Clustering of Voice Pathologies based on Sustained Voice Parameters

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Abstract: Signal processing techniques can be used to extract information that contribute to the detection of laryngeal disorders. The goal of this paper is to perform a statistical analysis through the boxplot tool from 832 voice signals of individuals with different laryngeal pathologies from the Saarbrücken Voice Database in order to create relevant groups, making feasible an automatic identification of these dysfunctions. Jitter, Shimmer, HNR, NHR and Autocorrelation features were compared between several groups of voice pathologies/conditions, resulting in three identified clusters.

1 INTRODUCTION

Healthy individuals are able to produce vibrations in the vocal folds periodically and with almost constant intensity (Cordeiro, 2016). "When there are pathological changes to the larynx, the level of signal and its fundamental frequency change" (Panek et al, 2015), thus, this sound variation caused by a disorder in the vocal tract may be audible or visible in certain characteristics obtained by signal processing.

The assessment to detect vocal pathologies is considered invasive and relatively expensive (Cordeiro et al, 2015). In addition, the investigation made by a specialist physician, as shown in Zwetsch et al (2006), is not always accurate, because certain laryngeal changes may be similar in certain prisms, although they are intrinsically different from each other.

An alternative method for the recognition of laryngeal disorders is automatic detection using speech processing, which, in reverse to the traditional artifice, "enables non-invasive, low cost and objective assessment of the presence disorders" (Panek et al, 2015).

Signal processing can be used to extract a set of parameters that contribute to the detection of laryngeal disorders. For this, several authors (Guedes et al, 2018; Teixeira J. P. et al, 2017; Teixeira F. et al, 2018; Fernandes J. et al, 2019) used recorded signal of sustained vowels from individuals with a healthy voice, as well as, patients who have some voice disorder. Thus, it is possible to extract relevant information that serves to identify the pathologic subjects or even to classify the pathology. For this purpose, the following parameters have been used extensively: absolute jitter, relative jitter, absolute shimmer, relative shimmer, Harmonic-to-Noise Ratio (HNR), Noise-to-Harmonic Ratio (NHR) and autocorrelation.

Most studies using artificial intelligence to identify the speech samples into one of the pathologies report the scarcity number of subject available for each class in the existent databases (Teixeira F. et al, 2018). Anyhow, some databases have a large number of pathologies available with a low number of subjects. If this slightly small number of individuals of any pathology could be grouped with subjects of a statistically similar pathology, it could become a larger group with a significant number of subjects.

The present work aims to perform a statistical analysis through the boxplot tool, based on the paper written by Teixeira J. P. et al (2018, p. 172). It is used

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the previously quoted parameters taken from the speech signal of 832 individuals for the possible grouping of voice pathologies in order to create relevant groups, making feasible an automatic identification of these dysfunctions. The most common symptoms that may indicate changes in the larynx relate hoarseness, breathiness and roughness (Teixeira J. P. et al, 2013, p 1112).

The section 2 of this document presents the background of the boxplot statistical analysis, followed with the description of material used in the analysis in section 3. Section 4 describes the seven parameters and for each one the statistical analysis between the all pathologies. Finally, Section 5 presents the discussion and final conclusions together

2 DESCRIPTIVE STATISTICAL ANALYSIS

The graphical presentation of a dataset made with the boxplot or box-and-whisker plot uses five indicators: the median, the first quartile, the third quartile, and the smallest and largest number of the set (Mann, 2010). It helps to visualize the distribution and skewness of the elements on the data set, in addition to identifying outliers. To draft the box-and-whisker plot is necessary to calculate the median, first quartile, third quartile and interquartile range of these elements (Hubert and Vandervieren, 2007). Then, find the points that are 1.5 plus and minus this interval in relation to the third and first quartile, respectively, and, finally, the highest and lowest values of the set are determined.

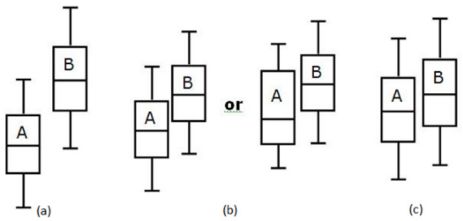

Figure 1: (a) First situation; (b) Second situation; (c) Third situation.

