Glottal competence in chronic obstructive pulmonary disease

Competência glótica na doença pulmonar obstrutiva crônica

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ABSTRACT

Purpose: This study correlates the extent of maximum phonation time (MPT) with the volume of air exhaled in the first second pulmonary (FEV₁) and compares the MPT emission of /s/, /z/ and s/z ratio in healthy subjects and those with chronic obstructive pulmonary disease (COPD).

Methods: We studied 14 normal volunteers (control group), mean age 65 years, and 16 patients with COPD, mean age 68 years. The diagnosis of COPD was done by clinical and pulmonary function evaluation. Participants underwent spirometry for analysis of the parameters FEV₁, forced vital capacity (FVC) and Tiffeneau index (FEV₁/FVC). The maximum phonation time, along with phonemes /s/ and /z/, s/z ratio correlation, and maximum phonation time in both normal and forced phonation were collected and recorded.

Results: In both groups, the maximum phonation time with normal phonation was lower than the maximum phonation time with forced phonation. The median of the maximum phonation time in the control group was higher than in the COPD group. There was no correlation between the maximum phonation time and FEV₁, in normal volunteers and patients with COPD. Conclusion: Patients with COPD have decreased maximum phonation time, while the s/z ratio does not suggest changes in the level of the vocal folds, since the values found were within the normal range. There was no correlation of the TMF and the measure of FEV₁.

Keywords: Larynx; Chronic Obstructive Pulmonary Disease; Phonation; Voice; Dysphonia

RESUMO

Objetivo: Correlacionar a medida do tempo máximo de fonação (TMF) com o volume de ar pulmonar expirado no primeiro segundo do sopro (VEF₁) e comparar o TMF, emissão do “s”, “z” e relação s/z em indivíduos saudáveis e indivíduos com doença pulmonar obstrutiva crônica (DPOC).

Métodos: Foram avaliados 14 voluntários saudáveis, com média de idade de 65 anos, e 16 indivíduos com DPOC, com média de idade de 68 anos. O diagnóstico da doença foi clínico e também obtido por exames da função pulmonar. Os participantes foram submetidos à espirometria para apreciação dos parâmetros VEF₁, capacidade vital forçada (CVF) e o índice de Tiffeneau (VEF₁/CVF). Registrou-se a emissão prolongada das vogais “a”, “i”, “u” para análise do tempo máximo de fonação na condição normal e forçada e aferiu-se a relação s/z após a sustentação dos fonemas /s/ e /z/.

Resultados: Nos dois grupos, o TMF com a fonação normal foi menor do que o tempo máximo de fonação, com a fonação forçada. A mediana do TMF do grupo controle foi maior do que a do grupo com DPOC, com a fonação normal e a fonação forçada. Não houve correlação entre o tempo máximo de fonação e os valores de VEF₁ nos grupos. Conclusão: Pacientes com DPOC têm diminuição do tempo máximo de fonação e a relação s/z sugere falta de coaptação glótica. Não houve correlação do TMF e a medida do VEF₁.

Descritores: Laringe; Doença Pulmonar Obstrutiva Crônica; Fonação; Voz; Disfonia
INTRODUCTION

Chronic obstructive pulmonary disease (COPD) is a common, usually progressive and debilitating disease characterized by respiratory signs and symptoms associated with the limitation of ventilatory capacity, usually caused by chronic inhalation exposure to particulate matter, mainly due to smoking(1,2). The reduction in lung volume promotes the reduction in subglottic pressure and compromises glottal closure of the larynx during phonation. The respiratory condition modifies phonation, although this relationship has yet to be demonstrated experimentally(3).

The diagnosis of COPD is confirmed by spirometry with the measurement of the expiratory volume-time curve, preferably in a stable phase of the disease. Spirometry allows the evaluation of a multitude of parameters, but the most important from the point of view of clinical application are forced expiratory volume in the first second (FEV₁), forced vital capacity (FVC) and Tiffeneau index (FEV₁/FVC) because they show less inter- and intra-individual variability. The existence of airflow limitation is defined by a Tiffeneau index below 0.70(1,4).

