12 – ORIGINAL ARTICLE
CLINICAL INVESTIGATION

Correlation of intraluminal esophageal pressure with the dynamic extension of tracheoesophageal voice in total laryngectomees[1]

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ABSTRACT

PURPOSE: To evaluate and correlate the amplitude of esophageal contractions triggered by swallowing water with dynamic extension and habitual, strong and weak sound intensity in total laryngectomees wearing a tracheoesophageal prosthesis.

METHODS: Thirty total laryngectomees using tracheoesophageal voice with a phonatory prosthesis were evaluated by measuring the amplitude of contractions in the proximal, middle and distal esophagus and the pressure of the pharyngoesophageal transition by manometry. In order to measure vocal intensity the subject was asked to emit phonation of the vowel /a/ at habitual, strong and weak intensity which was captured with a sound pressure meter. Dynamic extension was calculated by subtracting strong intensity from weak intensity.

RESULTS: A positive correlation was observed between contraction amplitude and dynamic extension in the proximal (rho: 0.45; p=0.01) and distal (rho: 0.41; p=0.02) esophagus There was no correlation with other parameters.. Total laryngectomees wearing a phonatory prosthesis with a dynamic extension above 21 dBNPS had greater contraction amplitude than laryngectomees with a dynamic extension below this value.

CONCLUSIONS: There was a positive correlation between pressure amplitude in the proximal and distal esophagus and increased dynamic extension. The individuals with normal dynamic extension had greater contraction amplitude in the proximal esophagus than individuals with dynamic extension lower than the expected values for age .

Key words: Speech, Alaryngeal. Manometry. Voice Quality.

Introduction

Since it was first described by Singer and Blom in 1980[1], voice rehabilitation for total laryngectomees with a tracheoesophageal prosthesis (TEP) has proved to be an excellent option for the patients.

Characteristics of tracheoesophageal voice and speech such as vocal intensity and dynamic extension have been studied in association with overall voice analysis, with different aerodynamic characteristics being tested for the various models of prostheses available[2-7]. However, there still is a lack of studies regarding the physiology of sound intensity and of dynamic extension for total laryngectomees since a lot remains to be determined about the production of tracheoesophageal voice, such as rhythm, modulation and characteristics of phonation intensity. Parameters such as loudness and pitch are often limited in laryngectomees, with consequences for the measurement of dynamic extension and fundamental frequency[8].

Physiologically, subglottic pressure is increased in individuals who produce laryngeal voice. The mechanism of regulation of phonation intensity in laryngectomees is not exactly known. The regulation of intensity during tracheoesophageal phonation seems to be influenced by occlusion of the stoma and by the characteristics of the phonatory prosthesis and of the esophagus, with the main advantage of a voice produced with a TEP compared to esophageal voice being that the lungs are the motor force for voice production[9-12].

The aerodynamic characteristics of tracheoesophageal voice production are determined by the aerodynamic factors of the prosthesis and by the characteristics of the esophagus and of the cricopharyngeal segment, which affect the determination of good and poor speakers[13-16]. However, it is still necessary to obtain data indicating which properties of the esophagus and of the cricopharyngeal segment specifically influence the vocal parameters.

In view of the lack of information about the intensity and dynamic extension of the voice of total laryngectomees wearing a TEP, correlating them with aspects of esophageal motility, the objective of the present study was to evaluate the dynamic extension and intensity of weak, strong and habitual phonation of tracheoesophageal voice and correlate them with intraluminal esophageal pressure.

Methods

The study was approved by the Research Ethics Committee of the Hospital, Protocol HCRP nº 14241/2009, and all subjects or persons responsible for them gave written informed consent to participate.

The study was conducted on 30 individuals submitted to total laryngectomy due to squamous cell carcinoma of the larynx and rehabilitated with tracheoesophageal voice using a Provox2® TEP with low resistance to air passage (Atos Medical AB, Sweden).

