PHONATORY DEVIATION DIAGRAM IN ORGANIC DYSPHONIA BY NEOPLASIA

Disfonias orgânicas por neoplasias: análise de diagramas de desvio fonatório

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ABSTRACT

Purpose: to compare acoustic data obtained through the phonatory deviation diagram of voices of dysphonic patients submitted to partial laryngectomy with voices of subjects of the same age range, however, without vocal complaint. **Methods:** the voices of 28 subjects were studied, being 14 partial laryngectomized patients and 14 subjects without vocal complaints, composing a control group. Both groups of males with same age and education level. The perceptual analysis of voices was conducted by GRBASI scale double-blind and through acoustic analysis software VOXMETRIA®. **Results:** partial laryngectomees voices 100% were distributed outside the normal quadrant, 64,3% were located in the right upper quadrant, 100% presented horizontal deviation of *jitter* and *shimmer* and 85,7% had a vertical deviation. The control group 28,5% were distributed within the normal quadrant, 71,5% were located in the right lower quadrant, 57,2% presented in the horizontal *shimmer* and 7,2% in *jitter*. Only 7,2% had a vertical deviation in the control group. Statistical significance was observed regarding the parameters of jitter, shimmer and GNE (glottal to noise excitation) and between the distribution of the voices in the upper right and left quadrants of the diagram in the presence of altered voices. **Conclusion:** the diagram allowed to analyze and discriminate the performance of normal and pathological voice differentiating them through their parameters, distribution, location and type of voice is considered a useful resource for voice analysis.

KEYWORDS: Dysphonia; Neoplasms; Speech Acoustic; Voice; Auditory Perception

INTRODUCTION

Some infirmities affect the voice, restricting communication and interaction. Among them, there is larynx cancer representing around 25% of all malignant head and neck tumors and 2% of all malignant diseases[1]. The treatment of larynx cancer depends on a series of factors such as size and location of the lesion, and may be performed with sophisticated techniques, for instance partial surgeries, endoscopy and precise radiotherapy techniques[2]. Partial laryngectomy is performed aiming to preserve the maximum of respiratory, sphincter and phonatory functions of larynx, and may be vertical or horizontal, according to the resection plan[3].

Consequently, individuals submitted to partial laryngectomy present changes in the laryngeal physiology producing a different sound signal which could not be compared to an integral laryngeal voice[4]. Vocal impairment may also interfere in speech intelligibility[5].

For the assessment of quality of voice, two important sources may be used: the perceptual and the acoustic analysis. The first one is a subjective method that varies according to the evaluator, his personal concepts about quality of voice, his skills of perception, discrimination and his experience. The second analysis is considered objective by many authors since it uses computer programs that quantify several measurable aspects of the voice signal captured, of great interest in the vocal clinic[6,7].

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As well as videolaryngoscopy exams, that show the structural normality of vocal chords, the perceptual analysis together with the acoustic analysis contribute significantly for the obtaining of data related to normal patterns of voice[8,9].

Measures obtained with the acoustic analysis should allow a coherent interpretation of numeric values[10]. The most frequently used parameters are: fundamental frequency (F0); jitter – varying pitch in the voice; shimmer; glottal noise measures; spectrographic data; phonatory deviation diagram, among others[11,12].

Within the components of the acoustic analysis, there is the Phonatory Deviation Diagram (PDD), originally called by German researchers as *Goettingen Hoarseness Diagram*- GHD. The bi-dimensional graph was proposed as a quantitative assessment method of the periodicity and of the noise of the sound signal, with its own acoustic characteristics. Afterwards, the interest and the clinical applicability of the hoarseness diagram motivated the development of a Brazilian program called Voxmetria (CTS Informatics), which allows the extraction of acoustic measures and offers the distribution of vocal samples in the phonatory deviation diagram. The program allows a graphic illustration of the quality of voice and can be easily interpreted. The diagram is based in four acoustic measures: three of them related to irregularity of the sound signal – jitter, shimmer and their correlation; the fourth one is related to the noise component, named glottal to noise excitation ratio – GNE[13-15]. The differential of this diagram is that it is able to assess very deviant voices, besides showing differences between dysphonic groups with different phonatory mechanisms and it allows monitoring of vocal quality[10,13-17].

