaxation, duration of intubation, and the size of the endotracheal tube.

Evaluation of vocal functions was carried out in the Unit of Phoniatrics, Ain Shams University, at three intervals: 1 day before intubation, 1 day after extubation, and 1 week later. The following assessment protocol was used to assess the vocal functions:

Patient interview

(1) Personal data.
(2) Analysis of patient's complaint (patient's own rating of severity) on a scale from 1 to 5, with 1 being very good and 5 being very bad.

Auditory perceptual assessment

The subjective impression (perceptual judgment) of the patient's voice was assessed by three expert phoniatricians using a modified GRBAS scale [11] [overall grade or severity (G), roughness of the voice (R), breathiness (B), asthenia (A), and strain (S)]. The degree of dysphonia was graded according to a 0–3 scale, where 0 is normal, 1 indicates mild dysphonia, 2 indicates moderate dysphonia, and 3 indicates severe dysphonia. The auditory perceptual assessment was documented by voice recording, which was carried out in a sound-treated room using a high-fidelity computerized audio recording system.

Laryngeal visualization

Visual augmentation and documentation of the larynx was carried out by a videokymography setup using the following: (a) a Kay Elemetrics Stroboscope set (RLS 9100; Kay Elemetrics Corp., New Jersey, USA), which consists of a Colored camera (PanasonicWV-KS-152), a Videorecorder (Mitsubishi; Mitsubishi Electric Corp., Japan), and a screen; (b) a continuous nonstroboscopic light source for illumination (halogen light); (c) a 90° rigid oral endoscope (Kay 9105); and (d) a high-speed digital Lambert Linescan camera for Videokymography (JVC, Jx 5100), with a pedal to switch the normal camera mode to the high-speed camera mode. The endoscope was placed so that the top line of the video image was positioned transverse to the desired section of the vocal folds (typically the middle of the vocal folds). Therefore, the active line was at the upper border of the screen, perpendicular to the glottal axis [12]. The selected line of the examination was the middle of the membranous vocal fold, which is the most vibrating part of the vocal fold. The outline borders of the chosen cycles from this selected scanned line were outlined manually to ensure accuracy in measurements. Thereafter, the parameters were extracted automatically using the software.

Procedure

(1) Each patient was asked to phonate a prolonged/a/ vowel at a comfortable pitch and loudness.
(2) The record 'button' was pressed.
(3) Once the scope was positioned properly, the footswitch was pressed to activate the high-speed (Linescan) mode of viewing the vocal folds while the patient was phonating.
(4) The clinician had to switch frequently (using the footswitch) between the normal video mode and the high-speed mode to ascertain the scope's position.
(5) The screen was divided into four parts by choosing a four-frame full image of the recording. This was to obtain the maximum number of glottal cycles as possible.
(6) The analogue videokymography patterns were captured and saved as a digital image by the Kay Elemetrics Stroboscopic set.
(7) The digital images were converted into a set of digital signals to be analyzed.
(8) The time-based parameters (open phase, closed phase, open quotient, closed quotient, opening time, and closing time) were all measured in milliseconds, whereas the maximum amplitude on each side and the maximum width were measured by means of pixels, and the following data were extracted automatically:
   (a) Closed phase (ms): the time at which the vocal folds are closed.
   (b) Open phase (ms): the time at which the vocal folds are opened.
   (c) Glottal cycle time (wavelength) (ms): the total time taken by both phases of the glottic cycle, the closed, and open phases.
   (d) Open quotient: it is the open phase divided by the total cycle.
   (e) Closed quotient: it is the closed phase divided by the total cycle.
   (f) Opening time (ms): the time at which the vocal folds are in the process of opening.
   (g) Closing time (ms): the time at which the vocal folds are in the process of closing.
   (h) Maximum amplitude on both sides (pixels): it is the maximum value of the glottal area on either side of an imaginary midline of the glottis during the opening phases.
   (i) Maximum width (in pixels): it is the maximum value of the entire glottal area during the opening phase.
   (j) Symmetry: It is based on the degree to which the vocal folds provide a mirror image to one another during vibration in terms of both amplitude and cycle phase.
   (k) Periodicity: It is based on the regularity of the successive cycles in terms of the wavelength (the time of the total open and the closed phases) and the amplitude (the lateral excursion of the vocal fold mucosa). Data were collected, verified, and then edited on a personal computer.

The data were analyzed statistically using the Statistical Package for Social Sciences program version 17 (SPSS Inc., Chicago, Illinois, USA). Quantitative data were presented as the mean and the SD. A paired Student's *t*-test was used to compare the preintubation and postintubation scores. The significance of the results was evaluated by probability, where *P* value greater than 0.05 indicates an insignificant difference and *P* value less than 0.05 indicates a significant difference. The correlation between nonparametric variables was determined using the Spearman rank correlation coefficient.

Results

Patients' self-rating of severity

Sixteen patients complained of postoperative voice change, ranging in severity from good in 11 patients (27.5%) to moderate in four patients (10%) and bad in one patient (2.5%). After 1 week, five patients still complained of voice change, ranging from good in four patients (10%) to moderate in one patient (2.5%) (Table 1).