According to Teixeira J. P. et al. (2018, p. 172) the boxplot is used for a descriptive statistical analysis and it compares the elements of a data set through three situations: in the first situation there is no overlap between the boxes, being B greater than A (Figure 1(a)). Hence, there's a difference between groups A and B. In the second situation (Figure 1(b)) the boxes overlay without their medians overlapping the boxes, so there is, probably, a difference between groups A and B. In the third situation (Figure 1(c)) the boxes overlap and their medians (at least one) overlie the boxes. No difference can be considered between groups A and B.

3 MATERIALS

The public available cured database described by Fernandes et al (2019) was used in this work. This database contains, among others, the seven parameters used here, extracted by the algorithms developed by Teixeira and Gonçalves (2016) and by Fernandes et al (2018). This cured database was made with the available features extracted from the Saarbrücken Voice Database (SVD) (Barry and Pützer). The SVD has, for each voice/subject, one segment of voice record with the sustained vowels /a/, /i/ and /u/ for High, Low and Neutral tones in a total of nine speech segments. Each segment of the voice consists in a steady state sustainable pronunciation of the respective vowel. The individuals were analysed and diagnosed by a physician. Many subjects accumulated several voice pathologies, but for this study, subjects with only one pathology were considered. This was because the individuals with several pathologies may interfere in the process of segmentation of characteristics to identify the type of dysfunction to be considered. Table 1 presents the pathologies and its number of subjects available in the cured database (Fernandes et al, 2019).

Table 1: Number of subjects for each pathology/condition.

Groups	Number of Subjects
Carcinoma	19
Chronic Laryngitis	41
Control	194
Cyst	3
Functional Dysphonia	75
Granuloma	2
Hyperfunctional Dysphonia	127
Hypofunctional Dysphonia	12
Hypopharyngeal Tumor	5
Hypotonic Dysphonia	2
Intubation Granuloma	3
Laryngeal Tumor	4
Psychogenic Dysphonia	51
Reinke's Edema	34
Spasmodic Dysphonia	62
Vocal Cord Paralysis	169
Vocal Cord Polyps	27

For proper generalization, the sample size of each group shall contain a relatively large number of elements. Therefore, at least the pathologies Cyst, Fibroma, Granuloma, Hypotonic Dysphonia, Intubation Granuloma, Laryngeal Dysplasia are not supposedly suited to any classification modelling because they have a smaller sample size than the 'relative large number of elements'. However, the purpose of this work is to use pathologies with few individuals in order to set them into relevant groups. Thus, only fibroma and laryngeal dysplasia dysfunctions will not be investigated because they have only one individual.

4 PARAMETERS CHARACTERIZATION AND ANALYSIS

For this study, seven of the acoustic parameters available in the cured database were used. The parameters we considered were: absolute jitter, relative jitter, absolute shimmer, relative shimmer, HNR, NHR and autocorrelation.

4.1 Absolute Jitter

Absolute jitter, as pointed out by Teixeira J. P. et al. (2018, p. 169), "is the glottal period variation between cycles, that is, the mean absolute difference between consecutive periods". This description can be presented in the form of an equation, as can be seen in Equation 1.

$$jitta = \frac{1}{N-1}\sum_{I=1}^{N-1}|T_i - T_{i-1}| \quad (1)$$

The variable T_i is the size of the glottal period and N is the total number of glottal periods.

The comparison for absolute jitter was made separating the genders as, in general, male voices have low fundamental frequency and, consequently, longer glottal periods. Therefore, for longer glottal periods, there are larger deviations (Teixeira J. P. et al 2018). Teixeira J. P. et al (2017) also highlights that individuals, regardless of gender, have higher jitter values when they cannot control the vibration of the vocal folds.

4.1.1 Female Gender

In order to make an easier comparison Figure 2 shows the boxplot of absolute jitter for all the pathologies that are being worked on. In this framework, for cases of hypopharyngeal tumor, hypotonic dysphonia and granuloma caused by intubation, nothing can be stated in the analyses, because there were not enough female subjects in the database to print the boxplot.

Regarding all pathologies, a table can be created with the samples and classify them according to the boxplot presented in Figure 2, based on the previously known theory shown in Figure 1. The number 1 points out the first situation (significant difference between groups) as more appropriate, the number 2 presents the second situation (there is, probably, a difference between groups) and the number 3 indicates the third situation (no difference between the groups). Table 2 presents how were the analysis made between each pathology with absolute jitter for female gender in a succinct way.