Thirty individuals (eight females and 22 males, mean age: 61 years) were recruited at the outpatient clinic for rehabilitation of laryngectomees on the occasion of their return visits. Five patients had been submitted to pharyngolaryngectomy and 25 to total laryngectomy, and mean postoperative time was six years. Six individuals had received primary placement of the TEP and 24 secondary placement. The number of speech therapy sessions for the acquisition of tracheoesophageal voice ranged from one to 21, with a mean of five sessions. The time of TEP use ranged from one to 12 years, with a mean of five years.

Individuals submitted to total laryngectomy and pharyngolaryngectomy due to squamous cell carcinoma between 1995 and 2000 were included in the study. Of these, only those who had closure of the mucosal, submucosal and muscular layers for pharynx reconstruction were selected. Total laryngectomees submitted to cervical dissection and adjuvant radiotherapy, speaking with primary or secondary TEP insertion, with digital occlusion were accepted for the study, regardless of the quality of phonation.

We excluded laryngectomees submitted to associated glossectomy or pelveglossectomy and to preventive or curative treatments for spasms and pharyngeal hypertonicity, i.e., neurectomy of the pharyngeal plexus, myotomy of the cricopharyngeal muscle, chemical denervation of the pharynx constrictor muscles with botulin toxin, or pharynx reconstruction without closure of the muscle layer. We also excluded total laryngectomees who presented cancer recurrence or metastases at the time of evaluation, a new primary head and neck tumor, and esophageal or gastrointestinal tract disease.

Also excluded were individuals with a complaint of dysphagia, with reduced hearing acuity and/or some type of cognitive impairment. The exclusion criteria were based on verbal questioning and analysis of the medical records of total laryngectomees.

Manometry

The individuals were submitted to manometry in order to obtain the amplitude of intraluminal esophageal pressure during swallowing. A silicone tube with eight-channels, each measuring 4 mm in outer diameter and 0.8 mm in inner diameter, was used. The four proximal channels were located at a distance of 5 cm from one another and were connected to pressure transducers with output to a BP 108® polygraph (Alacer Biomedica, Sao Paulo, Brazil). The manometry catheter was continuously perfused with filtered water at a flow of 0.5 ml/minute by a low compliance perfusion system.

After a 12 hour fast, the nostril of the patient was anesthetized with 2% lidocaine gel for the introduction of the manometry tube into the esophagus. The patient was then placed in horizontal dorsal decubitus and the outer ends of the eight channels of the tube were connected to the pressure transducers. The openings of the channels were positioned at 2, 7, 12 and 17 cm from the elevated pressure zone corresponding to the pharyngoesophageal transition. The recording of esophageal pressure was denoted proximal at 2 cm from the transition, middle at 12 cm, and distal at 17 cm.

After five minutes of stabilization, the patient was asked to perform ten swallows of 5 mL water at room temperature, with an interval of at least 30 second between swallows. The amplitude of contraction was measured in the proximal, middle and distal parts of the esophagus. The median amplitude for the ten swallows was calculated in the proximal, middle and distal esophagus, representing the amplitude for each individual. The pressure of the pharyngoesophageal transition was measured at the end of the ten swallows by the intermittent pull-through method, with the highest pressure observed at the transition being considered representative.

Sound intensity and dynamic extension

Sound signals were collected from the total laryngectomees in an acoustically treated room with mean environmental noise of 40 dBNPS measured with an Impac® IP-900-DL data logger Type II sound pressure meter (decibel meter). Air temperature was controlled at 22.3ºC and air relative humidity at 52%, measured with a digital thermohygrometer.

To measure the vocal intensity of the individuals, the sound pressure meter was connected to a computer and the measurements observed were registered with the aid of the program of sound intensity recording. The sound pressure meter used was Impac® IP-900-DL, which is authorized for scientific and expert research since its calibration follows the Norm NBR 10.151 of ABNT standard IEC-61672 Type 2.

The test for the calibration of the decibel meter was first performed, with the meter being configured for a level of sound pressure capture of 30 to 130 dBNPS, slow mode and unidirectional type of capture. With the decibel meter positioned one meter from the oral cavity, the laryngectomized patient was instructed to emit the sustained vowel /a/ for the capture of vocal intensity under three conditions:

- Habitual phonation: emission of the vowel /a/ at habitual intensity and frequency.
- Weak phonation: emission of the vowel /a/ as weakly as possible. Vocal recordings in the whispering range were not permitted.
- Strong phonation: emission of the vowel /a/ as strongly as possible. Vocal recordings in the crying range were not permitted.