Table 1 Patients' self-rating of severity in voice change

	N (%)				
Degree	Very good	Good	Moderate	Bad	Very bad
Before intubation	40 (100%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)
One day after extubation	24 (60%)	11 (27.5%)	4 (10%)	1 (2.5%)	0 (0%)
One week after extubation	35 (87.5%)	4 (10%)	1 (2.50%)	0 (0%)	0 (0%)

Auditory perceptual assessment

One day after extubation, there was mild to moderate voice change in 12 patients (30%), strained and leaky voice quality was perceived in four patients (10%), strained voice was perceived in seven patients (17.5%), whereas breathy quality was perceived in one patient (2.5%). Irregular quality was perceived in eight patients (20%). The pitch was decreased in nine patients (22.5%), increased in two patients (5%), and diplophonia was present in one patient (2.5%). The loudness was fluctuating in eight patients (20%) and decreased in four patients (10%); after 1 week, there was an improvement in all the perceived parameters; however, persistent dysphonia was perceived in three patients (7.5%), mild in two patients (5%) and moderate in one patient (2.5%) (Table 2).

Spearman's correlation was performed between the duration of anesthesia and the tube size with the severity of voice complaint. There was a positive significant correlation between the degree of voice change and both the duration of anesthesia and the tube size (Table 3). Also, Spearman's correlation was determined between the duration of anesthesia and tube size with the degree of dysphonia. There was a positive significant correlation between the degree of dysphonia and both the duration of anesthesia and the tube size (Table 3).

Laryngeal videokymography

The normal video mode of videokymography used before intubation showed that all the patients were free from any laryngeal lesions. One day after extubation, it indicated evidence of traumatic laryngeal lesions in 15 patients (37.5%). The types of lesions were vocal fold congestion (in 11 patients), increased vascular markings (in six patients), vocal fold edema (in five patients), and vocal fold ulceration (in three patients) (Fig. 1). One week after extubation, residual lesions were still present in three patients (7.5%), mild vocal fold edema in two patients and vocal fold congestion in one patient (Figs 2–8).

The high-speed mode of videokymography performed before intubation, 1 day after extubation, and 1 week after extubation was used to assess time-based parameters (open phase, closed phase, open quotient, closed quotient, opening time, closing time), all measured in milliseconds, and the maximum amplitude on each side and the maximum width, measured in pixels. In addition, a comparison was carried out between the parameters reflecting the symmetry of vocal fold vibrations, namely, opening time difference, closing time difference, maximum width difference, and phase shift. Comparison between all parameters, before intubation and 1 day after extubation, indicated a significant difference in all the parameters, except for closing time right and closing time

Table 2 Postextubation auditory perceptual assessment

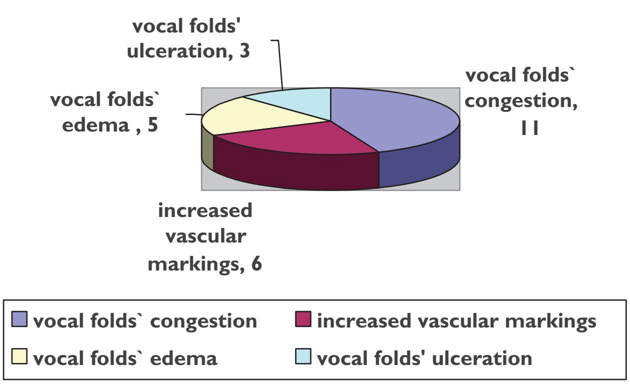
	N (%)			
Gradings	Normal (0)	Mild (1)	Moderate (2)	Severe (3)
Overall grade				
After 1 day	28 (70%)	9 (22.5%)	3 (7.5%)	0 (0%)
After 1 week	37 (92.5%)	2 (5%)	1 (2.5%)	0 (0%)
Strained				
After 1 day	33 (82.5%)	5 (12.5%)	2 (5%)	0 (0%)
After 1 week	39 (97.5%)	1 (2.5%)	0 (0%)	0 (0%)
Leaky				
After 1 day	33 (82.5%)	7 (17.5%)	2 (5%)	1 (2.5%)
After 1 week	39 (97.5%)	1 (2.5%)	0 (0%)	1 (2.5%)
Breathy				
After 1 day	39 (97.5%)	1 (2.5%)	0 (0%)	0 (0%)
After 1 week	40 (100%)	0 (0%)	0 (0%)	0 (0%)
Irregular				
After 1 day	32 (80%)	5 (12.5%)	2 (5%)	1 (2.5%)
After 1 week	37 (92.5%)	2 (5%)	1 (2.5%)	0 (0%)
Pitch	Normal	Increased	Decreased	Diplophonia
After 1 day	28 (70%)	2 (50%)	9 (22.5%)	1 (2.5%)
After 1 week	36 (90%)	0 (0%)	3 (7.5%)	1 (2.5%)
Loudness	Normal	Increased	Decreased	Fluctuating
After 1 day	28 (70%)	0 (0%)	4 (10%)	8 (20%)
After 1 week	35 (87.5%)	0 (0%)	2 (5%)	3 (7.5%)

Table 3 Correlation between the duration of anesthesia and tube size with the severity of voice complaint and degree of dysphonia

	Severity of voice complaint	Degree of perceived dysphonia
Duration of anesthesia	0.343*	0.356*
Tube size	0.402*	0.318*

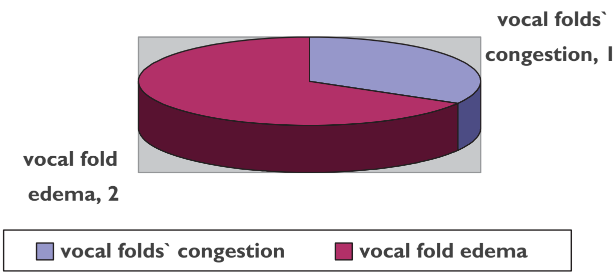
*$P < 0.05$; significant correlation.