According to the Brazilian Thoracic Association (BTA), the prevalence of COPD in Brazil is 15.8% in adults over 40 years(1). The most common symptom is cough, which may be daily or intermittent and may precede dyspnea or appear simultaneously with it. Reduced ventilatory capacity, weakness of the intercostal and abdominal muscles, along with the presence of dyspnea are the limiting factors responsible for the daily activities of individuals with COPD(5). The increased workload of the respiratory muscles, oxygen consumption and greater energy expenditure occur in an attempt to overcome the obstruction of the free flow of air, especially during expiration(6), which may favor the incoordination of respiration, phonation and performance of oral communication of the individual.

Oral communication is the means by which the individual relates experiences, ideas, knowledge and feelings and the individual with COPD may have difficulty communicating because phonation tasks impose considerable respiratory requirements for the performance of speech, both in terms of expiratory flow and excursions of expiration lung volume(7).

Despite the understanding that phonation can be altered by lung disease, there is no scientific evidence of objective measures and little phonatory evidence in routine clinical evaluation of patients with COPD(8). The clinical parameter for analysis of the phonatory and respiratory components of the mechanism of voice production and speech is maximum phonation time (MPT)(9,10). Another test that enables the evaluation of an individual’s ability to control the aerodynamic forces of tidal volume and myoelastic forces of the larynx is the sustained emission of fricative phonemes unvoiced /s/ and voiced /z/ (11).

Knowledge of phonatory condition in individuals with COPD may favor better performance of oral communication. Although phonation and, in turn, the production of speech, can be changed by lung disease, no references in the specialized literature have been observed(7,8). Thus, the aim of this study was to correlate the measurement of maximum phonation time with the volume of air which can be exhaled from the lungs in the first second and compare maximum phonation time, emission of /s/, /z/ and ‘/s’/’/z’ ratio in healthy individuals and individuals with chronic obstructive pulmonary disease.

METHODS

The study was approved by the Research Ethics Committee of the University Hospital, Ribeirão Preto School of Medicine, Universidade de São Paulo (Protocol No. 9473/2005). All participants signed a free and informed consent form to participate in the study. This was a prospective cross-sectional study.

We studied 16 individuals with COPD, aged between 56 and 77 years, mean 68.4 years, consisting of one female (6.2%) and 15 males (93.8%). We established the following criteria for inclusion in the study: patients with COPD in stable phase of the disease (asymptomatic cough and dyspnea, no indication for use of medications, COPD classified as moderate to very severe according to spirometry test); patients with relevant history of smoking in the past, but had abandoned the habit for at least six months.

We excluded individuals with a history of other chronic lung diseases and those with other significant diseases, such as severe heart disease, cancer, diabetes, or severe hypertension, in addition to a prior and/or current history of dysphonia.

The control group consisted of 14 individuals aged between 57 and 73 years, mean 65.3 years, consisting of three females (20%) and 11 males (80%), all with normal spirometry test, who had never been smokers or those who smoked for less than 10 pack/years, value defined by the total years of smoking multiplied by the total number of packs of cigarettes a day. Individuals with a history of other chronic lung diseases and those with other significant diseases, such as severe heart disease, cancer, diabetes, or severe hypertension, and a history and/or current dysphonia were not accepted, along with those who were past smokers who had quit smoking for at least one year. Both the control group and the group with COPD reported no vocal complaints.

Procedures

Spirometry

Both groups of the study underwent full spirometry analysis by a pulmonologist for the characterization of the diagnosis and severity of COPD. Spirometry was performed on a Pulmonet III ® spirometer (Sensormedics, Anaheim, CA, USA), according to the standards of the Brazilian Thoracic Association(4).

