ORIGINAL ARTICLE

ACOUSTIC ANALYSIS OF VOICE IN LARYNGEAL PATHOLOGY

Basavaraj Walikar[1], Karthik Shamanna[2], Devan P. P[3], Vidya B. Vandal[4]

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ABSTRACT: What distinguishes man from rest of animal kingdom is the ability to convey ideas, emotions and complex deductive logic by the human faculty referred to as speech, which is fundamentally dependent on tones produced by the human larynx and articulated into recognizable speech by the articulating apparatus. Therefore efficient functioning of this human speech apparatus is crucial for the functioning of humans. When this becomes faulty, efficient functioning is impeded and therefore remedial measures are to be taken.

A prospective case control study was done to study the voice pattern and its variation in different laryngeal pathology. This study involved analyzing the various parameters of speech in 40 patients suffering from laryngeal diseases, and comparing it with results obtained from analyzing speech in 40 normal adults who served as control.

In acute laryngitis, chronic laryngitis and vocal edema, Fo, F max, F min, Jitter and SNR were lower in subjects compared to control. In vocal cord palsy and vocal cord nodule Fo, F max, F min, SNR, shimmer and Jitter were higher in subjects compared to control. In vocal cord thickening Fo, F max, SNR, shimmer and Jitter were higher and F min was lower than control.
KEYWORDS: Acoustic analysis, laryngeal pathology, Voice disorder.

INTRODUCTION: Vocal dysfunction and other disorders of communication affect millions of people and have been identified as areas of national priority for scientific investigation.[1] The spectrum of vocal dysfunction is wide and includes inflammatory insults, benign lesions, nervous system disorders, dysphonia and aphonia. The impact of a voice disorder on an individual is more than a mere visible abnormality of the larynx or audible deviant voice quality.

In the past 10 years, there has been an explosion in the amount of technology available for voice analysis, in many cases; development of instruments is far-ahead of scientific and clinical knowledge regarding phonatory behavior.[2] In particular, we do not yet know how useful this instrumentation will become to the practicing otolaryngologists or speech language pathologist specializing in voice, currently, there are little standardizations of protocols for various measures of voice and a great variability in equipment and the way phonatory data is analyzed.

This study therefore, primarily done to analyze the fundamental factors that govern human voice both in health and disease, to study it complex inter-relationship, how these characteristics change as disease sets in, for early prevention and proper rehabilitation.

AIM OF THE STUDY: To study the voice pattern and its variation in different laryngeal pathology and to compare the pattern with normal voice.

METHODOLOGY: This study comprises 40 patients who were suffering from various laryngeal diseases who attended the E.N.T. outpatient department of Government Wenlock Hospital and K.M.C Attavar Hospital, Mangalore, and 40 normal adults served as control. A detailed proforma was filled for each patient with regard to history, clinical examination and investigations.

Cases (study group): 40 patients were selected based on the diagnosis of recurrent unilateral vocal fold paralysis, vocal nodule, acute laryngitis, chronic laryngitis, vocal cord edema, vocal cord polyp, vocal cord papilloma and vocal cord thickening. Malignancy cases were excluded from the study. Diagnosis was made through indirect laryngoscopy. The mean age range of patient with hoarseness of voice was between 30-50 years.

Control: 40 normal adults were investigated for their voice. They were non-smoking individuals with no history of laryngeal disease. The mean age range of the control subjects was matched with that of the study group and was between 30-50 years.

PROCEDURE: After obtaining consent and detailed history, each subject underwent thorough laryngeal assessment which included indirect and direct laryngoscopy and endoscopic examination.

Active voice analysis was done using the software called VAGHMI. The recording and the analysis was done in a sound proof room by using the microphone meant for the purpose. Only the sound /a/ was used for the purpose of analysis. The prolonged vowel /a/ was chosen because it is considered to be the most sensitive indicator of difference in vowel production.

The microphone was placed on a stand and during recording the distance between the mouth and the microphone was 4-6 cms. Each recorded sound was analyzed using the VAGHMI program for the following parameters: fundamental frequency in Hertz, jitter in percentage, shimmer in decibels and harmonic-to-noise ratio in numbers.