Figure 1



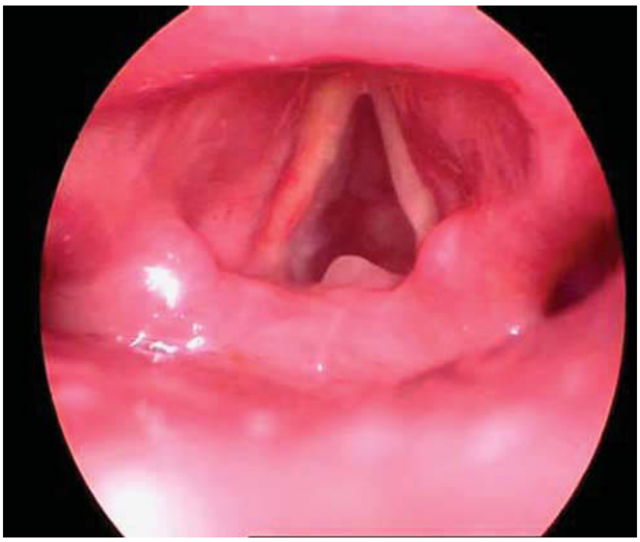
Distribution of laryngeal lesions 1 day after extubation.

Figure 2



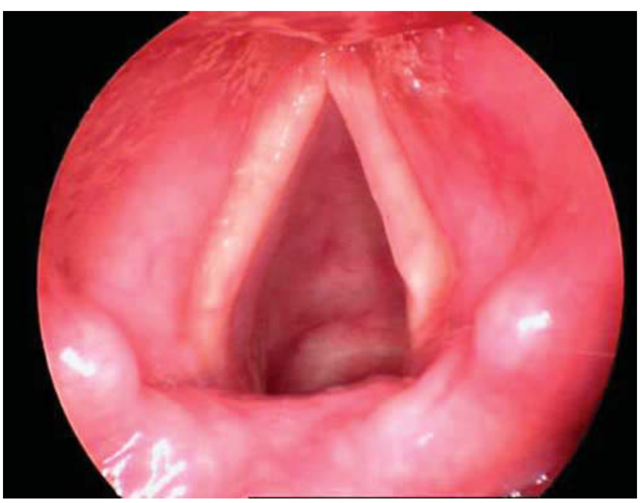
Distribution of laryngeal lesions 1 week after extubation.

Figure 3



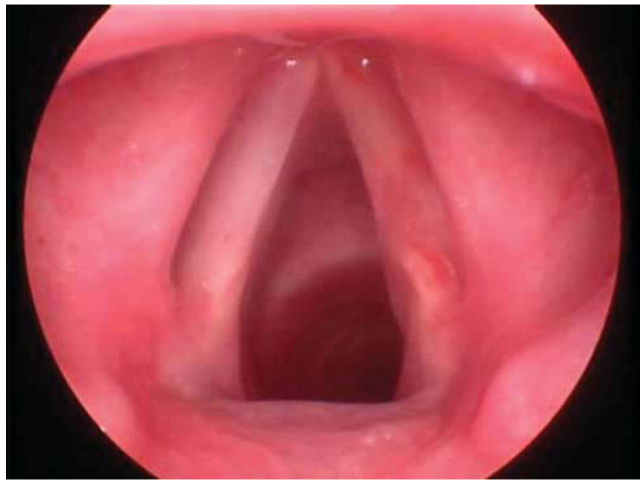
Vocal fold congestion (1 day after extubation).

Figure 4



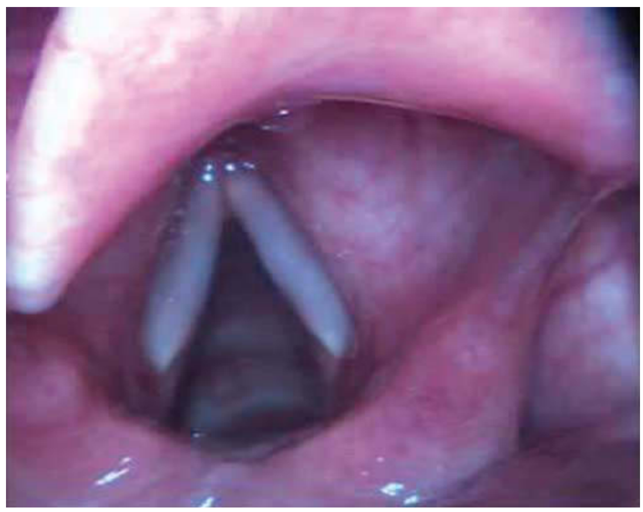
Same cases showing subsidence of the congestion (1 week after extubation).

Figure 5



Right vocal fold erythema (1 day after extubation).

