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Vocal Analysis of Individuals with Parkinson's Disease: Correlations between Perceptual Data, Acoustics and Electroglottography

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Abstract

The purpose of this study was to correlate degrees of vocal deviation using the GRBASI scale and perceptual analysis, with acoustic parameters and eletroglottography of individuals with Parkinson's disease (PD). 20 patients of both genders participated, with PD diagnosis at stages 2 and 3 of the Hoehn & Yahr scale (case group). The comparative control group consisted of 20 individuals without PD or any other neurological disorder and with vocals indicative of their sex and age. The beep was recorded simultaneously to the electroglottographic signal. The perceptual-hearing vocal assessment was performed using the GRBAS scale. The extracted acoustic parameters were: fundamental frequency (F_0), intensity, harmonics-to-noise ratio (HNR), jitter and shimmer. The electroglottographic waves were qualitatively analyzed using seven parameters. There were differences between the groups in their grade of dysphonia ($p < 0.0001$). There were positive and negative correlations drawn from the deviations from the international scale and acoustic variables and electroglottographic analysis. It was concluded that the integrated use of these three tools exhibited variables which, permitted the differentiation of vocal markers resulting from PD comparison with the control group, which, in turn, helped the clinical and physiological reasoning of the voices of patients with PD classification of voice disorders.

Index Terms: voice quality, evaluation, Parkinson's disease (PD), auditory perception, speech acoustics

1. Introduction

Parkinson's disease (PD) is among the most neurodegenerative diseases encountered in clinical practice [1], with an estimated prevalence of 3.3% in Brazil [2]. Approximately 75% of patients with PD present voice and speech problems, and the most common symptoms are: reduction of vocal intensity, roughness, breathing difficulties, vocal instability, monotones, tremor, difficulty starting a sentence and articulation imprecision [3]. Auditory-perceptual assessment in routine clinical treatments is traditional, and although subjective, it is still considered the gold standard [5,6], allowing for inferential correlations regarding pathophysiological and psychosocial aspects of voice to be made [3,4,5,6], and in conjunction with acoustic analysis has provided sensitive information about the phonation function [7,8,9]. Studies show that the voice commonly found in PD is rough, with breathing difficulties, asthenic and mild to intense instability [3,7,9], and more diverted acoustic parameters are vocal intensity, jitter, shimmer, harmonics-to-noise ratio, among other acoustic disturbance measures [1,7,9]. The electroglottography (EGG) is a noninvasive method to investigate the vocal physiology, measuring qualitatively and quantitatively the change in the contact area between the vocal folds during speech [9,10]. In a study using EGG, the authors identified abnormal vibration patterns in vocal folds of patients with PD; also finding changes in the opening and closing stages, and irregularities in wave amplitude between the glottal cycles, suggesting abnormalities in the motor control of the vocal folds [10,11]. Because of the need to advance and deepen the knowledge of the vocal alterations of patients with PD, the aim of this study was to investigate the data of perceptual voice assessment, acoustic and electroglottography in individuals with PD, and to understand if the assessed aspects correlated to acoustics aid in understanding physiological and clinical vocal markers arising from PD.

2. Methods

2.1. Participants

The study included 20 patients of both genders with PD (case group) from HUCAM Neurology Clinic and the Parkinson's Capixaba Association - ACP, aged between 52 and 76 years. The control group consisted of 20 individuals with no diagnosis of PD or any other neurological or vocal abnormality, with age and sex matching the patient group. The patient inclusion criteria were: to be under medical care and on active medication during the evaluation, not presenting symptoms of loss of cognition and being ranked in stage 2 or 3 in the modified Hoehn & Yahr scale.

It is a transversal study, an analytical controlled-case type approved by the Ethics Committee of the University Hospital Cassiano Antonio Moraes (HUCAM) of the Federal University of Espírito Santo - UFES with the opinion number 807 286. All participants signed the Informed Consent and Informed protocol, authorizing the study.

2.2. Material

Recording of the acoustic signal was carried out simultaneously on the electroglottographic recorder through EG2 electroglottographic surface electrodes (glottal Enterprises) which were fixed to the lobes of the thyroid cartilage of participants. Audio was transmitted through an audio-technical unidirectional head microphone ATM 75, with a cardioid polar diagram, positioned at 45 and 5 cm from the mouth of individuals. Necklaces were removed as were earrings and other metal accessories found on the heads and

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necks of participants. All recordings were performed in a quiet environment, with background noise below 50dB. The equipment was calibrated and monitored during all recordings by an acoustic engineer, to ensure recording quality.

The electrodes received a thin layer of hypoallergenic conductive gel (Spectra 360-Parker Lab) and were fixed with a cord round the neck to enhance contact with the thyroid cartilage. The acoustic signals and EGG were recorded and digitized, being reset at the beginning and end of emissions.

2.3. Procedure

The vocal recordings were randomized and analyzed blindly and in consensus, by speech experts in the vocal area, ranking the overall degree of deviation from the vocal quality (degree of dysphonia) (G) of GRBASI scale: 0 = no change, 1 = mild, 2 = moderate, 3 = severe. Other scale parameters were not assessed in this study. The fundamental acoustic frequency parameters (F_0), intensity, harmonics-to-noise ratio, jitter and shimmer were extracted by PRAAT program version 3.5.32 [12].