VAGHMI: This is an indigenous software developed for the objective analysis of the voice. This diagnostic and the clinical module have many parameters out of which few have been taken up for the present study as mentioned below.

Fundamental frequency (Fo): Defined as number of glottal pulses divided by time. It represents the number of times the vocal folds open and close per second and is measured in Hertz.

Jitter (Pitch perturbation): It is a cycle to cycle variation in frequency. There are numerous methods to calculate Jitter, which includes jitter factor, jitter ratio and jitter perturbation.

Shimmer: Shimmer is the relative average perturbation of the amplitude of the speech waveform and expressed in decibels (dB). Intensity correlate to loudness, it is measured in dB. Intensity reflects the amplitude for the vocal signal. Shimmer is another component of what is perceived as hoarseness. Shimmer is measured best during phonation of a vowel. It can be expressed as a percentage or in decibels.

Signal-to-Noise Ratio (SNR): SNR contrasts the periodic or regular signal produced by the vocal folds with the 'noise' or a periodic signal from the vocal folds. This is usually expressed in decibels. The more hoarse or noisy a voice is the lower the SNR. A high SNR indicates a relatively clear voice and a low SNR indicates poor quality of voice.

RESULTS: The gender and age group distribution is shown in tables 1 and 2.

Pathology	Male	Female	Total
Laryngitis (Acute, Chronic, Edema & Thickening)	12	09	21
Vocal Cord Nodule	03	06	09
Vocal Cord Palsy	06	04	10
Total	**21**	**19**	**40**

TABLE 1: SHOWING PATHOLOGY & GENDER DISTRIBUTION

	30 -40 Years Male	41-50 Years Male	30-40 Female
Laryngitis	03	09	09
Vocal Cord Nodule	03	-	06
Vocal Cord Palsy	03	03	04
Total	**09**	**12**	**19**

TABLE 2: AGE WISE DISTRIBUTION

Acute Laryngitis: Comparing the values observed in the 30-40 years male group, Fo, f max, F min were consistently higher in normal group when compared to the acute laryngitis though it does not meet the statistical significance, On the contrary, jitter and shimmer values were higher in the study groups with jitter values differences being statistically significant.

When comparing data in the 41-50 age range male groups, Fo, F max, SNR values were consistently higher in the control group when compared to the acute laryngitis. The jitter was higher in the normal in comparison with study group. Similar to the 30-40 age range, the difference in Shimmer values was statistically significant.

Fo, F max, F min and Shimmer values for the female pathological group was higher when compared to the male pathological group. The difference in Fo and f max between the two groups was statistically significant.

Chronic laryngitis: Fo, F max, F min, Jitter and SNR values were affected in the pathological group when compared to the control group. In the males value difference of Fo and F max was statistically significant. The parameter shimmer was found to be affected in the pathological group when compared to the control.

Vocal cord thickening: In the 41-50 yrs age male group, Fo value did not show much variation. F max, Jitter, shimmer and SNR were affected in the pathological group when compared to the

control group. F min value was lower in the pathological group. This difference was found to be statistically significant for the shimmer value.

In the female group, Fo, F max, jitter and SNR were affected in the pathological groups. Only the jitter values were statistically significant. There was minimal difference in the shimmer values between the groups; however the values were not statistically significant.

Vocal cord nodule: In the 30-40 yrs male group Fo, F max, F min, and Shimmer were affected in the pathological groups and was found to be higher, whereas jitter and SNR values were lower in the pathological group. Only the shimmer value reached statistical significance.

There was minimal difference between the female group and control for Fo, F min and SNR. The difference observed in the shimmer value between the pathological and control group was statistically significant.

