Long-term average spectrum loudness variation in speakers with asthma, paradoxical vocal fold motion and without breathing problems

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Abstract

Introduction: Vocal loudness variation can influence the reability of acoustics analysis. Therefore an intensity acoustic measure such as the Long Term Average Spectrum (LTAS) should be submitted to standard calibration and analysis procedures for realistic results. Purpose: The purpose of this study is to compare the LTAS intensity measures with and without implementation of intensity averaging procedures (calibration) in three different groups: asthma, paradoxical vocal fold motion disorder and asthma, and control group. Methods: Eighteen women of similar age were divided in 3 groups according to their diagnosis. Six women had asthma, six women had asthma and paradoxical vocal fold motion disorder and 6 women did not have breathing or voice problems. They were recorded according to a systematized procedure in studio conditions. Fifty-six speech samples were obtained. Those speech samples were submitted to averaged intensity procedures and compared to 56 speech samples not submitted to averaged intensity procedures according to a cluster analysis. Statistical analysis was made according to a six cluster division. Results: Cluster's distribution was almost the same when comparing samples with and without intensity averaging procedures. However two speech samples were considered different according to the intensity procedure. It shows that the loudness variation has an impact in the LTAS acoustic analysis. The comparison among the three different diagnoses was also analyzed according to cluster analysis considering the calibrated samples. The LTAS analysis among the three groups indicated a tendency to grouping the patients with asthma in specific clusters and to conglomerate PVFM and control subjects in same groups. Conclusions: Once LTAS analysis represents the vocal quality it is suggested that asthma patients have specific vocal quality features that differentiates from PVFM and control individuals. This acoustic method can be a useful approach in the diagnosis of these diseases.

1. Introduction

The purpose of this study is to compare the Long Term Average Spectrum (LTAS) intensity measures with and without implementation of intensity averaging procedures (calibration) in three different groups: speakers with asthma, speakers with paradoxical vocal fold motion disorder (PVFM) and asthma, and speakers without breathing problems.

The interest in comparing these groups relies on the fact that PVFM and asthma are diseases with similar manifestations and to differentiate the diagnosis has been a challenge.

Asthma is an inflammatory chronic disease characterized by hyper-responsiveness of the lower airway and variable obstruction of the airflow. This disease is reversible spontaneously or with treatment. The symptoms are stridor, dyspnea, chest pain and cough. The etiologies stem from genetic factors, ambient exposure and specific features that lead to the development and maintenance of the symptoms (III Brazilian Asthma Consensus, 2002).

Paradoxical vocal fold motion (PVFM) disorder is a condition characterized by the intermittent adduction of more than 50% of the vocal folds during the respiratory cycle, usually during inspiration[1]. The common symptoms are dyspnea, cough, and dysphonia and they are similar to asthmatics symptoms[2]. PVFM was first described by Patterson in 1974[3]. The original designation as "Munchausen's Stridor" suggested a factitious or conversion disorder[3]. Case series supported this hypothesis by describing patients with PVFM who had negative medical work-ups and a predilection for psychiatric disease[1,3]. However, further studies have diminished a psychiatric etiology bringing out inflammatory and neurological basis as main contributors[4,5]. Maschka et al[4] proposed that PVFM might represent a spectrum of underlying diseases that manifest as a single clinical entity. His group described cases of PVFM due to medical conditions such as brainstem compression, airway irritant exposure and laryngopharyngeal and gastroesophageal reflux disease (LPR and GER). The concomitance between asthma and PVFM is common (10% to 20% of the asthmatic patients present PVFM). However many patients are not diagnosed because the clinical manifestation is similar. Another troublesome aspect in differentiating both diseases is the fact that the adduction of the vocal folds in PVFM patients is intermittent. Therefore, the laryngoscope visualization of the paradoxical movement of the vocal folds during the respiratory cycle is only evident in symptomatic patients[1].

The treatment for PVFM depends on the case history and diagnostic findings. The underlying pathophysiology may never be fully appreciated. If gastroesophageal or laryngopharyngeal reflux is diagnosed, the treatment usually begins with proton pump therapy and a prokinetic agent[6]. Treatments that focus on medication often fail to reduce or eliminate the PFVM symptoms although they may reduce their severity. Surgical correction occurs rarely in this group although it has been reported[6]. Treatment of PVFM may be a combination of pharmacological and behavioral approaches. For patients with neuropathic etiology a successful treatment with Gabapentin (anticonvulsive) has been documented[7].