Figure 6



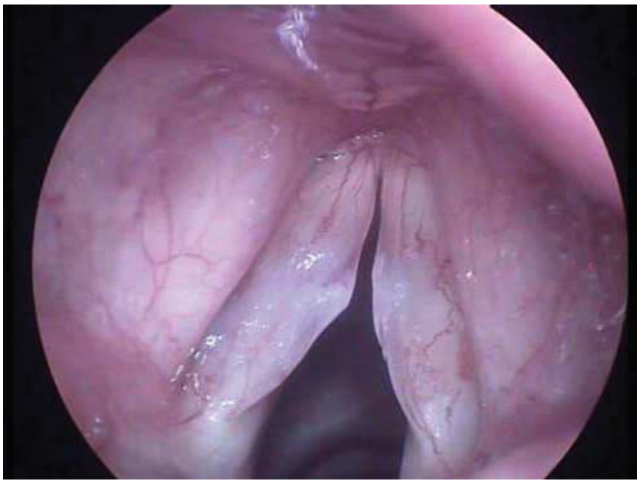
Same case showing resolution of the erythema (1 week after extubation).

left, for which a nonsignificant difference was found. Comparison between parameters indicating symmetry, before intubation and 1 day after extubation, indicated a significant difference in all the parameters, except for closing time difference. Comparison between all parameters, 1 day after extubation and 1 week after extubation, indicated a significant difference in all the parameters. Comparison between parameters reflecting symmetry, 1 day after extubation and 1 week after extubation, indicated a significant difference in all the parameters. Comparison between all parameters, before intubation and 1e week after extubation, indicated a nonsignificant difference in all the parameters. Comparison between parameters reflecting symmetry, before intubation and 1 week after extubation, indicated a nonsignificant difference in all the parameters (Tables 4–9 and Figs 9–11).

Effects of duration of anesthesia and tube size

The Spearman correlation coefficient was determined between the duration of intubation and tube size with

Figure 7



Showing bilateral edema of vocal folds with congestion (1 day after extubation).

Figure 8

Same case showing persistent mild edema and congestion of both vocal folds (1 week after extubation).

the severity of voice complaint and grade of dysphonia in the dysphonic group. There was a significant positive correlation between both the duration of intubation and the tube size with the severity of voice complaint and grade of dysphonia (Table 10). Also, there was a significant positive correlation between the aperiodicity in both the amplitude of mucosal wave and the glottal cycle time, and both the duration of intubation and the tube size in the dysphonic group (Table 11).

Discussion

Endotracheal intubation was first described in 1878 by MacEwen [13], but was not advocated for general anesthesia until 1910 by Elsberg [14]. It has since become one of the most common procedures performed in modern medical science [15]. The hazards of intubation have been well documented since the beginning of endotracheal anesthesia. Laryngeotracheal injuries have been a major concern for laryngologists. However, most of the concerns have been centered on the sequelae of prolonged intubation. In contrast, lesions secondary to short-term intubation have been discussed less extensively. Thus, reliable studies on the impact of short-term intubation on voice, particularly as part of general anesthesia, are scarce [16].

Dysphonia or change in voice quality reported by the patient following surgery is very often overlooked by the anesthesiologist and the treating physician. In view of its transient nature, no investigation of the causes of dysphonia is warranted despite the frequency of this condition. The diagnosis is always late and the etiology is invariably attributed to factors related to anesthesia [3].

In the present study, an attempt was made to examine and monitor the effects of short-term endotracheal intubation on voice in a group of patients undergoing surgery, by analyzing the patient's complaint, auditory perceptual judgment of the patients' voice, and assessment of vocal fold vibratory cycle using videokymography.

In terms of postintubation voice complaints, there is a large variation in its reported incidence. It has generally been reported to occur in between 4% [5] and 42% [17] of patients. The incidence in our study was 40%. This wide range of incidence may be attributed to the subjective nature of the complaint and the lack of consistency in the way this complaint was assessed.

Several studies have attempted to identify the causative factors of voice complaints. In this study, the incidence of voice complaints was found to be correlated positively to the duration of anesthesia, which is in agreement with the result of Jones *et al.* [18], who reported that the incidence of dysphonia following short-term tracheal intubation varies widely; it has been reported as being permanent in 3%. Jones *et al.*'s [18] study confirms a low incidence of prolonged or permanent dysphonia following short-term tracheal intubation. Also, the incidence of voice complaint was found to be positively correlated to the size of the tube, which is in agreement with the findings of Stout *et al.* [19], who studied the incidence of sore throat and dysphonia following general anesthesia, and found a positive correlation between the postoperative dysphonia endotracheal tube size. This may be explained by the fact that the longer the tube is kept in place, the greater the vocal fold affection, and the larger the size of the tube, the higher the deformation pressure exerted on the mucosal covering of the vocal fold.