30 - 40 Yrs. females	F max SD	F min SD
ACL	26.01	14
Chro. L	13.26	36
VCP	16.92	47
VCN	50.6	45
VCT	9.6	5
Control	5.33	26.5

Table 3: Fundamental Frequency max. & min. in 30-40 years females

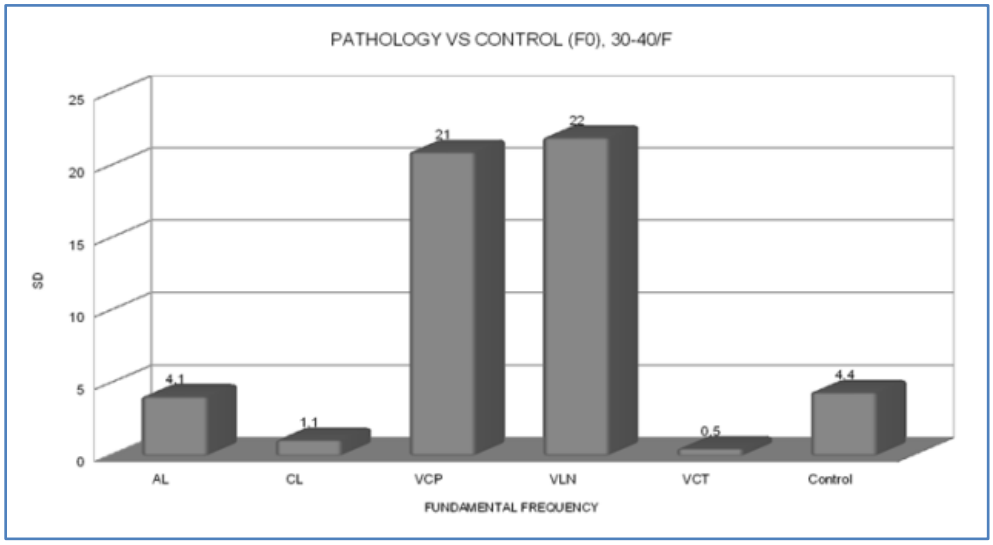
30-40 yrs. Male	F MAX SD	F MIN SD
ACL	12	0.8
Chro Laryngitis	28	26
V.C nodule	69	59
Control	19.0	18.4

Table 4: Fundamental Frequency max. & min. 30-40 yrs. Male

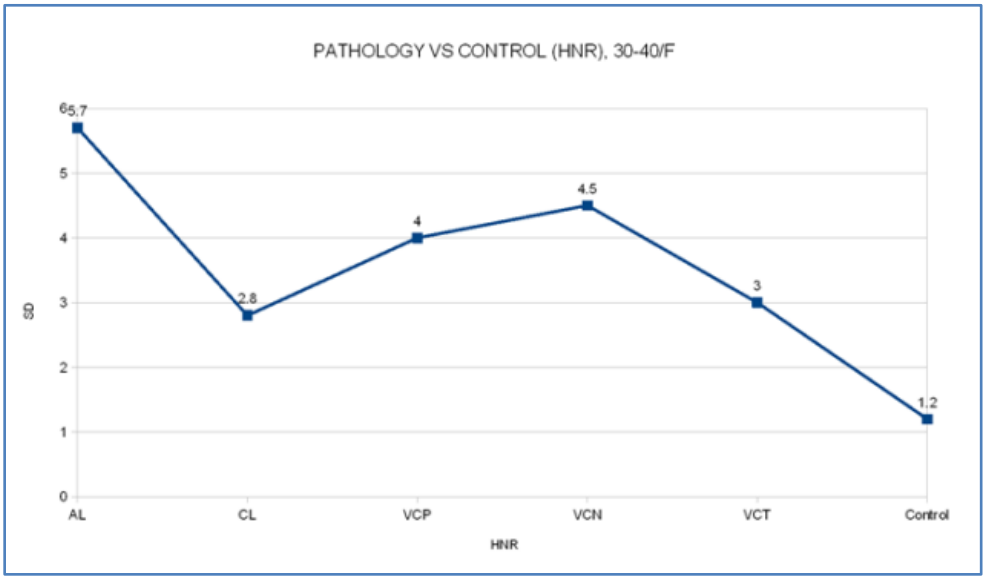
Vocal cord palsy: The values of Fo, F max, F min, Shimmer and SNR were affected in the pathological group (30-40 yrs male) when compared to the control group and was found to be higher. The F max difference was statistically significant.

In the 41-50 age male group, F o, F max, F min, Shimmer and SNR were affected in the pathological groups when compared to the control group and was found to be higher. The difference in the shimmer values was statistically significant.