To obtain the curves by spirometry, individuals remained in a seated position. The test was performed with a mouthpiece...
coupled to the spirometer along with a nasal clip to avoid any leak of air. The individuals were instructed on the maneuvers to be performed and were spurred on vigorously by the examiner to inspire until completely filling the lungs, hold the air, and then putting their lips around a clean mouthpiece and, immediately after, blow the air as quickly as possible and with maximum effort, prolonging the breath until the lungs felt fully empty.

**Analysis of spirometric ratios**

From curves considered of acceptable technical quality, the parameters FEV₁, FVC and Tiffeneau index were calculated for the diagnosis and severity classification of COPD. The calculation of predicted values for spirometric variables was performed using the equations of Pereira et al.² The results of the spirometric parameters were expressed as percentage of predicted, as recommended by the II Brazilian Consensus on COPD by the Brazilian Thoracic Association.⁴

**Standards of spirometric ratios**

- FEV₁: *Forced expiratory volume in the first second*: the volume of air exhaled in the first second of blow;
- FVC: *Forced vital capacity*: the total volume of air that can be forcibly exhaled in one breath;
- Tiffeneau index (FEV₁/FVC): fraction of air exhaled in the first second, relative to the total volume expired.

**Clinical vocal evaluation of the control of aerodynamic forces and myoelastic forces of the larynx**

For the evaluation, we applied the test of maximum phonation time of prolonged vowels and sustained emission of fricatives unvoiced /s/ and voiced /z/ and the s/z ratio, by measuring air flow during phonation, expressed in seconds.¹³

We asked the participant, following deep inspiration, to emit the vowels /a/, /i/, /u/ and the phonemes /s/ and /z/, in a prolonged manner and not to use residual air during application of the phonation sample. The frequency and intensity of voice should be normal, indicating naturalness and characterizing normal phonation. Next, the same procedure was repeated, but the individual was instructed to use the entire pulmonary reserve, characterizing forced phonation.

**Standards of clinical vocal assessment of the control of aerodynamic forces and myoelastic forces of the larynx**

We asked for the prolonged emission of vowel /a/ to be oral, central and open so it can highlight, by its articulatory nature, any changes in the myoelastic balance of the larynx. The vowel /a/ is the most acute in Portuguese and most anteriorly closed while the vowel /u/ is the most grave and most posteriorly closed.¹³

The prolonged emission of the unvoiced fricative phoneme /s/ allows verification of pulmonary air support and the ability to control it, since there is no vibration of the vocal folds. The emission of the voiced consonant /z/, requires vibration of the vocal folds.¹³

Participants remained comfortably seated without compressing the diaphragmatic muscles and feet flat on the floor while TMF was measured (in seconds) of each of the vowels and phonemes using a digital stopwatch (Technos®, Amazon, Brazil).

**Analysis of the results of the clinical vocal evaluation of the control of aerodynamic forces and myoelastic forces of the larynx**

Used for analysis were normality values (expressed in seconds) validated for the adult Brazilian population, considering 20 seconds for men, 14 seconds for women and an s/z ratio from 0.8 seconds to 1.2 seconds.¹³

The results of the maximum phonation time, emission of /s/ and /z/ and s/z ratio were compared between groups by applying two nonparametric tests: the Wilcoxon test (for dependent samples) and the Mann-Whitney U test (for independent samples), using software R®. To correlate the evaluated parameters, MPT and FEV₁, were considered. Therefore, we calculated the Pearson correlation coefficient (r), using the same software. In all statistical analyzes, we adopted a significance level of 5% (p≤0.05).

**RESULTS**

The results of spirometry allowed observation of Tiffeneau index values of 42.5 ± 10.1% for the COPD group and 76.9 ± 5.8% for the control group. There was limitation of airflow for the COPD group, which was defined as less than 0.70%, by Tiffeneau index.