Auditory perceptual assessment of the patient's voice indicated the presence of postintubation dysphonia. The results of our study described the postintubation dysphonia mainly as being of mild-to-moderate grade and irregular quality, with lower pitch and fluctuating

Table 4 Comparison between all parameters before intubation and 1 day after extubation

Parameters	Mean ± SD		*P*	Significance
	Before intubation	One day after extubation		
Closed phase	2.27 ± 0.71	1.98 ± 0.68	< 0.05	S
Open phase	2.17 ± 0.63	1.88 ± 0.7	< 0.05	S
Glottal cycle time	4.36 ± 1.18	4.81 ± 1.29	< 0.05	S
Open quotient	0.47 ± 0.05	0.42 ± 0.09	< 0.05	S
Closed quotient	0.49 ± 0.04	0.51 ± 0.08	< 0.05	S
Opening time right	0.89 ± 0.23	1.1 ± 0.89	< 0.05	S
Opening time left	0.97 ± 0.22	1.2 ± 0.13	< 0.05	S
Closing time right	1.03 ± 0.31	1.07 ± 0.66	> 0.05	NS
Closing time left	1.09 ± 0.27	1.2 ± 0.65	> 0.05	NS
Maximum amplitude right	25.7 ± 12.97	22.8 ± 7.54	< 0.05	S
Maximum amplitude left	27.5 ± 11.65	25.9 ± 6.65	< 0.05	S
Maximum width	53.4 ± 19.2	47.02 ± 9.1	< 0.05	S

S, significant.

Table 5 Comparison between parameters reflecting symmetry before intubation and 1 day after extubation

Parameters	Mean ± SD		*P*	Significance
	Before intubation	One day after extubation		
Opening time difference	0.03 ± 0.07	0.24 ± 0.37	< 0.05	S
Closing time difference	0.01 ± 0.05	0.01 ± 0.24	> 0.05	NS
Maximum width difference	0.1 ± 1.7	1.3 ± 0.9	< 0.05	S
Phase shift	0.04 ± 0.02	0.37 ± 0.29	< 0.05	S

S, significant.

Table 6 Comparison between all parameters 1 day after extubation and 1 week after extubation

Parameters	Mean ± SD		*P*	Significance
	One day after extubation	One week after extubation		
Closed phase	1.98 ± 0.68	2.25 ± 0.61	< 0.05	S
Open phase	1.88 ± 0.7	2.07 ± 0.43	< 0.05	S
Glottal cycle time	4.81 ± 1.29	4.71 ± 1.26	< 0.05	S
Open quotient	0.42 ± 0.09	0.47 ± 0.13	< 0.05	S
Closed quotient	0.51 ± 0.08	0.48 ± 0.04	< 0.05	S
Opening time right	1.1 ± 0.89	0.87 ± 0.41	< 0.05	S
Opening time left	1.2 ± 0.13	0.95 ± 0.31	< 0.05	S
Closing time right	1.07 ± 0.66	0.88 ± 0.41	< 0.05	S
Closing time left	1.2 ± 0.65	0.96 ± 0.25	< 0.05	S
Maximum amplitude right	22.8 ± 7.54	25.1 ± 13.84	< 0.05	S
Maximum amplitude left	25.9 ± 6.65	26.7 ± 12.58	< 0.05	S
Maximum width	47.02 ± 9.1	52.7 ± 17.4	< 0.05	S

S, significant.

Table 7 Comparison between parameters reflecting symmetry 1 day after extubation and 1 week after extubation

Parameter	Mean ± SD		*P*	Significance
	One day after extubation	One week after extubation		
Opening time difference	0.24 ± 0.37	0.06 ± 0.05	< 0.05	S
Closing time difference	0.01 ± 0.24	0.52 ± 0.04	< 0.05	S
Maximum width difference	1.3 ± 0.9	0.1 ± 1.8	< 0.05	S
Phase shift	0.37 ± 0.29	0.04 ± 0.05	< 0.05	S

S, significant.

loudness. Similarly, Beckford *et al.* [3] reported a mild degree of postoperative dysphonia and increased roughness or breathiness along with reduced loudness and minimal pitch variation in a group of 10 patients undergoing short-term outpatient surgical procedures under general anesthesia and endotracheal intubation.

In the current study, the overall grade of dysphonia was related to the duration of anesthesia. This is in agreement with Lesser and Lesser [20], who studied pre-endotracheal and postendotracheal intubation using laryngographs, and found a postoperative change in voice that was correlated with the length of intubation.

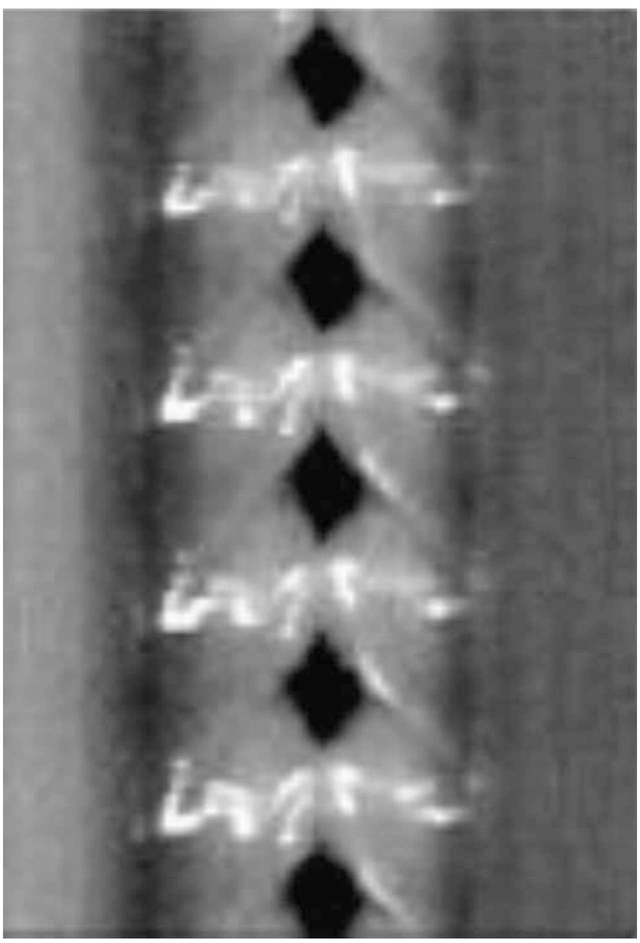
Table 8 Comparison between all parameters before intubation and 1 week after extubation