The GNE is the acoustic measure that calculates the noise produced by the oscillation of vocal chords. Its values are considered normal when higher or equal to 0,5dB. The GNE shows significant differences between pathological, aphonic and normal voices[10]. The fundamental frequency (F_0) is the number of times a waveform reproduces itself in a unit of time. The F_0 is affected by age and sex, with a mean distribution from 80 to 250 Hz in young adults. In man, it is expected a range from 80 to 150 Hz and in women, from 150 to 250 Hz. The jitter, disturbance index of F_0 in short time, shows the variability of the fundamental frequency measured between successive glottal cycles. It expresses how different a period is from the anterior or the successor one. The shimmer, disturbance of amplitude in short time, indicates the amplitude variability of a sound wave and it can be altered specially in situations of glottal resistance reduction and is correlated to the presence of noise at emission (hoarseness) and breathiness[11,18].

This study aims to analyze and compare the phonatory deviance diagrams of subjects submitted to partial laryngectomy in which the glottic architecture was altered with subjects of same age and sex without vocal complaints.

METHODS

This prospective observational study was approved by the Research with Human Being Ethics Committee of PUC-Campinas, protocol number 0621/11.

Voices of 28 subjects were studied: 14 comprising the partial laryngectomy group, and 14 without vocal complaints of same sex, age and educational level, comprising the control group. The partial laryngectomy group included male subjects from 46 to 71 years of age (mean age of 61 years) referred by the Head and Neck service of a School-Hospital in Campinas city, to the same hospital's Speech and Language service.

All subjects underwent partial laryngectomy affecting glottal level; those submitted to horizontal partial laryngectomy were excluded. The mean post-operatory time was nine months. By the time of the study, subjects were being discharged from speech therapy for better vocal conditions, and presented compensation of dysphagia and closed tracheostoma.

The control group was also comprised of 14 male subjects from 46 to 72 years of age (mean age of 62 years), same educational level and no vocal complaints.

The software VOXMETRIA® was used to obtain vocal samples, using a headset microphone *PLANTRONICS,* placed 5 cm far from the subject's mouth, directly adapted to a notebook *Sony* PCG – 61111X, in an acoustically controlled environment room.

All voices were submitted to two types of analysis: perceptual assessment in which sample consisted in counting from 1 to 20 and naming months of the year; and acoustic analysis of vowel /a/ sustained during a three seconds time, disregarding the beginning and the end of the emissions in order to uniformize the samples that were normalized by the Sound Forge program.

Voice samples were presented for perceptual analysis without identification; three of them were repeated in order to verify the consistency of the analyses, resulting in a correct rate over 80% of voices. The global degree of vocal deviance was graduated in four levels: zero for adapted voice, one for mild deviance, two for moderate deviance and three for intense degree of voice alteration.

For the categorization of vocal qualities according to the GRBASI scale, a training of two fourth grade speech language science students with more than one year experience in oncology speech language therapy and a voice specialist therapist, experienced in perceptual analysis of functional and organic dysphonic voices due to neoplasms was performed.

After the training, a consistency test was conducted and judges presented a number of correct responses superior than 80%; thus, the analyses of voices were performed. Considering the multi-dimensional characteristic of voice, criteria for acoustic categorization of voice types were defined as: rough – when the acoustic impression was of phonatory irregularity; breathy – when soundless air was present throughout emission; tense- when effort to phonation was observed; and irregular- when voice was produced with noise, instability of glottal source and little use of resonance.

The analysis of voice samples in the phonatory deviation diagram was conducted in two ways: the first one established by the program and related to the distribution in the PDD (within normality range or not); the second one according to the location in the diagram divided in four equal quadrants, and the classification of the horizontal (jitter and shimmer) and the vertical axis (GNE) deviations.

Vocal samples were studied and classified according to their location in the diagram regarding the normality area, considering that most altered voices are out of this area. Both groups were compared. This procedure was performed according to Madazio (2009)[14].

Results were statistically analyzed. The following tests were applied: Fisher Exact test, Binomial Proportion test, Wilcoxon Mann Whitney Median test, and Student t test for identifying possible significance in the comparison between the distribution and location of voices in the phonatory deviation diagram of both groups and its correlations with the perceptual analysis. The significance level was 5% ($p<0,05$).