The behavioral approach consists of a variety of respiratory-based exercises[1]. Short-term improvements have been seen in several reported treatments papers according to questionnaires and pulmonary function tests[2]. However, acoustic features have not been reported as indicators to differentiate the diagnosis among these diseases (PVFM and asthma) and to document treatment efficacy.

In clinical phonetics, establishing correlates among the perceptual, acoustic and physiologic information is found to be highly relevant for the study of the pathological speech [8].
An acoustic parameter related to voice quality settings [9] is the long-term average spectrum (LTAS) [10]. The spectrum slope represents the intensity in different frequencies ranges and allows the analysis of the spontaneous speech, contemplating laryngeal and supra-laryngeal settings.
The LTAS has been applied to investigate pathologic and professional voices; gender and age differences [11], and to monitor behavior and pharmaceutical dysphonia treatments. Differences between groups are figured out according to higher or lower intensities peaks in specific frequencies ranges. For example, in female LTAS there are intensity peaks in higher frequencies[11]. In voice professionals a singer's formant is seen near 5 kHz, indicating a resonant and louder voice.
However, it is an intensity measure and it can be influenced by variables such as speaker loudness variation, microphone settings such as distance from the mouth and the sound board configuration.
Moreover, intensity is not a linear scale. If there is a loudness increase of 10 dB it could yield an increase of 15 dB in the LTAS in resonances peaks [12]. For a reliable intra and inter speakers comparison analysis it is important to implement standard intensity procedures.

2. Methods

Eighteen women of similar age were divided in 3 groups according to their diagnosis. Six women had asthma, six women had asthma and paradoxical vocal fold motion disorder and 6 women did not have breathing or voice problems.
Recordings were carried out according to a systematized procedure in studio conditions. The data recorded was the "Our Lord" prayer. Subjects were asked to repeat the prayer three times for the sake of intra-speaker reliability. For didactic proposes the description of the recording procedures will be divided into three sections.
In the first section, the placement of head-set microphone and speech signal monitoring is considered. The subjects were seated inside the studio booth and wear head-set microphones placed at 14 cm distance from the speaker's mouth. This distance was the same for all subjects. The speakers counted numbers and their speech signals were monitored with the software Soundforge (VU Meter option).
The second section refers to the sound board (model Soundcraft 328 XD) configuration: (1) a 1 kHz pure tone of 80 dB (measured with a Radio-Shack Digital-Display sound-level meter) was played in an acoustic amplifier, at a 14 cm distance from the microphone. (2) Following the capture and recording of this tone the sound board was configured according to the speaker-specific monitoring features mentioned in the first section of the recording procedure.
The third section comprises the recording procedure of the speech sample. The subject remained seated with the head set microphone placed at a distance of 14 cm from the mouth. At this point the subjects were asked to say the "Our Lord" prayer 3 times as mentioned above.
After the recording procedure acoustic analysis was performed. The Long Term Average Spectrum (LTAS) analysis was done with the Multispeech Software. The frequency range was from 0 to 11 kHz and the period was 85,93 Hz. Three speech samples of each subject were analyzed with a total number of 56 samples.
The intensity measures were submitted to a standard-averaging intensity procedure based on a mathematical formula to calculate proportion. An intensity scale was determined according to the sound board output (section 1 of recording procedure) plus the sound level meter output (section 2 of recording procedure). A standard scale of 80 dB was determined as reference.
The comparison between standard and non-standard intensity measures and among the 3 diagnosis was based on cluster analysis according to a six cluster's division. Cluster analysis is a set of statistics techniques with the purpose to group objects according to their characteristics, forming homogeneous conglomerated and groups. The acoustic features analyzed were intensity and frequency. Therefore the intensity measures for the frequencies from 0 to 11 kHz according to an 85,93 Hz period were computed.

3. Results

3.1 Comparison between standard and non-standard intensity measures

Fifty-six speech samples submitted to averaged intensity procedures were compared to 56 speech samples not submitted to averaged intensity procedures according to a cluster analysis.
The application of a six cluster's division indicated similar but no identical results between standard and non-standard intensity measures (Tables 1 and 2). Table 1 shows that the cluster's distribution of LTAS intensities measures without standard intensities procedures presents 7 asthma patients at the first cluster and 5 asthma patients at the second cluster. The cluster's distribution of LTAS intensities measures with standard intensities procedures (Table 2) indicates the presence of 9 asthma patients at the first cluster and 3 asthma patients at the second cluster.
This statistical and significant difference between LTAS intensities measures with and without standard intensities procedures indicates that 2 speech samples were considered different according to the intensity procedure. It shows that the loudness variation has an impact in the LTAS acoustic analysis.