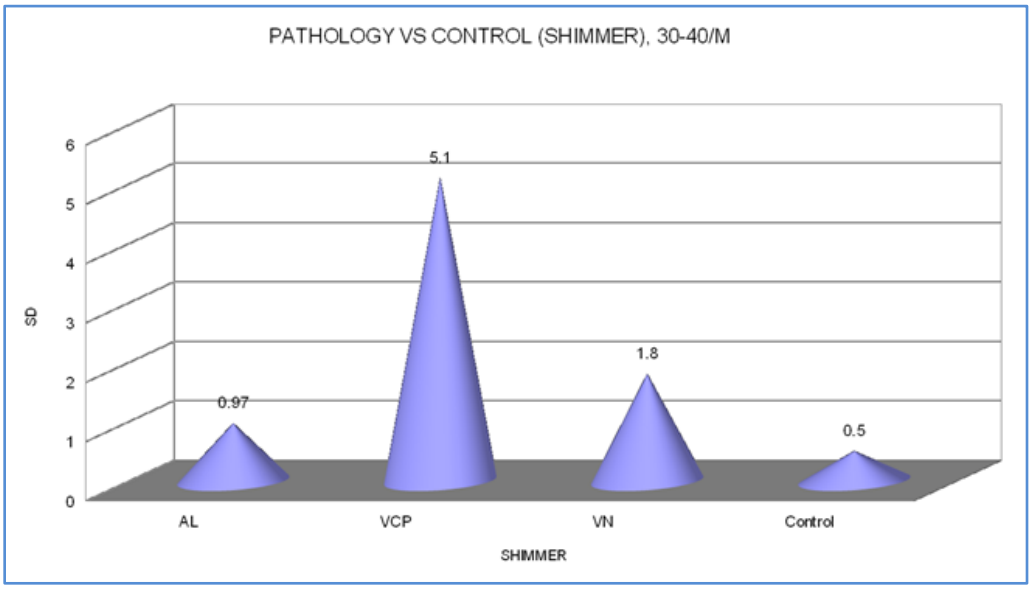
In the female group Fo, F max, F min, jitter and Shimmer values were affected in the pathological groups and was found to be higher than the control groups. F max was statistically significant.



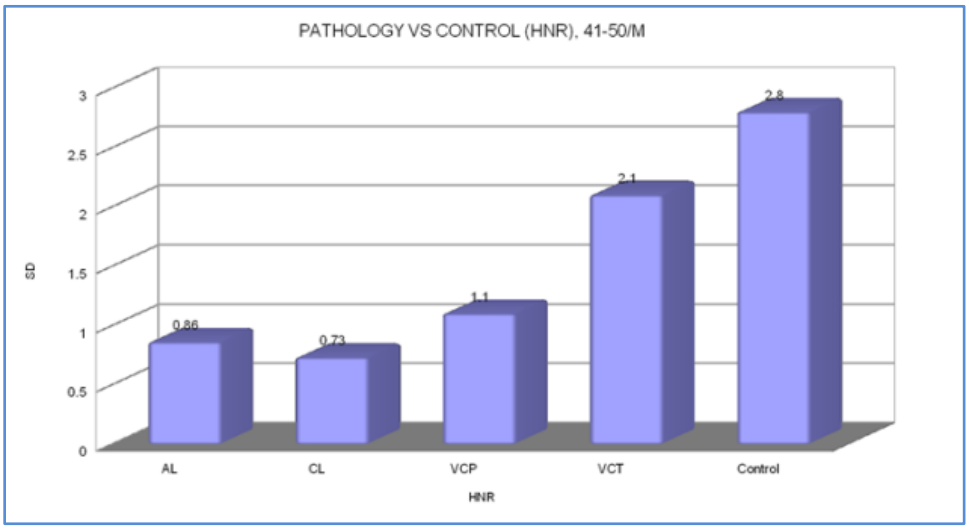
Graph I: Fundamental frequency in 30 – 40 yrs. female vs. Control group



Graph 2: SNR (HNR) in 30 – 40 yrs. female vs. Control group



Graph 3: Shimmer in 30 – 40 yrs. male vs. Control group



Graph 4: SNR (HNR) in 41 – 50 yrs. male vs. Control group

DISCUSSION: The impact of voice disorder on an individual is more than mere visible audibility or audible deviant voice quality. Of late there has been a lot of stress on the objective voice analysis as against the subjective qualification of voice disorder in the past. The objective analysis using computer program plays a prime role in assessing the various parameters of voice. Present study is an attempt to obtain the acoustic parameters in pathological population in comparison with age and sex matched normal subjects.