The anticipated value for FEV₁ normality is > 80% and the results found for the COPD group was 40.2 ± 8.1% for the control group was 98.5 ± 12.6%. According to these criteria, patients with COPD showed a Tiffeneau index value below the lower limit of normality while the control group was above the lower limit, according to data set by the II Brazilian Consensus on COPD by the Brazilian Thoracic Association.⁴

Difference in MPT was observed between the control group and patients with COPD, both when assessed with normal phonation and in the evaluation with forced phonation. TMF was longer in individuals in the control group than in individuals in the COPD group with normal phonation (Table 1) and forced phonation (Table 2).

In the control group, the s/z ratio during normal phonation had a median of 0.8 seconds (minimum 0.6 s, maximum 1.7 s) and in the COPD group, the median was 1.3 seconds (minimum 0.7 s, maximum 2.3 s), with a significant difference between groups (p=0.04).

When we assessed the correlation between the measurement of MPT and FEV₁, there was no correlation between...
the variables, neither in the control group nor in the group of patients with COPD, both in normal and forced phonation (Table 3)

**DISCUSSION**

Individuals with obstructive airway disease, due to the high resistance to air flow, have limited ventilatory capacity that increases the work of breathing with high respiratory frequency at rest\(^{(14)}\). In the literature, no studies were found to debate the dynamic phonatory and glottal competence in COPD. Through the results found in this study, we can infer that patients required many air refills for maintenance and end of the phrase during conversation, since the maximum phonation time presented by patients was significantly lower than the control group, revealing lower normality values for the adult population\(^{(13)}\). Phonation tasks require considerable respiratory demands, both in terms of expiratory flow and in terms of excursions of expiration lung volume and this should be considered for all individuals who depend on speech for their livelihood, including those with COPD\(^{(2)}\).

It is also inferred that the decrease in MPT for patients in this study denoted a compromise of respiratory, phonic and articulation coordination, which can directly influence the performance of oral communication and the very intelligibility of the speech of individuals with COPD. This reasoning is supported by the knowledge that lung volume is important to sustain phonation tasks. Healthy individuals can maintain the

A table showing the comparison of median maximum phonation time (MPT), in seconds (s), between the group of individuals with COPD and control group in normal phonation.

<table>
<thead>
<tr>
<th></th>
<th>Control</th>
<th>COPD</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Vowel /a/</strong></td>
<td>Median 12 s</td>
<td>Median 7 s</td>
<td>&lt;0.01*</td>
</tr>
<tr>
<td></td>
<td>Min.-max. 6-20 s</td>
<td>Min.-max. 2-12 s</td>
<td></td>
</tr>
<tr>
<td><strong>Vowel /i/</strong></td>
<td>Median 13 s</td>
<td>Median 7 s</td>
<td>&lt;0.01*</td>
</tr>
<tr>
<td></td>
<td>Min.-max. 7-29 s</td>
<td>Min.-max. 3-12 s</td>
<td></td>
</tr>
<tr>
<td><strong>Vowel /u/</strong></td>
<td>Median 14 s</td>
<td>Median 7 s</td>
<td>&lt;0.01*</td>
</tr>
<tr>
<td></td>
<td>Min.-max. 7-23 s</td>
<td>Min.-max. 3-12 s</td>
<td></td>
</tr>
<tr>
<td><strong>Phoneme /s/</strong></td>
<td>Median 11 s</td>
<td>Median 8.5 s</td>
<td>0.03*</td>
</tr>
<tr>
<td></td>
<td>Min.-max. 5-18 s</td>
<td>Min.-max. 4-11 s</td>
<td></td>
</tr>
<tr>
<td><strong>Phoneme /z/</strong></td>
<td>Median 13 s</td>
<td>Median 6.5 s</td>
<td>&lt;0.01*</td>
</tr>
<tr>
<td></td>
<td>Min.-max. 5-21 s</td>
<td>Min.-max. 3-14 s</td>
<td></td>
</tr>
<tr>
<td><strong>Relationship s/z</strong></td>
<td>Median 0.8 s</td>
<td>Median 1.3 s</td>
<td></td>
</tr>
</tbody>
</table>

*Significant values (p≤0.05) – Mann-Whitney U test

**Note:** COPD = chronic obstructive pulmonary disease

A table showing the comparison of median maximum phonation time (MPT), in seconds (s), between the group of individuals with COPD and control group in forced phonation.

