ACOUSTIC/AERODYNAMIC ASSESSMENT OF NORMAL AND DYSPHONIC VOICE

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Abstract: Voice production is a complex multidimensional phenomenon resulting from the combination of acoustic, aerodynamic and elastic forces. The evaluation of voice characteristics in clinical practice is often based only on perceptual and acoustic evaluation, but an exhaustive assessment should take into consideration also aerodynamic parameters.

In this study two groups of subjects, the first one composed by patients affected by organic dysphonia and the second one by controls with normal voice, underwent: simultaneous acoustic/aerodynamic voice assessment by means of EVA device (SQ-Lab, Aix-en-Provence, F); maximum phonation time measurement; GIRBAS perceptual evaluation. Statistical analysis allowed to search for correlations between the perceptual voice quality grading and the recorded acoustic/aerodynamic parameters.

***Keywords* : dysphonia, acoustic assessment, aerodynamic evaluation**

I. INTRODUCTION

The evaluation of voice characteristics in clinical practice is often based only on perceptual and acoustic evaluation. Due to the diffusion of digital systems and software for voice recording and analysis, acoustic measurements are commonly obtained in patients affected by laryngeal disorders. Nevertheless there are no widely accepted and standardized methods; therefore assessing objectively vocal emission is an unsolved problem.

Up to now, only a few studies have been dedicated to the analysis of aerodynamic parameters. Aerodynamic methods have been described since several decades [1-7], but their diffusion has been limited due to the scarcity of specifically designed instruments.

Voice production is a complex multidimensional phenomenon resulting from the combination of acoustic, aerodynamic and elastic forces; it was stated by Hirano [2] that the glottis should be considered as an energy transducer which converts aerodynamic power into acoustic energy. Therefore an exhaustive assessment of vocal function should ideally take into consideration both aerodynamic and acoustic parameters.

The assessment of voice should be based on objective measurements in order to allow a comparison of the results across different voice clinics and different therapeutic protocols.

The goal of this study was to analyze acoustic and aerodynamic indexes in a group of patients affected by dysphonia and in a control group of subjects with normal voice, in order to search for the parameters which better correlate with the dysphonia severity and which allow to discriminate dysphonic vocal emissions from normal ones. We also looked for correlations between the subjective parameters obtained with GRBAS Scale and the objective indexes acquired by the acoustic/aerodynamic evaluation.

II. METHODS

The study includes 51 patients (34 women and 17 men) affected by benign organic dysphonia (22 patients with vocal fold polyps, 12 with cysts, 12 with Reinke's edema, 2 with nodules, 1 with sulcus glottidis). The control group is composed by 23 subjects with normal voice, homogeneous for age and gender.

Both the dysphonic and the normal subjects underwent videolaryngostroboscopy, to ascertain and obtain a documentation of the status of vocal folds.

The protocol for the multidimensional voice evaluation consisted of maximum phonation time measurement, the perceptual voice assessment by means of the GIRBAS Scale [8], and the acoustic/aerodynamic evaluation with EVA device (SQ-Lab, Aix-en-Provence, F).

More in details:

a) Maximum Phonation Time (MPT) measurement was obtained during emission of the vowel /a/ at a comfortable pitch and loudness; three consecutive trials were performed and we considered the best one.
b) Perceptual voice evaluation was by means of the GIRBAS scale [8], which includes the six parameters of the grade of dysphonia (G), instability (I), roughness (R), breathiness (B), asthenia (A), and strain (S). The voice samples were computer recorded using a dynamic microphone (AKG, model C 1000 S) at a constant distance of five centimetres from the patient's mouth during the production of a sustained /a/, the repetition of single words and sentences, and conversation. All of the voice

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samples were subsequently evaluated by a jury of four experienced listeners (two voice therapists and two phoniatricians), and scored in the usual manner (0=normal; 1=slight disturbance; 2=moderate disturbance; 3=severe disturbance). The parameters G,R,B were then taken into consideration for statistics in this study.

c) Acoustic/aerodynamic evaluation. Voice recordings were performed by means of the EVA system, which allows simultaneous analysis of acoustic and aerodynamic indexes. A rubber mask, connected to a mouthpiece, is placed on the mouth of the patients strictly adherent to the skin in order to avoid any air leak. The mouthpiece contains a calibrated directional microphone and a grid pneumotachograph. The microphone and the aerodynamic sensor are coaxial so that voice sound and phonatory airflow may be recorded at the same time. The microphone is at the distance of two centimeters from the patient's mouth.

Two different tests were performed:

1. Voice range profile: the recording is made while the patient pronounces a sustained /a/ at comfortable pitch and intensity for at least 4-5 seconds. Afterwards four traces are displayed on the computer screen: 1- sound wave form, 2 - intensity, 3 - fundamental frequency, 4 - airflow. A one-second segment is selected for analysis in the most stable part of the wave form. Among the available ones, the following acoustic indexes were taken into consideration: Mean Fundamental Frequency (F_0), coefficient of variation of F_0 (CV F_0), Jitter %, Shimmer %, Harmonics to noise ratio (HNR), Intensity coefficient of variation (I CV).
   The considered aerodynamic indexes were: mean oral airflow (OAF), expressed in cc per second; Oral airflow coefficient of variation; this index relativizes the OAF standard deviation to the mean airflow value per second; it is an indicator of airflow instability and, indirectly, of the capability to achieve and maintain glottic closure during phonation; Glottic leakage (= Mean OAF/Mean Intensity) is expressed in cc/s/dB; this index evaluates the amount of air utilized to produce one decibel in one second; it estimates the efficiency of the glottis in transforming aerodynamic power into acoustic energy.