Parameters	Mean ± SD		*P*	Significance
	Before intubation	One week after extubation		
Closed phase	2.27 ± 0.71	2.25 ± 0.61	> 0.05	NS
Open phase	2.17 ± 0.63	2.07 ± 0.43	> 0.05	NS
Glottal cycle time	4.36 ± 1.18	4.71 ± 1.26	> 0.05	NS
Open quotient	0.47 ± 0.05	0.47 ± 0.13	> 0.05	NS
Closed quotient	0.49 ± 0.04	0.48 ± 0.04	> 0.05	NS
Opening time right	0.89 ± 0.23	0.87 ± 0.41	> 0.05	NS
Opening time left	0.97 ± 0.22	0.95 ± 0.31	> 0.05	NS
Closing time right	1.03 ± 0.31	0.88 ± 0.41	> 0.05	NS
Closing time left	1.09 ± 0.27	0.96 ± 0.25	> 0.05	NS
Maximum amplitude right	25.7 ± 12.97	25.1 ± 13.84	> 0.05	NS
Maximum amplitude left	27.5 ± 11.65	26.7 ± 12.58	> 0.05	NS
Maximum width	53.4 ± 19.2	52.7 ± 17.4	> 0.05	NS

Table 9 Comparison between parameters reflecting symmetry before intubation and 1 week after extubation

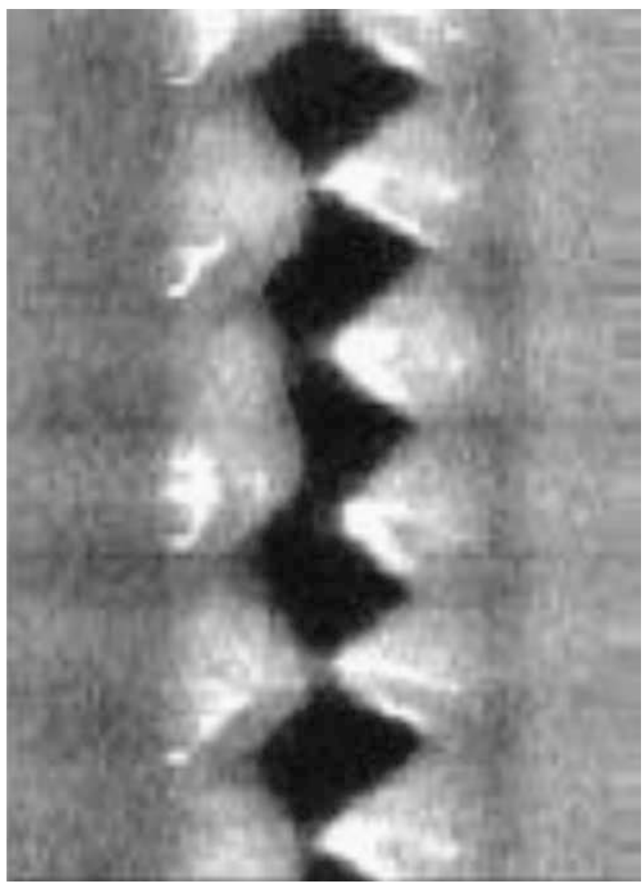
Parameters	Mean ± SD		*P*	Significance
	Before intubation	One week after extubation		
Opening time difference	0.03 ± 0.07	0.06 ± 0.05	> 0.05	NS
Closing time difference	0.01 ± 0.05	0.52 ± 0.04	> 0.05	NS
Maximum width difference	0.1 ± 1.7	0.1 ± 1.8	> 0.05	NS
Phase shift	0.04 ± 0.02	0.04 ± 0.05	> 0.05	NS

Figure 9



Preintubation kymography showing symmetry in phase and amplitude.

Figure 10



Postintubation asymmetry in amplitude.

Figure 11

Postintubation asymmetry in phase.

Table 10 Correlation between both the duration of intubation and tube size with the grade of dysphonia and severity of voice complaint in the dysphonic group

	Grade of dysphonia	Severity of voice complaint
Duration of anesthesia	$r=0.89$ (significant correlation)	$r=0.75$ (significant correlation)
Tube size	$r=0.82$ (significant correlation)	$r=0.84$ (significant correlation)

Table 11 Correlation between the aperiodicity in both the amplitude of the mucosal wave and glottal cycle time, and both the duration of intubation and the tube size in the dysphonic group

	Aperiodicity in amplitude	Aperiodicity in the glottal cycle time
Duration of anesthesia	$r=0.9$ (significant correlation)	$r=0.81$ (significant correlation)
Tube size	$r=0.85$ (significant correlation)	$r=0.79$ (significant correlation)

The postoperative change in voice was seen as an increase in the spread of the lower frequencies and an increase in the fundamental. Moreover, the size of the endotracheal tube was found to be correlated with the overall grade of dysphonia. This finding is in agreement with that of Hamdan *et al.* [21], who studied vocal symptoms and acoustic changes perceived in the short period after endotracheal intubation, in an attempt to find an association between these changes and the endotracheal tube parameters, and found a positive correlation between the degree of perceived dysphonia and the endotracheal tube size.