For analysis of electroglottographic waves, text grids were prepared with graphic images of the regions of greatest stability for the output signal (within the first few seconds of the recording) produced by the PRAAT software. Each text-grid was qualitatively analyzed following the fourth geometric shapes wave from the glottal configuration: Wave with extended pulse (type 1), wave with sloping peak (type 2), wave with convex form (type 3) and wave with edge ramp (type 4) [9,13]. In addition, 6 other qualitative parameters were evaluated: change in frequency, periodic oscillation amplitude, oscillation peak in the closing phase, noise pitch, change during closing and/or opening phase and presence or absence of ad-hoc electroglottography.

2.4. Statistical analysis

Statistical analysis was performed using the Statistical Package for Social Sciences (SPSS) 21.0. For comparison of the international standard scale between the groups we used the chi-square test. The Tukey test (ANOVA) was used to investigate the variables of acoustic analysis. The Spearman coefficient test was performed to correlate overall degree of results, with data from acoustic and electroglottographic analysis. It was adapted to a minimum level of significance of 5% ($p \leq 0.05$) in all tests.

3. Results

The age of participants (patients and control) varied between 52 and 76 years (mean 64 years) with a mean of 63.6 ± 7.2PD years for men (n = 12) and 65.4 ± 7.4PD years for women (n = 8). PD patients had a poorer voice quality when compared to the voices of the control group ($p < 0.0001$) (Table 1).

Table 1. *Comparison between the groups in relation to the degree of dysphonia*

Degree of dysphonia	Case		Control		p Value
	n	%	n	%	
No Change	0	0,0	6	30,0	p<0,0001*
Mild	3	15,0	9	45,0	
Moderate	8	40,0	5	25,0	
Intense	9	45,0	0	0,0	

*Statistically significant values (p ≤ 0.05) - Chi-square test.

The average vocal intensity was also significantly different in patients compared to control participants (Table 2), featuring vocal volume reduction of the speech in PD patients, regardless of gender.

Table 2. *Comparison of acoustic parameters extracted from the acoustic analysis between groups (patients and control participants) in relation to gender.*

	Intensity	F_0	*Jitter*	*Shimmer*	HNR
	p	*p*	*p*	*p*	*p*
CGM x MC	0,002*	0,979	0,465	0,057	0,411
CGW x WC	0,023*	0,991	0,465	0,195	0,590

Significant values (p ≤ 0.05) - Analysis of variance (ANOVA) with Tukey post hoc test.

Note: CGM = case group men; MC = men control group; CGW = case group women; WC = women control group.

The intensity ($p < 0.0001$) and harmonics-to-noise ratio ($p < 0.013$) correlated negatively in their deviation from *degree of dysphonia*. However, jitter ($p < 0.0001$) and shimmer ($p < 0.002$) showed positive correlations in their deviation from *degree of dysphonia* (Table 3).

Table 3. *Correlations between the degrees of deviation from the international scale (APA) and the variables of acoustic analysis of patients compared to the control group.*

Degree of dysphonia		
Acoustic Analysis	Correlation	*p*
Intensity	-0,662	0,0001*
F_0 medium	0,093	0,569
Jitter	0,575	0,0001*
Shimmer	0,473	0,002*
HNR	-0,390	0,013*

*Values of Spearman correlation significant at the 0.05 level (5%).

Table 4 shows negative correlations between periodic oscillation of amplitude ($p < 0.0001$), closing peak oscillation ($p < 0.0001$), electroglottographic noise impulse signal ($p < 0.007$) and the change in the closing phase ($p < 0.0001$) regarding its deviation from degree of dysphonia, and positive frequency changes between the items ($p < 0.003$), ad-hoc electroglotographic ($p < 0.008$) and electroglottographic wave type ($p < 0.0001$).

Table 4. *Correlation between deviation from the international scale (APA) and the variables of electroglottographic analysis of patients compared to the control group.*

Electroglottographic Analysis	Correlation	*p*
Change in Frequency	0,453	0,003*
Periodic Oscillation Amplitude	-0,563	0,0001*
Oscillation of the Closing Peak	-0,682	0,0001*
Eletroglottographic Sound Wave	-0,423	0,007*
Change in the Closing Phase	-0,562	0,0001*
Changes in the Opening Phase	-0,257	0,109
Ad-Hoc Electroglottographic	0,416	0,008*
Type of Electroglottographic Wave	0,533	0,0001*

* Spearman correlation test. Significance level of 0.05 (5%).

4. Discussion

The auditory-perceptual analysis (APA) is carried out by professionals trained to identify auditory characteristics present in the voice signal that indicate whether or not changes occur in the quality of the vocal production system [6,10,11,13,14], taking into account not only the auditory aspects, but also prosodic, social and emotional speech, and so it is therefore considered the international gold standard in voice disorders classification [5,13,14].