Dynamic extension was calculated by subtracting strong phonation from weak phonation.

For analysis, the laryngectomees were divided into two groups: with dynamic extension above 21 dBNPS and with dynamic extension below 21 dBNPS.

Statistical analysis

The Shapiro-Wilk “W” test was first applied to determine the type of sample distribution and the best statistical analysis to be applied. Since the hypothesis of normality was rejected for all variables in at least one group, nonparametric tests were used, with the level of significance set at $p \leq 0.05$ in all analyses.

Dynamic extension and intensity data were correlated using the Spearman correlation coefficient [rho] which measures the intensity of relation between variables. Data for the two groups of laryngectomees were compared by the nonparametric Mann-Whitney test for two independent samples.

Results

Data regarding the intensity of tracheoesophageal voice observed in total laryngectomees during habitual, weak and strong phonation and the intensity of dynamic extension are listed in Table 1. Table 2 presents the pressure amplitude observed in the distal, middle and proximal esophagus and in the pharyngoesophageal transition.

TABLE 1 - Intensity of tracheoesophageal voice (dBNPS) in total laryngectomees wearing a tracheoesophageal prosthesis during habitual, strong and weak phonation and dynamic extension.

	Intensity of tracheoesophageal voice (dBNPS)		
	Mean ± SD	**Median**	**Range**
Habitual phonation	73.2 ± 7.05	73.8	54.7-89.3
Strong phonation	83.18 ± 9.27	83.81	63.5-106.5
Weak phonation	64.2 ± 5.87	64.45	54.5-81.05
Dynamic extension	18.98 ± 6.57	19.29	4.7-35.5

SD: Standard Deviation

TABLE 2 - Amplitude of esophageal pressure (mmHg) in the distal, middle and proximal esophagus of total laryngectomees wearing a tracheoesophageal prosthesis and in the pharyngoesophageal transition.

	Amplitude of esophageal pressure (mmHg)		
	Mean ± SD	**Median**	**Range**
Istal esophagus	49.1 ± 48.89	39.08	0-238.75
Middle esophagus	40.02 ± 36.53	34.9	0-165.4
Proximal esophagus	17.06 ±15.1	15.08	0-66.1
Pharyngoesophageal transition	18.88 ± 12.17	15.65	4.5-55

SD: Standard Deviation

Evaluation of the correlation between intraluminal esophageal pressure and phonation intensity revealed that there was a correlation between the amplitude of intraluminal pressures in the proximal (rho 0.45; p=0.01) and distal (rho 0.41; p=0.02) esophagus and dynamic extension (Table 3).

TABLE 3 - Spearman correlation coefficient (rho) between strong, weak and habitual phonation and dynamic extension and intraluminal pressure amplitude in the proximal, middle and distal esophagus and in the pharyngoesophageal transition.

	Habitual phonation		**Strong phonation**		**Weak phonation**		**Dynamic extension**	
	rho	p-value	rho	p-value	rho	p-value	rho	p-value
Proximal esophagus	-0.033	0.86	0.250	0.18	-0.130	0.49	0.452	0.01
Middle esophagus	0.117	0.54	0.268	0.15	-0.025	0.90	0.344	0.06
Distal esophagus	0.078	0.68	0.274	0.14	-0.018	0.93	0.415	0.02
Pharyngoesophageal transition	0.216	0.25	0.239	0.20	0.269	0.15	0.312	0.09

When total laryngectomees wearing a TEP were divided into two groups according to dynamic extension above 21 dBNPS, considered to be normal, and below this value, considered to be altered, it could be seen that individuals with normal dynamic extension (above 21 dBNPS) had a greater contraction amplitude in the proximal esophagus than individuals with dynamic extension below 21 dBNPS (Table 4).