RESULTS

The perceptual analysis using the GRBASI scale showed that eight subjects from the partial laryngectomy group (57,2%) presented degree 3 of deviance (intense) and six (42,8%) presented degree 2, or moderate deviance. None of the subjects submitted to partial laryngectomy were classified with adapted or mild degree of deviance. In the control group, four voice samples (28,5%) were classified with degree 2 of vocal deviance (moderate), six (42,8%) with degree 1 (mild) and four (28,5%) with degree 0 (adapted voice). The statistical analysis revealed that the vocal alteration degree of subjects from the partial laryngectomy group is significant in comparison with the control group, as presented in Table 1.

Table 1 – Classification of the global degree of vocal deviance of subjects submitted to partial laryngectomy and subjects without vocal complaint according to the perceptual analysis

	Partial Laryngectomy		Control	
	n	%	n	%
Degree 0	0	0	4	28,5
Degree 1	0	0	6	42,8
Degree 2	6	42,8	4	28,5
Degree 3	8	57,2	0	0
Total	14	100	14	100

Wilcoxon Paired test, p value lower than 5% (0,00088).Legend: Degrees: 0 (adapted), 1 (mild), 2 (moderate), 3 (intense)

The perceptual analysis of both groups evidenced that the most altered voices were classified with intense degree of deviance (nine subjects – 64,2%), mostly located in the upper right quadrant of the diagram. The group without vocal complaints presented mild to moderate deviances, and vocal samples were divided between the lower right (10 subjects – 71,4%) and the lower left (4 subjects- 28,5%) quadrants of the diagram. The Binomial proportion test revealed statistical significance in the relation between the perceptual analysis and the location of voices in quadrants of both groups when the GGD resulted in altered voices of degrees 2 and 3 and the upper right and lower right quadrants (altered voices), as showed in Table 2.

Table 2 – Comparison of the global degree of vocal deviance (grbasi) with the location of voices in the phonatory deviance diagram quadrants of subjects submitted to partial laryngectomy and the group without vocal complaint

Quadrants	Lower Left		Lower Right		Upper Left		Upper Right	
	n	%	n	%	n	%	n	%
Partial Laryngectomy Subjects								
Degrees 0-1	0	0	0	0	0	0	0	0
Degree 2	0	0	3	21,4	0	0	3	21,4
Degree 3	0	0	2	14,2	0	0	6	42,8
Total	0	0	5	35,6	0	0	9	64,2
Control Subjects								
Degrees 0-1	4	28,5	6	42,8	0	0	0	0
Degree 2	0	0	4	28,5	0	0	0	0
Degree 3	0	0	0	0	0	0	0	0
Total	4	28,5	10	71,3	0	0	0	0

p value (p-0,144) Binomial Proportion test. Legend: Lower Left Quadrant = adapted voices, Lower Right Quadrant =rough voices, Upper Left Quadrant = moderate degree, Upper Right Quadrant =breathy voices.

According to the distribution of voices in quadrants of the PDD, Table 3 indicates that all voices of subjects submitted to partial laryngectomy, 14 (100%), were distributed out of the normality quadrant. Vocal samples of control group were distributed: four (28,5%) in the lower left quadrant, and ten (71,5%) out of the normality quadrant, all of them in the lower right quadrant. The statistical analysis of both groups' voices regarding their distribution in the diagram (in or out of the normality area) did not point statistical significance with the Fisher exact test and the Chi-square test.

Table 3 – Area configuration and distribution of voices from the partial laryngectomy group and the control group in the phonatory deviation diagram, in and out of the normality quadrants

Areas	Partial Laryngectomy Subjects		Control Subjects	
	n	%	n	%
Within Normality	0	0	4	28,5
Out of Normality	14	100	10	71,5
Total	14	100	14	100

Legend: Within normality quadrant =Lower Left Quadrant; Out of normality quadrant =Upper Left and Right Quadrants, and Lower Right Quadrant (Madazio, 2009)

Regarding the location of vocal samples and the types of voices, Table 4 shows that nine subjects submitted to partial laryngectomy (64,2%) were located in the upper right quadrant and five (35,7%) in the lower right. In the control group, ten (71,5%) were in the lower right and four (28,5%) in the lower left, the quadrant of normality. There was statistical significance regarding the location of voices in the quadrants of both groups when voices were altered.