<table>
<thead>
<tr>
<th></th>
<th>Control</th>
<th>COPD</th>
<th>Valor de p</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Vowel /a/</strong></td>
<td>Median 18 s</td>
<td>Median 10.5 s</td>
<td>&lt;0.01*</td>
</tr>
<tr>
<td></td>
<td>Min.-max. 9-38 s</td>
<td>Min.-max. 2-17 s</td>
<td></td>
</tr>
<tr>
<td><strong>Vowel /i/</strong></td>
<td>Median 23 s</td>
<td>Median 11 s</td>
<td>&lt;0.01*</td>
</tr>
<tr>
<td></td>
<td>Min.-max. 6-35 s</td>
<td>Min.-max. 2-21 s</td>
<td></td>
</tr>
<tr>
<td><strong>Vowel /u/</strong></td>
<td>Median 16 s</td>
<td>Median 11 s</td>
<td>&lt;0.01*</td>
</tr>
<tr>
<td></td>
<td>Min.-max. 11-39 s</td>
<td>Min.-max. 4-17 s</td>
<td></td>
</tr>
<tr>
<td><strong>Phoneme /s/</strong></td>
<td>Median 15 s</td>
<td>Median 12 s</td>
<td>0.04*</td>
</tr>
<tr>
<td></td>
<td>Min.-max. 8-27 s</td>
<td>Min.-max. 5-17 s</td>
<td></td>
</tr>
<tr>
<td><strong>Phoneme /z/</strong></td>
<td>Median 18 s</td>
<td>Median 8.5 s</td>
<td>&lt;0.01*</td>
</tr>
<tr>
<td></td>
<td>Min.-max. 8-33 s</td>
<td>Min.-max. 4-18 s</td>
<td></td>
</tr>
</tbody>
</table>

*Significant values (p≤0.05) – Mann-Whitney U test

**Note:** COPD = chronic obstructive pulmonary disease

A table showing the Pearson correlation coefficient (r) between the maximum phonation time (MPT) and FEV1 value in individuals with COPD and control group in normal phonation and forced phonation.

|            | Control          | COPD            | |                  | COPD            | |
|------------|------------------|-----------------| |                  | COPD            | |
| **MPT Vowel /a/ X FEV\(_1\)** | r = -0.16 | p = 0.62 | r = 0.58 | | r = -0.06 | p = 0.83 |
| **MPT Vowel /i/ X FEV\(_1\)** | r = -0.15 | p = 0.64 | r = 0.79 | | r = 0.38 | p = 0.15 |
| **MPT Vowel /u/ X FEV\(_1\)** | r = -0.27 | p = 0.39 | r = 0.96 | | r = 0.41 | p = 0.11 |
| **MPT Phoneme /s/ X FEV\(_1\)** | r = -0.55 | p = 0.07 | r = 0.39 | | r = -0.10 | p = 0.71 |
| **MPT Phoneme /z/ X FEV\(_1\)** | r = -0.32 | p = 0.31 | r = 0.97 | | r = -0.26 | p = 0.33 |

Pearson correlation coefficient test (r) - (p≤0.05)

**Note:** COPD = chronic obstructive pulmonary disease
flow of expiratory air, while patients with severe obstruction have difficulties, due to the obstructive airflow limitations of the lung\(^2,3\).