Table 1. Cluster analysis of the LTAS intensities measures without standard intensities procedures.

	Diagnoses			
Clusters	Asthma	Without breathing problems	PVFM	Total
cluster 1	7			7
cluster 2	5	9	6	20
cluster 3			3	3
cluster 4		3	3	6
cluster 5		6	6	12
cluster 6	6			6
Total	18	18	18	54

Table 2. Cluster analysis of the LTAS intensities measures with standard intensities procedures.

Clusters	Diagnoses			
	Asthma	Without breathing problems	PVFM	Total
cluster 1	9			9
cluster 2	3	9	6	18
cluster 3			3	3
cluster 4		3	3	6
cluster 5		6	6	12
cluster 6	6			6
Total	18	18	18	54

3.2 Comparison among PVFM, asthma and control individuals according to standard intensity measures

The analysis of the LTAS among the three groups indicated a tendency to grouping the patients with asthma in the first and sixth cluster groups (Tables 2).
The acoustic features analyzed were intensity and frequency. The main difference between the first and sixth cluster was the higher intensity between 2 kHz and 5 kHz frequencies. The similarity of the spectrum slope between 0 and 1 kHz is probably what defines the asthma group (Figures 1 and 2).

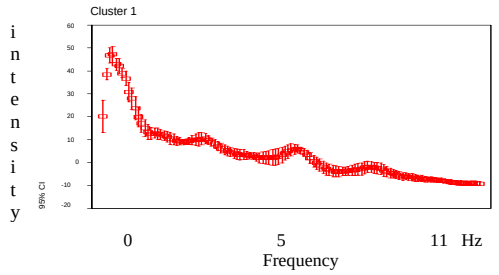

Figure 1

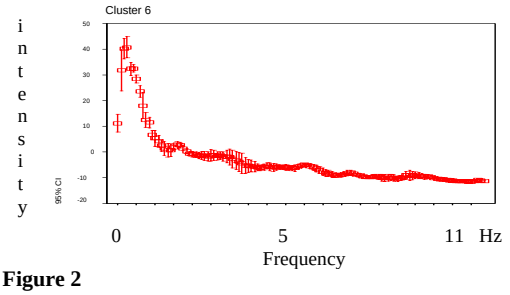

Figure 2
Figures 1 and 2 – First and sixth clusters: mean spectral slopes over the frequency range from 0 to 11 kHz in speech samples obtained by the application of intensity averaging procedures.

The patients with PVFM and speakers without breathing problems were distributed in similar cluster groups (Cluster 2 to 5). The second and fifth clusters groups were similar; however the fifth cluster presented an overall lower intensity (Figures 3 and 4). It is interesting to point out that these clusters represent the majority of the samples.

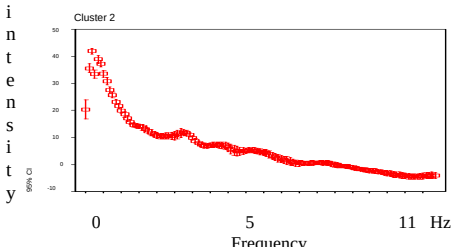

Figure 3

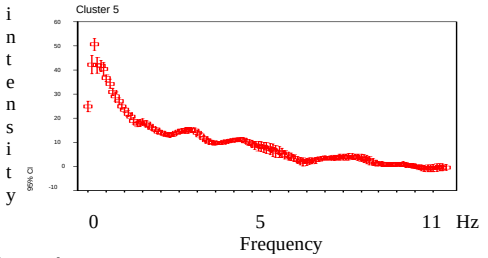

Figure 4
Figures 3 and 4 - Second and fifth clusters: mean spectral slopes over the frequency range from 0 to 11 kHz in speech samples obtained by the application of intensity averaging procedures.

Among the third and forth cluster groups there are defined peaks representing probably supra-laryngeal settings (Figures 5 and 6) because the peaks are in higher frequencies. The third cluster represents one patient with PVFM (figure 5) and the forth cluster represents one patient with PVFM and one with asthma (Figure 6) (Table 2).