Table 4- Distribution of voices in the four quadrants of the phonatory deviation diagram

Quadrants	Partial Laryngectomy Subjects		Control Subjects	
	n	%	n	%
Lower Left	0	0	4	28,5
Lower Right	5	35,7	10	71,5
Upper Left	0	0	0	0
Upper Right	9	64,2	0	0
Total	14	100	14	100

Binomial Proportion test, p Value lower than 5% (0,0037). Legends: upper right quadrant corresponds to breathy voices, lower right – rough voices, upper left – voices with the worst degree of alteration, and lower left corresponds to normal or adapted voices (Madazio,2009).

Concerning the horizontal axis deviances of jitter and shimmer, it is possible to observe in Table 5 that 14 (100%) voices of the partial laryngectomy group presented deviances in both parameters. In the control group only one subject (6,7%) presented altered jitter, and eight (57,2%) presented altered shimmer. Comparing the deviances presented in both groups, the Fisher exact test revealed statistical significance in the parameter jitter (p-value <0,001), as well as in the shimmer, in which the unpaired test pointed statistical significance regarding values of shimmer between the two groups (p-value <0,001).

Table 5 – Horizontal deviances – jitter e shimmer: partial laryngectomy and control subjects

	Acoustic Parameters			
	jitter		*shimmer*	
	n	%	n	%
Partial Laryngectomy Subjects	14	100	14	100
Control Subjects	1	7,2	8	57,2
Total	14	100	22	157,2

Wilcoxon-Mann Witney test, p value- (0, 000000997) for shimmer. Fisher Exact test, p value-(0,00000074) for jitter.
Legend: jitter: 0 to 0,6% = Normal, jitter:> 0,6% = Altered.
shimmer: 0,0 to 6,5%= Normal. shimmer:> 6,5%= Altered (Behlau, 2001; Madazio, 2009)

The vertical axis deviances (GNE) presented in both groups can be seen in Table 6. It can be observed that 12 subjects from the partial laryngectomy group (85,7%) presented vertical axis deviances, differing from the control group in which only one subject (7,2%) presented alteration in this parameter. Statistical analysis using Fisher exact test and Student t test indicated statistical significance between the two groups regarding this parameter (p< 0,001).

Table 6- GNE proportion – vertical deviance: partial laryngectomy and control subjects

Subjects	GNE Proportion	
	N	%
Partial Laryngectomy	12	85,7
Control	1	7,2
Total	13	92,9

Fisher Exact test. p value (p-0,0000687)
Legend: 0,0 to 0,5 dB= Altered; ,5 to 1,0= Normal (Behlau, 2001; Madazio, 2009)

DISCUSSION

In this article, the acoustic and the perceptual analysis of voices of a group of individuals submitted to partial laryngectomy were compared to a control group composed by subjects of same age and without vocal complaints.

It is important to stress that comparisons between results of different programs of vocal acoustic analysis may present differences, even when using similar measures, due to algorithm differences, to fundamental frequency calculation methods, to types of microphones used, to types of storage of recorded voices, and to types of continuous or sustained speech used[9]. Types of acoustic analysis differ greatly in its measuring characteristics, thus the perceptual analysis is supreme in the vocal clinic. Therefore, the importance of perceptual analysis in the speech language therapy must be enhanced; the perceptual and technological assessment tools are complementary, and enable access to more accurate evaluations of vocal quality by specialists[19].

Voices were analyzed using the phonatory deviation diagram and their distribution and location in the diagram quadrants were studied. It was possible to verify that the totality of vocal samples from the partial laryngectomy group were distributed out of the normality quadrant. Authors point that altered voices are located out of the lower left quadrant, in which are located adapted voices[10,13,20-22]. The statistical analysis revealed that there was no significant difference in the comparison of the distribution of both groups. Such fact may be explained by the number of voices of the normality quadrant in the control group out. Studies showed that pathological voices occupy specific regions in the diagram[10] and that more altered voices are found in the upper right quadrant[14,15] corroborating the findings observed in the present study. This author also found that breathy voices are located in the upper right quadrant, which was also verified in the present study. Regarding the global degree of deviance, moderate and intense deviations were present in the totality of the partial laryngectomy group and in most of the control group subjects.