FUNDAMENTAL FREQUENCY:

Acute laryngitis: The Fo and related values like F max and F min were consistently lower in the 30-40 and 41-50 age range male pathological group when compared to the controls. However this specific feature was opposite in the female pathological group, where they had higher values for Fo and related parameters. The range of frequencies used for phonation was larger in the pathological group. There is a clear cut variation in the way the vocal apparatus behave in two sexes as indicated in the two results. Acute laryngitis affected the younger age group than the older age group in male. This particular aspect has to be studied in depth. The pathological condition had an immense effect on each of the voice parameters in both male and female pathological groups. The frequency parameters were significantly different in the pathological and control groups in females, which could be, attributed to the fact that in both the groups, female vocal tract was more vulnerable for this change.

Chronic laryngitis: In the chronic cases the parameters were consistently lower in the pathological group when compared to the control group. The behavior of the male group was similar though the lowering of frequencies was greater in the chronic than the acute group. Perhaps the vocal tract differs in males and females as indicated in the results for the laryngitis.
It is interesting to note that as the disease becomes chronic, the range of frequencies increases respectively for both the sexes. Again this variation was marked in female group.

Vocal Cord Thickening: The Fo value of this pathological population was comparable to the control group for the both the sexes. The edema and vocal cord thickening which are grouped under this pathological group did not differ much perhaps owing to the fact that the diagnosis of the two conditions is highly subjective.

Vocal cord nodule: In general, the vocal nodule had similar effect on the sexes like that of the acute laryngitis though the finding were opposite with the males showing higher parameters and female showing lower parameters in comparison with control. This sex related variation continued even for the range of frequencies phonated with males showing higher in comparison with controls. Perhaps it would have been more apt to include the details of the size of the vocal nodule in this pathological population. The fact that, none of these parameters reached statistical value for the difference in Fo and related factors is supporting this view.

Vocal cord palsy: The Fo, F max, F min were affected and consistently higher in the study group when compared to the control group for the both the sexes and age ranges. This was statistically significant too. So the affect of vocal cord palsy, whether it is right or left involvement was towards increasing the Fo value. This could be focusing on the fact that bilateral synchronous movement of the vocal folds was essential to get a normal Fo value and that unilateral movements lowered to Fo value.

Moreover the variation observed in the range of frequencies for this pathological group was highest in the sample taken up for this study, again indicating that bilateral synchronous movement was essential for the normal Fo and related values.

Murry[3] Studied 80 males, with 20 normal, 20 unilateral paralyses, 20 benign masses, and 20 laryngeal cancers. He found significant different frequency in paralysis of vocal fold in speech fundamental frequency. Fo of men with unilateral vocal fold paralysis were different from normal.

JITTER: Jitter is the measure of frequency perturbation over a period of time. The jitter parameter adds to the hoarseness element of voice. Jones et al.[4] have highlighted the importance of jitter, indicating that jitter is a potential and sensitive measure of vocal cord dysfunction in females, although it was not statistically significant. Any pathology affecting the vocal cord adds upon the noise element in the voice, which is expected to reflect on the jitter parameter in general. This does not support the view of Fernadis,[5] wherein he comments that age, sex and Fo did not influence the jitter value. The jitter constantly remained lower than controls for both the sexes for laryngitis cases, acute as well as chronic. So the disease per se has no effect on the jitter. This is in opposition with Hanson's finding,[6] wherein he found abnormal jitter values.

A different pattern was seen for other pathologies such as vocal cord palsy, vocal nodule and vocal thickening. With a higher mean of jitter value in palsy cases it can be assumed that unilateral cord movement contributes to the synchronic movement of the vocal cord, which in turn affects affects the jitter values. The picture of jitter was highly varying values; the male values were constantly lower. This could be attributed to the fact that the size of nodule was not taken into consideration during data collection. It could also be that the female vocal system is highly vulnerable; that is the nodule has direct affect on the acoustic parameters.