In terms of the nature of the postintubation vocal fold pathological lesions, our study found laryngeal affection in the form of vocal fold congestion, increased vascular markings, vocal fold edema, and ulceration, identified in 15 patients (37.5%). The greatest damage to the mucosa occurs at the presumed site of direct tube–mucosal contact in the posterior glottis, which is subjected to dynamic shearing forces resulting from the to and fro movements of the tube with each respiratory cycle or because of the ventilator pushing many times against the thin mucosal covering. Holzki [22] studied lesions in the respiratory tract related to intubation in children, and found that they occurred in 20% of cases. This percentage increases if the caliber of the endotracheal tube is larger; in fact, according to the author, they are the main cause of laryngeotracheal trauma. Hence, the choice of the endotracheal tube's diameter is another important point to consider. Because of the V-shape of the glottis, the posterior part of the larynx will be in close contact with the tube. When large-caliber endotracheal tubes are used, this region may develop ischemia caused by compression of the tube on the mucosal layer. In these cases, necrosis and superficial ulceration of the mucous layer may be observed immediately following extubation.

Assessment of vocal fold vibration can be carried out using several techniques. The most commonly used ones are stroboscopy and the more recent one is videokymography, which is useful as it can assess irregular oscillations of the vocal folds, providing an excellent spatial resolution and an excellent image rate, with the ability to objectify and describe in a simple manner most of the basic features of the vocal fold vibration. In addition, it allows the study of the phase differences between the left and the right vocal folds [23].

The postoperative videokymographic assessment of vocal fold vibration in this study showed deviations of the mucosal wave. These might be the underlying pathophysiological correlates of the perceived features of dysphonia. Asymmetrical vocal fold vibration may give rise to irregular voice quality, whereas the incomplete glottic closure may produce a breathy or a leaky voice quality. However, the reduced amplitude of lateral excursion (mucosal wave propagation) may be a correlate of the perceived decreased and fluctuating loudness. This is in agreement with the results obtained on the effects of short-term endotracheal intubation on vocal function of a study carried out previously by Beckford *et al.* [3], who studied the effects of short-term endotracheal intubation on vocal functions in 10 patients scheduled for outpatient gynecological procedures under general anesthesia. Also, Preschel and Eysholdt's [24] studies reported a decrease in the mucosal waves and propagation in patients following endotracheal intubation. Also, Aref *et al.* [25], in their study aimed at the assessment of the short-term effects of endotracheal intubation, found postoperative stroboscopic deviations in the form of asymmetrical vocal fold vibration and incomplete glottic closure in addition to reduced amplitude of the mucosal wave.

However, the changes observed in the mucosal wave after intubation could be independent of any intrinsic change in the vocal fold morphology, as the gross laryngeal pathology is located posteriorly away from the phonatory glottis. Therefore, intrinsic laryngeal trauma cannot be considered the only factor that explains the mechanism of postintubation vocal changes. Hence, other factors such as breathing support, which may be decreased postoperatively either because of musculoskeletal tenderness or pain, may be potentially responsible for the pathogenesis of kymographic changes and the resultant voice change.

Histologically, Hilding [26] has described subepithelial changes including desquamation, disarray, and cleavage of epithelium in postintubated vocal folds. Moreover, Leonard *et al.* [7] found microscopic evidence of damage, particularly subepithelial. This damage was found to extend well anterior to the expected site of maximal tube contact along the membranous portion of the vocal folds. This indicates that if the damage is apparent on clinical examination, the actual extent of the injury may be greater and includes portions of the vocal folds critical for phonation.

Leonard *et al.* [7] and Hamdan *et al.* [21] reported that the violation of this subepithelial structural layer by aggressive intubation may result in stiffness of the vocal fold and subsequent persistent dysphonia.

However, restricted ventilation after general anesthesia resulting from musculoskeletal tenderness because of the paralyzing agents and postoperative exhaustion in the patient may be responsible for some changes in perceived vocal and videokymographic deviations associated with general anesthesia [27].

Sparse information is available on the time course of postintubation dysphonia. It was assumed that the post-intubation abnormal features reverted to normal within 1 week. In the current study, the parameters of the objective and subjective modalities were measured 1 week after extubation. The results indicated a tendency toward a regressive course of the resulting dysphonia, vocal fold pathology, and videokymographic deviations of the glottal cycle. Moreover, a mild-to-moderate degree of dysphonia was found in three patients who showed persistent videkymographic changes in the mucosal wave. Consequently, a period of 1 week is a critical time for the postintubation vocal dysfunction to resume its postoperative normal function.