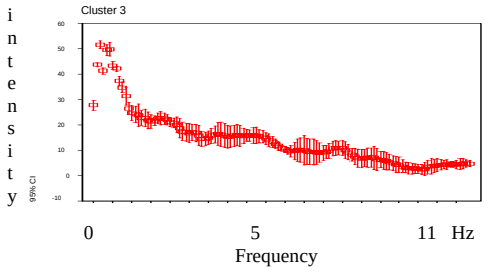

Figure 5

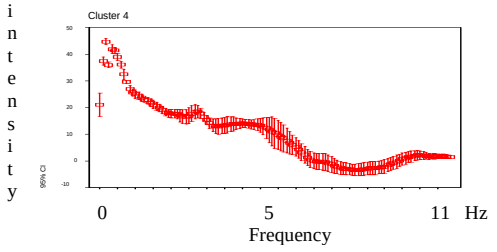

Figure 6
Figures 5 and 6 – Third and forth clusters: mean spectral slopes over the frequency range from 0 to 11 kHz in speech samples obtained by the application of intensity averaging procedures.

Besides cluster analysis the mean LTAS analysis of each group was compared. Figure 7 shows the slopes spectrums obtained from each disease. It shows the similarity of the PVFM and control groups LTAS and a different slope in asthma group. This result was indicated by the statistical analysis as described above.

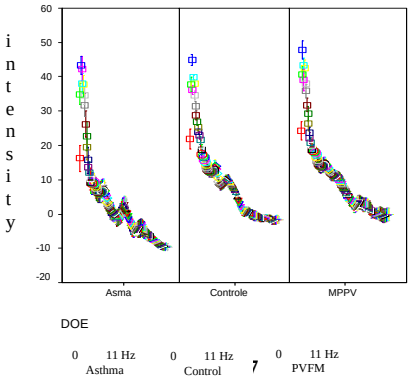

Figure 7 – Groups spectral slopes over the frequency range from 0 to 11 kHz in speech samples obtained by the application of intensity averaging procedures.

4. Discussion

The purpose of this study was to compare LTAS intensity measures submitted and not submitted to intensity averaging procedures in three different groups: speakers with asthma, speakers with paradoxical vocal fold motion disorder (PVFM) and asthma, and speakers without breathing problems; in order to investigate interfering effects related to loudness.

Statistic results indicated similar cluster conglomerates comparing intensity measures submitted and not submitted to intensity averaging procedures. However two samples were posted in different clusters in this comparison, indicating that the loudness variation has a significant impact in the LTAS acoustic analysis, stressing the importance of an intensity standard procedure when dealing with acoustic measures as pointed by Nordenberg and Sundberg (2003). Once calibration and intensity procedure are performed they guarantee that the data for comparison analysis among the three diagnoses group is reliable.

Cluster analysis was applied to the 3 diagnosis groups: PVFM, asthma and without breathing problems speakers. According to the cluster's analysis there were 4 main conglomerates (Table 2). Asthma patients were grouped separated, mainly in the first and sixth clusters. The acoustic features responsible were the higher intensity between 2 kHz and 5 kHz, and the lower intensity up to 1 kHz.

The PVFM and control speakers had their LTAS in similar clusters. The analysis of the LTAS of these clusters indicates similar slopes, but there are different intensities peaks in each cluster.

LTAS analysis is the acoustic parameter related to the vocal quality analysis. Statistical results indicate that there are differences between asthma and PVFM patients' voice qualities. This acoustic method can be a useful approach in the diagnosis of these diseases. It is important to point out that the recording were performed in asymptomatic patients, indicating the acoustic vocal quality analysis as a possible diagnostic exam.

This result shows that LTAS analysis allows refining the group's delimitations, specially the asthma group. Further correlation analysis with perceptual and physiologic vocal aspects, and a follow up study could be performed to analyze the impact of treatment in these patients.

5. Conclusions

Results from comparison between LTAS intensities measures with and without standard intensities procedures indicates that 2 speech samples were considered different according to the intensity procedure. It shows that the loudness variation has an impact in the LTAS acoustic analysis.

LTAS analysis indicates there are differences between asthma and PVFM patients' voice qualities. This result shows LTAS analysis allows refining the group's delimitations, specially the asthma group.

6. References

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