For patients with COPD who use oral communication for most social activities, the evaluation of speech activity can provide relevant criteria for measuring performance and promote better oral communication\(^8\). To overcome this disadvantage, we proposed a questionnaire on speech during physical activity and noticed a high correlation of questionnaire responses to the performance of speech and daily living activities in individuals with COPD\(^5\), concluding that there is improvement in the activities of speech after a respiratory rehabilitation program in patients with COPD. We recommend that validated and objective phonation tasks be added in the evaluation of individuals with COPD, as dyspnea interferes with the communication of these individuals\(^8\).

Given that there was no correlation of the value of FEV\(_1\), with MPT, it is important to consider that individuals with COPD have weak lungs and likely due to age, we can infer a presbylarynx with sagging vocal folds and incomplete glottic closure.

To measure temporal phonation, the production of a prolonged vowel without the interference of glottal closure is required and to test the limitation of obstructive lung airflow, the repetition of “pi” or “pa” could be used, which requires a laryngeal performance of glottic resistance to lung airflow for the production of the phoneme and does not evaluate continuous airflow. These observations are also evidenced in aeromechanical acoustic studies, which show different levels of lung volume on different laryngeal activities, such as reading words aloud\(^10\) and vertical movement of the larynx\(^3\). Authors reinforce the need for scientific evidence on objective measures of speech to be used in the clinic in patients with COPD\(^8\).

The application of the s/z ratio clinical test is superb to verify the competence of myoelastic forces of the larynx and lung aerodynamics. Values below the lower limit may indicate glottal hyperconstriction and values above the upper limit are indicative of a lack of glottal closure\(^11\).

The decrease in lung airflow in the MPT test, also found in the control group, was likely due to senility. Perhaps it would be necessary to consider age for the interpretation of the results of MPT. However, currently, the normative data from the TMF are available for child and adult population\(^13\). Therefore, we believe that further research is needed to define normality values of MPT for the elderly population.

The COPD group showed further significant lowering in the test of MPT, generating air flow insufficient to promote the Bernoulli phenomenon during the glottic cycle. This event causes the subglottic air pressure to suck vocal folds toward the laryngeal lumen, favoring the glottal closure for adjusting the intensity and frequency of sound needed for speech production, as predicted by aerodynamic-myoeastic theory of the larynx\(^7\).

Lung volume affects the speech and its reduction increases the ability of vocal fold adduction, whereas subglottic pressure also increases and with it, the glottic competence tends to improve\(^3\). Another relevant consideration is that lung volume is a factor that is directly related to laryngeal position during phonation. A high lung volume allows low laryngeal position, also changing the frequency of the voice\(^9\).

Voice latency time is greater during the production of an unvoiced phoneme with high lung volume\(^19\). The results from the present investigation do not permit to reveal differences in lung volume in the COPD group compared to the control group during the production of /s/. The s/z ratio showed values close to normality limits\(^10\). When the two groups were compared, a higher value was observed for this ratio in the group with COPD, which suggests glottic muscle weakness in these patients. The amounts found led us to infer that there was absence of glottal competence\(^10\) and should review the complaint and include the assessment of laryngeal function in individuals with COPD.

Expiratory flow disturbances can be consequences of inadequate use of the respiratory muscles, which causes conflict between subglottic pressure and vocal resistance\(^10\). Therefore, it is believed that obstruction of free flow of air, especially during expiration, may influence MPT and s/z ratio in patients with COPD, since the larynx mechanically joins the respiratory tract, allowing it to suffer direct influence on it.

Therefore, one should consider the need to obtain objective phonatory measures through scientific evidence to conduct phonation tests in routine clinical evaluation of patients with COPD and to establish normality values of clinical vocal parameters for the senile population, for the evaluation and interpretation of results and implementation of therapeutic actions.

**CONCLUSION**

Patients with COPD have decreased MPT, which can be attributed to obstructive lung airflow limitation. The s/z ratio suggests change in glottal closure during phonation in the group of individuals with COPD. A correlation of the measurement of the maximum phonation time of vowels /a/, /i/, /u/ and the phonemes /s/, /z/, measured by FEV\(_1\), was not observed among the groups studied.

**REFERENCES**