4.1.2 Male Gender

In male-focused absolute jitter study, Table 3 shows all pathologies together, pointing out the level of intersection between them. Like in female gender group, this table results from the statistical analyses of all dysfunctions compared with themselves, like in Figure 2.

4.2 Relative Jitter

According to Teixeira J. P. and Fernandes P. (2014), this parameter "is the average absolute difference between consecutive glottal periods divided by the average period and expressed as a percentage", as shown in Equation 2.

$$jitter = \frac{\frac{1}{N-1}\sum_{i=1}^{N}|T_i - T_{i-1}|}{\frac{1}{N}\sum_{i=1}^{N}T_i} \times 100 \quad (2)$$

The descriptive statistical analysis presented in Table 4 succinctly presents a comparison between the studied pathologies and their possible classification based on how the dysfunctions are connected each other, according to the boxplot overlap of each pair of pathologies/conditions.

4.3 Absolute Shimmer

Absolute shimmer (ShdB) refers to the amplitude variation peak-to-peak of a sound wave, in decibels, extracted from a recorded signal that generates an extensive and sustained vowel. This parameter can be enunciated as the absolute mean of the multiplication between a constant of value 20 and a base 10 logarithm of the ratio between two consecutive periods, as can be seen in Equation 3.

$$ShdB = \frac{1}{N-1}\sum_{i=1}^{N-1}\left|20 \times \log\left(\frac{A_{i+1}}{A_i}\right)\right| \quad (3)$$

The variable A_i is the magnitude of the glottal period and N is the total number of glottal periods.

Based on the information provided in Table 5 it is possible to compare the pathologies and classify them according to this parameter.

4.4 Relative Shimmer

One of the parameters for voice acoustical analysis that affects the vocal quality of patients is the relative shimmer, which is determined, according to Teixeira J. P. et al (2018, p. 170) "as the mean absolute difference between magnitudes of consecutive periods, divided by the mean magnitude, expressed as a percentage", as presented in Eq. 4.

$$Shim = \frac{\frac{1}{N-1}\sum_{i=1}^{N-1}|A_{i+1} - A_i|}{\frac{1}{N}\sum_{i=1}^{N} A_i} \times 100 \quad (4)$$

Table 6 shows the descriptive statistical analysis of the relative shimmer parameter, which is used to compare the pathologies each other based on the level of intersection presented by their boxplot.

4.5 HNR

The HNR parameter represents the relationship between the periodic and aperiodic components of a speech segment, being the first component result from the vibration of the vocal cords, while the second component is a glottal noise. Several authors inquire for different ways to express the HNR. In this work, will be followed the Equation 5 presented by Fernandes et al. (2018). According to the authors HNR "consists in measure the energy of the first peak of the normalized autocorrelation and consider that this is the energy of the harmonic component of the signal, and consider the remaining energy as the noise energy given by the difference between 1 and the harmonic energy".

Table 7 resumes the comparison between pathology groups and points out each one can be considered the same group or not, based on the existence of overlap between the boxplot's groups, like in Figure 2, and inform what is the level of intersection between the groups.

$$HNR(dB) = 10 \times \log_{10}\frac{r'_x(\tau_{max})}{1 - r'_x(\tau_{max})} \quad (5)$$

The expression $r'_x(\tau_{max})$ is the maximum local of the normalized autocorrelation.

4.6 NHR

Oppositely to the HNR, according to Fernandes (2018), the NHR is the liaison between the aperiodic component, more specifically the noise, and the periodic component, related to the vibration of the vocal cords. As this parameter is not measured in the logarithmic domain, its values follow opposite directions and are not exactly inverse to the HNR. The Equation 6, which describes the NHR, is determined as a function of the autocorrelation.

$$NHR = 1 - autocorrelation \quad (6)$$

The investigation of pathologies with results presented in Table 8, were conceivable to analyze and classify the dysfunctions among themselves, in order to shortly express the relation between pathologies, according to this parameter.