However, despite being a commonly used system, it provides only subjective information, which depends on the evaluator's experience, which is why in recent years the literature has highlighted the need to complement vocal functional diagnosis with objective data for further characterization and monitoring of dysphonia [10,11,13,14]. Due to the vocal utterance involved in so many systems and structures, especially neurological diseases, acoustic voice analysis acquires status, both for diagnostic purposes and prognosis of the voice framework [13,14,15,16]. Acoustic analysis in individuals with PD is referred to as a complementary indicator to other speech therapy and laryngeal ratings [16].

Through the use of digital processing techniques for speech signals, the noninvasive extraction of objective measurements from patient's voice signals serves as a support tool for the diagnosis of laryngeal pathologies [9,14,15] and in the assessment of voice quality. By also being a non-invasive instrument, electroglottography is considered very useful in assessing and monitoring the treatment of vocal-sourced disorders [9,17,18].

The evaluation of the Egv bnG signal is essentially qualitative, based on the interpretation of the shape of the path of the electroglottographic wave, which visually indicates the phases of the glottal cycle - phase opening, open on closing and closed [9,17,18,19]. The clinical and scientific value is found in its ability to illustrate glottal cycles in affected voices (or not), however, it doesn't provide a diagnosis per se. It does produce further details on phonation physiology and should be used in combination with other methods of assessment. With this prerogative in mind, this study investigates relationships between variables of the APA, acoustic analysis and EGG vocals markers resulting from PD [17,18,20].

In this study it was observed that individuals with Parkinson's disease have voices with a higher degree of vocal quality deviation when compared with the control group (Table 1). Indeed, in studies of PD patients with vocal complaints, when compared to healthy subjects, significantly worse performance of vocal quality and intensity was found in PD patients [16,17,19,21]. In the present study, we found vocal intensity values reduced in the group with PD compared to the control group (Table 2). Several studies corroborated the presence of reduced vocal intensity in individuals with PD [3,4,17,19,21]. Furthermore, we found that the reduction of vocal intensity evident in PD, is directly correlated with shifted voice, or voices with the worst vocal quality (Table 3). In fact, physiologically, the presence of reduced vocal intensity is recognized in the literature as a classic symptom of PD, and can emerge as one of the first symptoms [4,19,21] of the disease.

There is a positive correlation between the shimmer and the international scale when comparing case versus control groups, i.e. when the shimmer value increases there is also an increase in the degree of deviation from the international scale and the reduction of vocal quality. Increased shimmer values can be found in neurological dysphonia, especially in the hypokinetic (characterized in PD), which relates to the reduction of glottic resistance, decreased intensity of voice, hoarseness and shortness of breath [5,22,23]. The jitter showed a positive correlation in this study, demonstrating that when there is an increase in this parameter, the deviation of vocal quality also increases. Yet, the harmonics-to-noise ratio has been negatively correlated, i.e., the lower the HNR value the further the degree of vocal deviation, this being an expected correlation, because its value is considered within the normal range when ≥ 20 dB (Table 3).

From a clinical and physiological point of view, the correlations between the degree of dysphonia and EGG were consistent only in so far as their positive correlations between changes in frequency, i.e., for the step which increases the overall degree of deviation, there is also an increase in the frequency of change in the negative relationship between the international scale and periodic oscillation amplitude. We, therefore, found that voices with larger deviation from the international scale had less periodic oscillations, and, thus, drew more irregular measurements (table 4). Studies indicate that irregularities in oscillation amplitude at the peak of the wave region can be interpreted as the presence of abnormalities in the voice box after the start of contact between the phases "in lock" and "closed" [17,18,20].

By perceptual analysis one can understand deviations of vocal production at the glottic level (source), the vocal tract (filter), so that, for this analysis one can identify the interaction between source and filter, in both healthy voices as well as in affected ones. The acoustic evaluation translates objective data at source and also from the filter. The eletroglottographic readings are interesting from the point of view of operation and activation (opening and closing) during the speech and glottal cycle. It is a fact that there are advantages and limitations to each vocal evaluation method, whether an objective, subjective or electrophysiological signal. However, it's important to highlight that other complementary techniques including laryngoscopy and stroboscopic assessment of the glottal area are required. Despite the above, the APA is considered sovereign regarding other assessments. One cannot always expect direct relationships to exist between general vocal quality and the objective parameters of voice signal investigations exhibited by advanced voice analysis tools. It is known that the voice is multidimensional, and so on a continual basis, it is recommended to correlate and understand the relationships between perceptual findings, both acoustic and physiological, in order to make the most accurate clinical reasoning, based on the leading example of global voice quality pioneered by APA.

5. Conclusions

The integrated use of these three tools showed variables capable of differentiating the vocal markers resulting from DP when compared to healthy subject voices.

PD patients presented fluctuations in voice quality and reduced vocal intensity, demonstrating the important discriminatory power of vocal markers in relation to these symptoms. From a clinical point of view, we find physiological correlations between the degree of deviation from the international scale and acoustic parameters such as intensity and EGG, shimmer, jitter, HNR, change frequency and periodic oscillation amplitude. It is self-evident that a greater understanding of the vocal differences between groups is facilitating the clinical analysis of voice and physiological markers resulting from PD.

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