Concerning the location of vocal samples of the control group, it was observed that only a small part located within the quadrant compatible to adapted voice, that is, the lower left quadrant of the diagram. Great part of the control group's voices (71,5%) were in the lower right quadrant; such location is characteristic of rough voices[14]. This finding stands out, especially considering that the control group had as inclusion criterion the absence of vocal complaints; in its great majority, they were individuals self-referred as healthy, attending sports club, who were invited to take part in this study.

Alterations found in this group may be relate or associated to presbyphonia, which consists in an age-related voice disorder, resulting from anatomic and physiological changes of larynx that interfere in the vocal quality[23].

Presbyphonia is a voice aging process in which the vocal quality is extremely modified over the years. It can be easily recognized in the phonation of an individual after his sixth or seventh decade of life, being more aggravated depending on the individual's life style and health background[24]. Increased roughness/hoarseness have been associated with the aging voice and may be an intrinsic characteristic of the vocal quality in presbyphonia[25,26]. Such modifications found in aging voices suggest that, many times this process is unnoticed once it is considered normal for the age, justifying the lack of vocal complaint in the control group.

Vocal samples of the partial laryngectomy group were located, in its great majority, in the upper right quadrant, corroborating a study in which post-partial laryngectomy voices obeyed the same location[16].

The perceptual analysis when associated to the acoustic analysis revealed that, of the eight voices (57,2%) of subjects submitted to partial laryngectomy that were classified as degree 3, six (42,8%) were located in the upper right quadrant confirming the findings of a study that affirms that the worse the dysphonia the higher the chance of the vocal sample be located in the upper right quadrant[14]. Six voices (42,8%) were classified as degree 2 and their location distributed: three (21,5%) in the upper right quadrant, and three (21,5%) in the lower right quadrant. The perceptual analysis of the control group showed that four (28,5%) of the vocal samples were classified as degree 2 (moderate), located in the lower right quadrant. Six (42,8%) had mild degree, four located in the lower right quadrant (28,5%) and two (14,3%) in the lower left quadrant (adapted voice).

The Phonatory Deviation Diagram offered a quantitative analysis of vocal samples of both groups. The jitter measures, that indicate frequency disturbance in a short time, showed that all voices from the partial laryngectomy group presented alterations. In the control group, this parameter was present in a minority of subjects. Jitter values below 0,6 are considered normal and the average of this parameter in the partial laryngectomy group was 11,41, revealing a high value and corroborating a study that reports that in normal individuals the jitter value is small; nevertheless, in the presence of vocal cords lesions there is a higher aperiodicity and jitter values are more elevated[26]. Some authors affirm that this measure's values are higher in cases of vocal cords disorders, such as what happens in individuals submitted to partial laryngectomy of this study[23,27,28] and is correlated to roughness[14,29-32]. The statistical analysis of this parameter by the Fisher exact test indicated significance regarding the horizontal axis deviance in the comparison of both groups (p-0,00000074).

There was alteration in shimmer values in both groups. Shimmer is related to amplitude variations of the sound wave in a short time and represents irregular alterations in the glottal cycle amplitude from one cycle to another[11,18]. Normal values of shimmer are below 6,5 according to studies that used this measure[12,14,20]. It was possible to observe that the average of the partial laryngectomy group was 31,02 while the control group presented average of 8,6, indicating alteration in both groups.

The shimmer alterations found in the partial laryngectomy group are related to the vocal quality prejudice due to larynx surgery affecting the glottis. Authors refer that after partial laryngectomy it is expected that subjects present worsening of speech intelligibility and prejudice of vocal quality[4].

Authors of a study also point that the vocal quality is proportional to the vocal cords integrity after a conservative laryngectomy. Thus, the vocal function is affected by the extension of glottic carcinomas resection[33]. The same authors refer that shimmer alterations are usually related to reduced glottic resistance and that the increased jitter and shimmer parameters reflect an increase in the aperiodicity of the glottic cycle and in the variability of the sound wave amplitude.