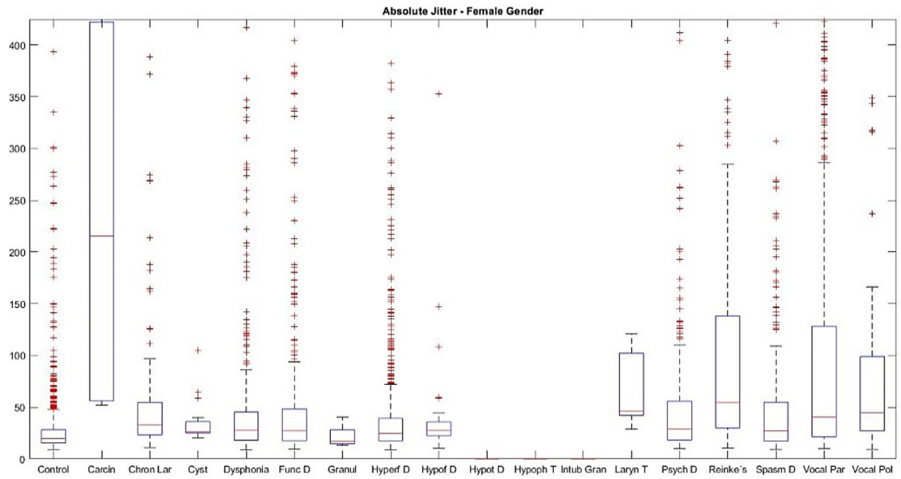

Figure 2: Comparison of boxplot of the pathologies groups using absolute jitter for female voice signals.

Table 2: Result of the analysis of boxplot for absolute jitter for female voice signals.

	Vocal	Par	Spasm D	Reinke's	Psych D	Laryn T	Intub Gran	Hypoph T	Hypot D	Hypof D	Hyperf D	Granul	Func D	Cyst	Chron Lar	Carcin	Control
Vocal Pol	3		3	3	3	3				3	2	2	3	2	3	2	2
Vocal	Par		3	3	3	3				3	3	2	3	2	3	2	2
		Spasm D	3	3	3	3				3	3	3	3	3	3	1	2
			Reinke's	3	3	3				1	2	1	2	2	3	2	1
				Psych D	3	3				3	3	2	3	3	3	1	3
					Laryn T	3				1	1	1	3	1	3	2	1
						Intub Gran											
							Hypoph T										
								Hypot D									
									Hypof D	3	3	3	3	3	1	3	
										Hyperf D	3	3	3	3	1	3	
											Granul	3	3	2	1	3	
												Funct D	3	3	1	3	
													3	3	1	3	
													Cyst	3	1	3	
														Chron Lar	1	2	
															Carcin	1	

Table 3: Result of the analysis of boxplot for absolute jitter for male voice signals.

	Vocal	Par	Spasm D	Reinke's	Psych D	Laryn T	Intub Gran	Hypoph T	Hypot D	Hypof D	Hyperf D	Granul	Func D	Cyst	Chron Lar	Carcin	Control
Vocal Pol	3		3	3	3	1	3	3	3	3	3	1	3	3	3	3	3
Vocal	Par		3	3	3	2	3	3	3	3	3	1	3	2	3	3	2
		Spasm D	3	3	3	3	3	3	3	3	3	1	3	2	3	3	2
			Reinke's	3	1	3	3	3	3	3	3	2	3	3	3	2	3
				Psych D	1	3	3	3	3	3	3	2	3	3	3	3	3
					Laryn T	1	1	1	1	3	1	1	1	1	1	3	1
						Intub Gran	3	3	3	1	3	3	3	3	3	3	3
							Hypoph T	3	3	3	3	3	3	3	3	2	3
								Hypot D	3	3	3	3	3	3	3	2	3
									Hypof D	3	3	3	3	3	3	2	3
										Hyperf D	2	3	3	3	3	2	3
											Granul	3	2	2	2	1	3
												Funct D	3	3	3	2	3
													3	3	3	3	3
													Cyst	3	3	2	3
														Chron Lar	2	3	
															Carcin	2	

Table 4: Result of the analysis of boxplot for relative jitter.