TABLE 4 - Pressure amplitude (mmHg) in total laryngectomees wearing a tracheoesophageal prosthesis with dynamic extension below (n=20) and above (n=10) 21 dBNPS, measured in the proximal, middle and distal esophagus and in the pharyngoesophageal transition.

	Dynamic extension below 21 dBNPS			**Dynamic extension above 21 dBNPS**			**p-value**
	N=20			**N=10**			
	Mean ± SD	**Median**	**Range**	**Mean ± SD**	**Median**	**Range**	
Proximal esophagus	12.5 ± 9.7	13.5	0-32.1	26.1 ± 19.9	20.8	0-66.1	0.03
Middle esophagus	42 ± 44.1	38.6	0-165.4	36 ± 12.7	33.8	20.5-62.5	0.78
Distal esophagus	51.5 ± 58.9	26.3	0-238.7	44.3 ± 18.1	43.2	18-70	0.48
Pharyngoesophageal transition	17.7 ± 12.9	13.5	4.5-55	21.2 ± 10.1	19.3	7.2-41.1	0.18

SD: Standard Deviation

Discussion

Dynamic extension is the variation of phonation intensity from the weakest to the strongest level that an individual is able to produce. This measurement is made with a sound pressure meter by subtracting strong from weak phonation. In persons with a normal larynx, dynamic extension is directly related to glottis resistance to the passage of air. However, in total laryngectomees, various factors influence dynamic extension.

The amplitude of esophageal pressure after swallowing water is reduced in laryngectomees compared to normal persons[13,17,18]. A positive correlation was observed between contraction amplitude in the proximal and distal part of the esophagus and dynamic extension in laryngectomees. The manometric data were collected during deglutition, but the indication that increased intraluminal pressure in the distal part favored greater dynamic extension is a sign that good speakers need to have adequate intraluminal pressures for an efficient control of sound intensity.

During voice production, laryngectomees rehabilitated with a TEP have greater pressure in the middle and distal esophagus than non-speaking patients[15]. Improved esophageal motility optimizing the intraluminal pressures of the esophagus may favor the development of voice regarding the measurements of sound intensity in total laryngectomees.

The increased intraluminal pressure in the proximal part with increased dynamic extension leads us to believe that this region of the esophagus functions as an air reservoir, and that adequate pressure is necessary to control the directioning of air to the pharynx, where the vibratory source of total laryngectomees is located.

The difference observed in the group with normal dynamic extension which had a greater intraluminal pressure amplitude in the proximal part of the esophagus than the group with dynamic extension below 21 dBNPS supports the idea that the proximal region of the esophagus requires appropriate pressure in order to function as a good air reservoir for the production of alaryngeal speech.

Other aspects to be considered are the type of stoma occlusion[3,5,7] and the aerodynamic characteristics of the TEP[2,5], which influence the measurements of dynamic extension. No reports characterizing dynamic extension correlated with esophageal motility in laryngectomees were detected in the literature surveyed. In the present study we determined the values of sound intensity regardless of the type of voice and noted that there is a relationship between sound intensity and intraluminal esophageal pressure[19].

There has been a concern about characterizing good or poor speakers according to the properties of esophageal motility observed in total laringectomees[13-16]. However, little is known about the influence of esophageal motility on vocal intensity.

There is no difference in dynamic extension in patients submitted to reconstruction of the pharynx with flaps[20]. What has been observed is that different types of prostheses[2-7] and the manner of stoma occlusion[3,5,7] influence dynamic extension. In this group of laryngectomees, all subjects performed digital occlusion of the stoma and wore the same prosthesis. It was noted that esophageal motility in the proximal and distal part has an influence on dynamic extension, showing that intraluminal pressure is important for the control of dynamics extension in total laryngectomees.

Despite this information, further studies are needed using phonation tests of different intensity during the manometric exam in order to better understand the behavior of the esophagus during phonation.

Conclusions

A positive correlation was detected, indicating that the increase in intraluminal pressure in the proximal and distal part of the esophagus is associated with an increase in dynamic extension. The group of individuals with a dynamic extension considered normal had a higher intraluminal pressure in the proximal esophagus than individuals with low dynamic extension values.

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