2. Airway interrupted method for indirect estimation of subglottic pressure [9] (P, in hPa), during the emission of a sequence of "pa". For this test a pressure sensor allowed to measure intraoral pressure and to derive subglottal pressure.
   The values of laryngeal resistance (LR, calculated as the ratio P/OAF), the Glottal efficiency index (GEI, calculated as the ratio dB/hPa) and the laryngeal efficiency (LE, measured as the ratio $dB/(hPa \cdot dm^3/s)$) have been derived by the EVA software.

Statistical analysis

Data are presented as mean ± SD.

Intergroup comparison was performed with the Mann-Whitney test. Associations between parameters were determined by Pearson's correlation coefficients. Two-sided exact tests were used and p values of less than .05 were considered significant. All statistics were calculated using the Statistical Package for the Social Sciences 17.0 for Windows software package (SPSS Inc, Chicago, IL).

III. RESULTS

Table 1 reports results of statistical analysis concerning 13 considered acoustic/aerodynamic parameters of the voice and maximum phonation time (MPT). All variables but L.R., FO and oral airflow were significantly different in dysphonic subjects when compared to normal controls (Tab. 1).

Tab. 1

	Case	**Control**	**p**
G.E.I	7.33 ± 2.58	11.11 ± 3.90	<0.001
L.E.	35.47 ± 26.88	127.60±146.15	<0.001
L.R.	53.34 ± 31.79	77.55 ± 68.41	ns
P	12.14 ± 4.44	8.13 ± 2.77	<0.001
MPT	11.45 ± 5.59	18.08 ± 6.44	<0.001
F0 (Hz)	163.22±46.61	163.24±48.65	ns
CV F0	2.46 ± 3.26	0.74 ± 0.32	<0.001
I CV	1.26 ± 0.58	0.85 ± 0.30	0.002
Jitter %	2.30 ± 4.73	0.44 ± 0.24	<0.001
Shimmer %	1.02 ± 0.90	0.30 ± 0.15	<0.001
HNR	13.13 ± 8.69	20.33 ± 3.23	<0.001
Glottic leakage	3.00 ± 2.28	1.92 ± 0.70	0.017

	Case	Control	p
Oral airflow	225.05±179.90	150.95± 5.46	ns
OA CV	7.24 ± 8.40	3.55 ± 2.14	0.048

The correlation between the grade of dysphonia (measured by GIRBAS scale) and the six parameters reported in table 2 - in particular three aerodynamic parameters and three acoustic ones - resulted significant. The values of CV FO, Jitter and Shimmer increased when G increased, whereas G.E.I., L.E. and HNR decreased. Also the correlation between G and the other variables was evaluated, but no significant results were found (Tab. 2). Roughness was significantly correlated with the same variables and also with glottic leakage, oral airflow and OA CV. Breathiness, instead, was correlated with different variables: L.R., MPT and oral airflow; in particular values of airflow increased when B raised, while LR and MPT were inversely related to B value.

Tab. 2

	Grade of dysphonia		**Roughness**		**Breathiness**	
	correlation	**p**	**correlation**	**p**	**correlation**	**p**
G.E.I	- 0.347	0.024	-0.374	0.018	-0.173	ns
L.E.	- 0.364	0.019	-0.332	0.039	-0.316	ns
L.R.	-0.095	ns	0.029	ns	-0.322	0.046
MPT	-0.281	ns	0.05	ns	-0.405	0.007
CV F_0	0.537	<0.001	0.545	<0.001	0.137	ns
Jitter %	0.534	<0.001	0.554	<0.001	0.174	ns
Shimmer %	0.527	<0.001	0.590	<0.001	0.142	ns
HNR	- 0.489	<0.001	-0.559	<0.001	-0.081	ns
Glottic leakage	-0.032	ns	-0.331	0.026	0.281	ns
Oral airflow	0.00	ns	-0.319	0.031	0.293	0.048
OA CV	0.275	ns	0.333	0.026	-0.072	ns

IV. Discussion

Our results confirm that both acoustic and aerodynamic parameters are useful in the assessment of dysphonia as they allow to differentiate an hoarse voice from a "normal" one. Nevertheless overlapping between data obtained by the analysis of dysphonic and normal voices was found; this result is in agreement with the current literature [10-12]. In particular three aerodynamic parameters and three acoustic ones were significantly related to the degree of dysphonia as perceptually measured by the GRBAS scale; nine parameters were significantly related to roughness changes and three with breathiness. These data highlight that perceptual voice evaluation is a reliable means for voice evaluation.

V. Conclusion

This study confirms the utility of both acoustic and aerodynamic indexes for the objective assessment of voice pathologies. Further work will analyze from the acoustic /aerodynamic point of view the outcome achieved by phonosurgery in patients affected by organic pathologies of the vocal folds.

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