Conclusion and recommendations

The results of the present study indicate that there is a need to inform patients scheduled for general anesthesia by the possible postoperative voice change that could last longer than 1 day. Furthermore, surgeons and anesthesiologists should take into consideration the adverse effects that the duration of anesthesia and tube size might exert on voice postoperatively. Furthermore, it is important to make an early diagnosis by following the protocol of assessment of voice for patients with dysphonia postoperatively; moreover, it would be prudent to adopt preventive measures such as the use of proper tube size, use of intraoperative steroids in cases of difficult intubation to minimize vocal fold edema, and involve experts in cases of difficult intubation, or the use of fiberoptic intubation to avoid rough maneuvers such as the use of introducers (boojie), which might injure the vocal folds.

Acknowledgements

Conflicts of interest

There are no conflicts of interest.

References

1 Sung MW, Kim KH, Koh TY, Kwon TY, Mo JH, Choi SH, *et al.* Videostrobokymography: a new method for the quantitative analysis of vocal fold vibration. Laryngoscope 1999; 109:1859–1863.
2 Hedden M, Ersoz CJ, Donnelly WH, Safar P. Laryngotracheal damage after prolonged use of orotracheal tubes in adults. JAMA 1969; 207: 703–708.
3 Beckford NS, Mayo R, Wilkinson A, Tierney M. Effects of short-term endotracheal intubation on vocal function. Laryngoscope 1990; 100: 331–336.
4 Harris TM, Johnston DF, Collins SRC, Heath ML. A new general anaesthetic technique for use in singers: the brain laryngeal mask airway versus endotracheal intubation. J Voice 1990; 4:81–85.
5 Jones MW, Catling S, Evans E, Green DH, Green JR. Hoarseness after tracheal intubation. Anaesthesia 1992; 47:213–216.
6 Sataloff RT, Bough ID Jr, Spiegel JR. Arytenoid dislocation: diagnosis and treatment. Laryngoscope 1994; 104 (Pt 1): 1353–1361.
7 Leonard R, Senders C, Charpied G. Effects of long term intubation on vocal fold mucosa in dogs. J Voice 1992; 6:86–93.
8 Horii Y, Fuller BF. Selected acoustic characteristics of voices before intubation and after extubation. J Speech Hear Res 1990; 33:505–510.
9 Yonick TA, Reich AR, Minifie FD, Fink BR. Acoustical effects of endotracheal intubation. J Speech Hear Disord 1990; 55:427–433.
10 Svec JG, Schutte HK, Sram F. Videokymography: high-speed line scanning of vocal fold vibration. Proceedings of XVI World Congress of Otorhinolaryngology, Head and Neck Surgery; Sydney, Australia; 1997. pp. 1685–1688.
11 Kotby MN. Voice disorders; recent diagnostic advances. Egypt J Otolaryngol 1986; 3:69–98.
12 Svec JG, Schutte HK, Sram F. Instructional course: videokymography. XVII World IFOS Congress, Cairo, Egypt; 2002.
13 Macewen W. Clinical observations on the introduction of tracheal tubes by the mouth, instead of performing tracheotomy or laryngotomy. BMJ 1880; 2:163–165, Quoted from Stoeltuing (1986).
14 Elsberg C. Clinical experience with intratracheal insufflation (Meltzer), with remarks upon the value of the method for thoracic surgery. Ann Surg 1910; 52:23–39, Quoted from Lesser and Williams (1988).
15 Gleeson MJ, Fourcin AJ. Clinical analysis of laryngeal trauma secondary to intubation. J R Soc Med 1983; 76:928–932.
16 Ha IW, Kim MC, Lee SJ, Kim AR, Chang JS, Jun BH, Choi IS. Effects and related factors of endotracheal intubation on voice change following general anesthesia. Korean J Otorhinolaryngol Head Neck Surg 2011; 54:137–141.
17 Stock MC, Downs JB. Lubrication of tracheal tubes to prevent sore throat from intubation. Anesthesiology 1982; 57:418–420.
18 Jones GO, Hale DE, Wasmuth CE, Homi J, Smith ER, Viljoen J. A survey of acute complications associated with endotracheal intubation. Cleve Clin Q 1968; 35:23–31.
19 Stout DM, Bishop MJ, Dwersteg JF, Cullen BF. Correlation of endotracheal tube size with sore throat and hoarseness following general anesthesia. Anesthesiology 1987; 67:419–421.

20 Lesser TH, Lesser PJ. Laryngeal trauma vs length of intubation. J Laryngol Otol 1987; 101:1165–1167.

21 Hamdan AL, Sibai A, Rameh C, Kanazeh G. Short-term effects of endotracheal intubation on voice. J Voice 2007; 21: 762–768.

22 Holzki J. Laryngeal damage from tracheal intubation. Paediatr Anaesth 1997; 7:435–437.

23 Svec JG, Sram F, Schutte HK. Videokymography: a new high-speed method for the examination of vocal-fold vibrations. Otorinolaryngologie a Foniatrie 1999; 48:155–162.

24 Preschel U, Eysholdt U. Short-term changes of larynx and voice after intubation. Laryngorhinootologie 1993; 72:93–97.

25 Aref EM. Effects of short-term endotracheal intubation on vocal function: a multidimensional study [MD thesis]. Cairo, Egypt: Faculty of Medicine, Ain Shams University; 1996; Unpublished.

26 Hilding AC. Laryngotracheal damage during intratracheal anesthesia. Demonstration by staining the unfixed specimen with methylene blue. Ann Otol Rhinol Laryngol 1971; 80:565–581.

27 Schutte HK. Integrated aerodynamic measurements. Journal of Voice 1992; 6:127–134.