	Vocal	Par	Spasm D	Reinke's	Psych D	Laryn T	Intub Gran	Hypoph T	Hypot D	Hypof D	Hyperf D	Granul	Func D	Cyst	Chron Lar	Carcin	Control
Vocal Pol	3		3	3	3	2	3	3	3	3	3	2	3	2	3	2	2
Vocal	Par		3	3	3	2	3	3	3	3	3	2	3	2	3	3	2
		Spasm D	3	3	2	3	3	3	3	3	3	2	3	2	3	3	2
			Reinke's	3	2	3	3	3	3	3	3	1	3	2	3	3	2
				Psych D	1	3	3	3	3	3	3	2	3	3	3	2	3
					Laryn T	1	1	1	1	1	1	1	1	1	1	3	1
						Intub Gran	3	3	3	3	3	3	3	3	3	2	3
							Hypoph T	3	3	3	3	2	3	3	3	2	3
								Hypot D	3	3	3	2	3	3	3	1	3
									Hypof D	3	3	2	3	3	3	2	3
										Hyperf D	2	3	3	3	2	3	
											Granul	2	3	2	1	3	
												Funct D	3	3	2	3	
													3	3	2	3	
													Cyst	3	1	3	
														Chron Lar	2	3	
															Carcin	1	

4.7 Autocorrelation

The correlation of two signals, by itself, is the sum of the values of their products. Therefore, as Fernandes (2018) said, the autocorrelation can be elucidated as the correlation of a signal with itself. The autocorrelation function, for a sound wave, is a method of detecting the periodicity of the signal, in which the autocorrelation of the signal window is divided by the autocorrelation of the window used, as can be seen in Equation 7.

$$r_x(\tau) = \frac{r_a(\tau)}{r_w(\tau)} \tag{7}$$

where the expression $r_a(\tau)$ is the normalized autocorrelation of part of the selected signal and $r_w(\tau)$ is the normalized autocorrelation of the used window.

Table 9 presents the level of connection between the pathologies.

Table 5: Result of the analysis of boxplot for absolute shimmer.

	Vocal Pol	Vocal Par	Spasm D	Reinke's	Psych D	Laryn T	Intub Gran	Hypoph T	Hypot D	Hypof D	Hyperf D	Granul	Func D	Cyst	Chron Lar	Carcin	Control
Vocal Pol	3	3	3	3	1	3	3	3	3	3	1	3	2	3	3	2	
Vocal Par	3	3	3	2	3	3	3	3	3	3	1	3	3	3	3	3	
Spasm D	3	3	2	3	3	3	3	3	3	3	1	3	3	3	3	3	
Reinke's	3	2	3	3	3	2	3	3	3	2	1	2	2	3	3	2	
Psych D	1	3	3	3	3	3	3	3	3	2	3	3	3	2	3		
Laryn T	1	1	1	1	1	1	1	1	1	1	1	1	1	3	1		
Intub Gran	3	3	3	3	2	3	3	3	3	3	3	3	3	3	3		
Hypoph T	3	3	3	2	3	3	3	3	3	3	3	3	2	3			
Hypot D	3	3	3	3	3	3	3	3	3	3	3	3	2	3			
Hypof D	3	2	3	3	3	3	3	3	3	3	3	3	2	3			
Hyperf D	2	3	3	3	2	3	3	3	3	3	3	3	2	3			
Granul	2	2	2	1	2												
Funct D	3	3	2	3													
	3	3	3	3													
Cyst	3	2	3														
Chron Lar	3	3															
Carcin	2																

Table 6: Result of the analysis of boxplot for relative shimmer.

	Vocal Pol	Vocal Par	Spasm D	Reinke's	Psych D	Laryn T	Intub Gran	Hypoph T	Hypot D	Hypof D	Hyperf D	Granul	Func D	Cyst	Chron Lar	Carcin	Control
Vocal Pol	3	3	3	3	1	3	3	3	3	3	1	3	2	3	3	2	
Vocal Par	3	3	3	2	3	3	3	3	3	3	1	3	3	3	3	3	
Spasm D	3	3	2	3	3	3	3	3	3	3	1	3	3	3	3	3	
Reinke's	3	2	3	3	3	2	3	3	3	2	1	2	2	3	3	2	
Psych D	1	3	3	3	3	3	3	3	3	2	3	3	3	2	3		
Laryn T	1	1	1	1	1	1	1	1	1	1	1	1	1	3	1		
Intub Gran	3	3	3	3	2	3	3	3	3	3	3	3	3	3	3		
Hypoph T	3	3	3	2	3	3	3	3	3	3	3	3	2	3			
Hypot D	3	3	3	3	3	3	3	3	3	3	3	3	2	3			
Hypof D	3	2	3	3	3	3	3	3	3	3	3	3	2	3			
Hyperf D	2	3	3	3	2	3	3	3	3	3	3	3	2	3			
Granul	2	2	2	1	2												
Funct D	3	3	2	3													
	3	3	3	3													
Cyst	3	2	3														
Chron Lar	3	3															
Carcin	2																