Most of the voices in the control group also presented altered shimmer. Studies affirm that the shimmer alters especially in glottic resistance situations or presence of mass lesions, and it is correlated to the presence of noise at emission and breathiness[11, 14,31,34]. Shimmer is frequently associated to the noise at emission and, thus, tend to be higher in cases of breathiness[28]. The author affirms that jitter and shimmer values are usually higher in male voices. Therefore, both groups presented alteration in this parameter, the first one as a result of organic alterations due to partial laryngectomy affecting the glottis, and the second one because of functional disorder compatible with presbyphonia.

In a study in which the acoustic parameters of voice of elderly men were analyzed, the author found that shimmer tends to gradually and linearly decrease and that this acoustic parameter is more sensitive to male vocal age[23]. Data found in the mentioned study disagree with the majority of literature that affirms that jitter and shimmer measures tend to change with aging and that it is expected an increase of both jitter and shimmer in men.

Alterations found in this parameter corroborate previous studies that affirm that shimmer, as well as jitter, increase over the years due to anatomic and physiological changes during the aging process, increasing signal instability[27,33]. Considering that individuals from this study are between 26 and 78 years old, part of the group may present presbyphonia characterizing the alterations found in voices of the group without vocal complaint. Statistically there was significance between the two groups regarding this parameter (p-0, 000000997).

Concerning the vertical axis deviances, the GNE measure was altered in most of the partial laryngectomy group (85,7%). The GNE proportion is related to breathiness, which is caused by an increase of the sonorous airflow[35]. GNE indicates if the vibration of vocal cords or a turbulent airflow generated in the vocal tract is originating the vocal signal; thus, the alteration in this parameter is natural in breathy voices[14]. In the control group, only one subject (6,7%) presented altered GNE. In the comparison of both groups regarding this parameter, there was statistical significance ($p < 0,001$).

CONCLUSION

Voices of subjects submitted to partial laryngectomy affecting the glottis present altered jitter, shimmer and GNE. There was a statistically significant relation between the perceptual analysis and the location of the voices in the phonatory deviation diagram, out of the normality area and in the upper right quadrant.

There was no significant difference in the comparison of the distribution of voices in both groups. Such fact may be explained by the number of voices of the control group out of the normality quadrant. The control group, even without vocal complaint, with good health and mean age of 62 years presented deviances in the PDD, which may be associated to the natural process of vocal aging, an alert of presbyphonia in this age group.

RESUMO

Objetivo: comparar dados acústicos obtidos por meio de diagrama de desvio fonatório de vozes de pacientes disfônicos submetidos a laringectomias parciais com vozes de sujeitos de mesma faixa etária, porém sem queixa vocal. **Métodos:** foram estudadas as vozes de 28 sujeitos sendo 14 sujeitos laringectomizados parciais e 14 sujeitos sem queixa vocal, compondo um grupo controle. Ambos os grupos do sexo masculino com mesma faixa etária e nível de escolaridade. **Resultados**: as vozes dos laringectomizados parciais 100% distribuíram-se fora do quadrante de normalidade, sendo que 64,3% se localizaram no quadrante superior direito, 100% apresentaram desvios horizontais *e 85,7%* tiveram desvio vertical de ruído. Do grupo controle 28,5% distribuíram-se dentro do quadrante de normalidade, 71,5% localizaram-se no quadrante inferior direito, 57,2% apresentaram desvio horizontal de irregularidade – em *shimmer* e 7,2% em *jitter*. Apenas 7,2% apresentou desvio vertical de ruído no grupo controle. Houve significância estatística em relação aos parâmetros de *jitter, shimmer* e GNE (glottal to noise excitation) e entre a distribuição das vozes nos quadrantes direito superior e inferior do diagrama, na presença de vozes alteradas. **Conclusão:** o diagrama permitiu analisar e discriminar vozes alteradas daquelas com disfonia após laringectomia parcial diferenciando-as por meio de seus parâmetros, distribuição, localização e tipo de voz sendo considerado um recurso útil para análise vocal.

DESCRITORES: Disfonia; Neoplasias; Acústica da Fala; Voz, Percepção auditiva

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