SHIMMER: The shimmer values of males and females did differ and this was statistically significant. Shimmer was higher in the females in the study sample. Shimmer values of pathological population consistently varied from controls.

The shimmer increased with age and a similar observation was seen for laryngitis group. This particular aspect correlated with the jitter. This is in agreement with Honson's study,[6] wherein he found abnormal shimmer values in laryngitis.

The shimmer in females was different from that of males. So the disease per se has a variable affect on the sex. Surprisingly, this was not the case in chronic laryngitis. Though the shimmer values were affected, they were not differing markedly from controls.

Like all other parameters, palsy was affecting the shimmer values more and this was more in the males than females

The shimmer values were abnormal even in the vocal nodule case. The thickening had a maximum effect on the shimmer values in males. Point to be stressed here is that, this particular pathology group had males in the age range of 41-50 years only. So this worsening could be also attributed to the age factor. Vocal edema also had an effect on shimmer by increasing its value significantly. Shimmer seems to be highly sensitive for the vocal pathology.

SIGNAL - TO-NOISE RATIO (SNR): SNR is the direct measure of the hoarseness element in the voice. SNR correlates well with the spectrographic findings. SNR is often used as one of the diagnostic tool mainly because of its stability. There was a clear cut statistically significant

difference in the SNR values in male and female pathological group. SNR was stable across the age group in males.

Martin[7] analyzed eighty phonatory samples representing normal subjects as well as patients with unilateral vocal fold paralysis, vocal nodules and functional dysphonia. Dysphonic severity of rough voices was predicted more successfully by SNR than shimmer. Dysphonic severity of breathy voices were predicted only by the combined features of less jitter, more shimmer, and lower SNR. No combination of acoustic variables was successful in the prediction of the hoarse voice type.

Nuez and Batalla[8] conducted an objective evaluation of voice disorder in 48 school children. The severity of the hoarseness was classified into four groups according to Yanagiihara method. A multivariate analysis was carried out using shimmer and SNR as variables, only the SNR predicted the severity of the spectrographic record.

Chronic laryngitis also had an effect on SNR values. Similar to the findings in laryngitis case, a differential pattern was observed in palsy cases, but with opposite effect of age. Vocal nodule thickening and edema did not affect the SNR valves. The SNR needs to be explored in depth before commenting on the diagnostic value of the same in the pathological population.

Limitation of the study: Smaller sample size.

CONCLUSION: Computer software based acoustic analysis of voice in various laryngeal pathology was studied using Fo, F min, F max, jitter, shimmer and SNR as parameters. It was observed that there were significant variations in values in the study group as compared to controls and significant variations in values were also observed between male and female pathological groups. Although the software program for acoustic analysis of voice is in its infancy, this study highlights the fact that in the future with advanced computer hardware and software program; we can make a diagnosis of laryngeal pathology by analyzing the pattern of voice profile parameters. This can be useful in situations where proper laryngeal examination could be difficult, particularly in children and elderly patients and can be performed without cumbersome procedures and the need for sedation.

We therefore conclude that an objective analysis of voice plays an important role in diagnosing various laryngeal pathology and can be used as a supportive tool to other subjective assessment. However, further research has to be carried out by incorporating a wider range of acoustic parameters involving a larger study group.

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AUTHORS:

1. Basavaraj Walikar
2. Karthik Shamanna
3. Devan P. P.
4. Vidya B. Vandal

PARTICULARS OF CONTRIBUTORS:

1. Associate Professor, Department of Otorhinolaryngology, Al-Ameen Medical College, Bijapur.
2. Assistant Professor, Department of Otorhinolaryngology, Bangalore Medical College and Research Institute, Bangalore.
3. Professor and HOD, Department of ENT, A.J. Institute of Medical Sciences, Mangalore.
4. Post Graduate, Department of Pedodontics, S. Nijalingappa Institute of Dental Sciences and Research, Bagalkot.

NAME ADDRESS EMAIL ID OF THE CORRESPONDING AUTHOR:

Dr. Basavaraj Walikar,
Department of ENT,
Al-Ameen Medical College,
Bijapur.
E-mail: drbasavarajwalikar@gmail.com

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