Table 7: Result of the analysis of boxplot for HNR.

	Vocal Pol	Vocal Par	Spasm D	Reinke's	Psych D	Laryn T	Intub Gran	Hypoph T	Hypot D	Hypof D	Hyperf D	Granul	Func D	Cyst	Chron Lar	Carcin	Control
Vocal Pol	3	3	3	3	1	3	3	3	3	3	2	3	3	3	3	3	
Vocal Par	3	3	3	2	3	3	3	3	3	3	2	3	3	3	3	3	
Spasm D	3	3	1	3	3	3	3	3	3	3	2	3	3	3	2	3	
Reinke's	2	1	2	3	3	3	2	1	2	2	3	3	2	3			
Psych D	1	3	3	3	3	3	3	3	3	3	3	3	3	2	3		
Laryn T	1	1	1	1	1	1	1	1	1	1	1	1	1	2	1		
Intub Gran	3	3	3	3	3	3	3	3	3	3	3	3	3	1	3		
Hypoph T	3	3	3	3	3	3	3	3	3	3	3	3	2	3			
Hypot D	3	3	3	3	3	3	3	3	3	3	3	3	2	3			
Hypof D	3	3	3	3	3	3	3	3	3	3	3	3	2	3			
Hyperf D	3	3	3	3	3	3	3	3	3	3	3	3	2	3			
Granul	3	2	2	1	3												
Funct D	3	3	2	3													
	3	3	2	3													
Cyst	3	1	3														
Chron Lar			3														
Carcin	1																

Table 8: Result of the analysis of boxplot for NHR.

	Vocal Pol	Vocal Par	Spasm D	Reinke's	Psych D	Laryn T	Intub Gran	Hypoph T	Hypot D	Hypof D	Hyperf D	Granul	Func D	Cyst	Chron Lar	Carcin	Control
Vocal Pol	3	3	3	3	1	3	3	3	3	3	2	3	3	3	3	3	
Vocal Par	3	3	3	2	3	3	3	3	3	3	2	3	3	3	3	3	
Spasm D	3	3	1	3	3	3	3	3	3	3	2	3	3	3	3	3	
Reinke's	3	1	3	3	3	3	3	3	3	3	1	3	2	3	3	2	
Psych D	1	3	3	3	3	3	3	3	3	3	3	3	3	3	2	3	
Laryn T	1	1	1	1	1	1	1	1	1	1	1	1	1	2	1		
Intub Gran	3	3	3	3	3	3	3	3	3	3	3	3	3	2	3		
Hypoph T	3	3	3	3	3	3	3	3	3	3	3	3	3	2	3		
Hypot D	3	3	3	3	3	3	3	3	3	3	3	3	3	2	3		
Hypof D	3	3	3	3	3	3	3	3	3	3	3	3	3	2	3		
Hyperf D	3	3	3	3	3	3	3	3	3	3	3	3	3	2	3		
Granul	3	3	2	1	3												
Funct D	3	3	2	3													
	3	3	2	3													
Cyst	3	1	3														
Chron Lar	3	3															
Carcin	2																

Table 9: Result of the analysis of boxplot for autocorrelation.

	Vocal Pol	Vocal Par	Spasm D	Reinke's	Psych D	Laryn T	Intub Gran	Hypoph T	Hypot D	Hypof D	Hyperf D	Granul	Funct D	Cyst	Chron Lar	Carcin	Control
Vocal Pol	3	3	3	3	3	1	3	3	3	3	3	2	3	3	3	3	3
Vocal Par		3	3	3	3	2	3	3	3	3	3	2	3	3	3	3	3
Spasm D			3	3	3	1	3	3	3	3	3	2	3	3	3	3	3
Reinke's				3	3	1	3	3	3	3	3	2	2	3	3	3	2
Psych D					3	1	3	3	3	3	3	3	3	3	3	2	3
Laryn T						1	1	1	1	1	1	1	1	1	1	2	1
Intub Gran							3	3	3	3	3	3	3	3	3	2	3
Hypoph T								3	3	3	3	3	3	3	3	2	3
Hypot D									3	3	3	3	3	3	3	2	3
Hypof D										3	3	3	3	3	3	2	3
Hyperf D											3	3	3	3	3	2	3
Granul												3	3	2	1	3	
Funct D													3	3	2	3	
Cyst														3	3	2	3
Chron Lar															3	1	3
Carcin																3	3
Control																	2

Table 10: Results from the analysis considering the all parameters.

	Vocal Pol	Vocal Par	Spasm D	Reinke's	Psych D	Laryn T	Intub Gran	Hypoph T	Hypot D	Hypof D	Hyperf D	Granul	Funct D	Cyst	Chron Lar	Carcin	Control
Vocal Pol	YES	YES	YES	YES	YES	NO	YES	YES	YES	YES	NO	NO	YES	NO	YES	NO	NO
Vocal Par		YES	YES	YES	YES	NO	YES	YES	YES	YES	YES	NO	YES	NO	YES	NO	NO
Spasm D			YES	YES	YES	NO	YES	YES	YES	YES	YES	NO	YES	NO	YES	NO	NO
Reinke's				NO	NO	NO	NO	YES	YES	NO	NO	NO	NO	NO	YES	NO	NO
Psych D					NO	YES	YES	YES	YES	YES	YES	NO	YES	YES	YES	NO	YES
Laryn T						NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
Intub Gran							YES	YES	YES	NO	NO	NO	YES	YES	YES	NO	YES
Hypoph T								YES	YES	YES	YES	NO	YES	YES	YES	NO	YES
Hypot D									YES	YES	NO	NO	YES	YES	YES	NO	YES
Hypof D										YES	NO	NO	YES	YES	YES	NO	YES
Hyperf D											YES	NO	YES	YES	YES	NO	YES
Granul												NO	NO	NO	NO	NO	NO
Funct D													YES	YES	NO	NO	YES
Cyst														YES	YES	NO	YES
Chron Lar															YES	NO	NO
Carcin																NO	NO

5 DISCUSSIONS AND CONCLUSIONS

The descriptive statistical analysis of each criteria presents the situation that best fits each comparison of the sets. By observing each factor among all the disturbances, it was possible to assemble Table 10, which exposes whether or not the pathologies can be grouped based on these parameters.

When comparing two elements, it can be observed the values arranged for each of the seven parameters. Thus, if a comparison has a value other than the third situation (3) this analysis can already indicate that the sets cannot be clustered. This is because, in order for the sets to be joined, all the parameters must present similarities for both pathologies. Hence, Table 10 presents the expressions "YES" and "NO" indicating that the pathologies may or may not be gathered, as well as the red color for the sets marked with the second expression “NO”

As shown in Table 10, carcinoma, granuloma and laryngeal tumor cannot be grouped with other pathologies. Reinke’s edema, spasmodic dysphonia, paralysis and polyps in the vocal cords can be clustered together due to the similarity with each other. Hyperfunctional, hypophunctional, hypotonic dysphonia, hypopharyngeal tumor and intubation granuloma can be bundled with functional dysphonia cyst and chronic laryngitis.

The pathologies spasmodic dysphonia, paralysis and polyps in vocal cords can agglomerate with chronic laryngitis, granuloma by intubation, hypopharyngeal tumor, functional, hypofunctional and hypotonic dysphonias, as all factors can be associated to the third situation.

It is visible that some pathologies like Chronic Laryngitis, Hypotonic Dysphonia and Hypopharyngeal Tumor can be grouped with all the dysfunctions, except the groups that are not arranged with any dysfunction.

Therefore, it is noticeable that the pathologies with resemblance can be clustered, while divergent dysfunctions are kept away from the other groups.

This work, in the future, can be used to confirm if the use of Artificial Intelligence for clustering of pathological diseases exhibit satisfactory results,

since the sets of these pathologies, in this study, already shows what pathologies can be clustered.

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