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RESEARCH ARTICLE

Voice Disorder Analysis of Thyroid Patients

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Abstract— Here an effort has been made to extract more details from human voice spectrum and facilitating the clinician in better diagnosis of Thyroid patients. Classical acoustic voice analysis has limitation of not having sufficient insight into the human voice spectrum. As Thyroid disease can mimic a variety of common complaints, hence early detection of thyroid disease is important to prevent progression to life-threatening medical conditions like thyroid storm and myxedema coma. Thyroidal imbalances can have an immediate and dramatic effect on the voice. Two methods have been adopted. The one method is the acoustic voice analysis which shows significant differences between normal and thyroid voices. The other method is Bio spectral analysis which involves the pulling of anomalous frequencies of the thyroid patient by correlating human voice frequencies with musical tones. With this approach a prospective effort has been made to extract more details about the disease non invasively.

Keywords— Voice acoustic analysis, Voice, Thyroidectomy, Lambdoma matrix, Vocal profiling.

I. INTRODUCTION

According to the population based cancer registries (PBCR) India, the total cancer cases are increased from 979,786 cases in the year 2010 to 1,148,757 cases in the year 2020. The number of Head & Neck Cancer cases were 122,643 in 2010 with projected estimation of 218,421 by 2020. The number of patients with Larynx as cancer sites were 25,172(11.5%) in 2010 with projected estimation of 33,885(15.5%) by 2020. The number of patients with Thyroid as cancer sites were 4,464(2.0%) in 2010 with projected estimation of 19,113(8.8%) by 2020 [27]. The statistics shows that there will be a dramatic increase in Thyroid cases. The thyroid is one of the largest endocrine glands in the body, is found in the neck sits in front of the trachea (also known as the windpipe). When it doesn't function properly, leads to Thyroid disorder. And 15% to 30% of urban people have prone to thyroid disorder due to existing life style and women are four times more prone to thyroid disorders than men. Parathyroid disease (hyperparathyroidism) causes symptoms in most people, but it will decrease the life expectancy in all patients by about 5-6 years, and the fact that people with hyperparathyroidism have nearly twice the chance of developing breast and prostate cancer, heart disease, and stroke .Vocal dysfunction is one of the very important complications of thyroid patients [5,6,7]. Thyroid Function Test (TFT) is the initial diagnosis step, which measures variation in hormones of thyroid. But, for the existing TFT, the patients are more reluctant and existing diagnosis tests are not cost effective.

Even though, the Thyroid cancer is an emerging cancer as per the Bangalore and Chennai PBCR. India is facing shortage of oncologists and radio therapists having the the ratio of oncologists to cancer patients is about 1:2,000. This leads to a large number of cases undetected, under-diagnosed or improper registration of deaths due to cancer, making the situation more pathetic [27,28].

Acoustic voice analysis can give important objective data on voice disturbances, especially those with organic and functional origins. Therefore it will find the characteristics of voice changes in Thyroid patients and their possible impacting factors [1,4].The objective here is to investigate the features of voice changes in Thyroid patients. And the success of acoustic voice analysis that capture signal irregularities originates from the irregularities of the vibrating vocal folds, may to correlate results with the perceived roughness [2].

II. THYROID GLAND AND VOICE DISORDER

A. Normal Thyroid Homeostasis

The Homeostasis is the ability or tendency to maintain internal stability in an organism to compensate for environmental changes. An example of homeostasis is the human body keeping an average temperature of 98.6 degrees. Other examples are keeping the concentration of salts and glucose constant and with 5 litres of blood the osmolarity of blood remains at 300 mOsm, to compensate for environmental changes. In a similar way the Thyroid gland will also have its own Homeostasis as shown in Fig.1. Thyroid gland is controlled by the Thyroid Stimulating Hormone (TSH) and is in turn controlled by TSH releasing hormone (TRH) as shown in Fig.1. Clinically the TSH is important due to close proximity of hypothalamus and pituitary and diseases affecting one involve the other. Pituitary will senses the less thyroid hormone production by thyroid and TSH rises to stimulate the thyroid gland. Here, the primary problem is with thyroid gland and is called as primary hypothyroidism.

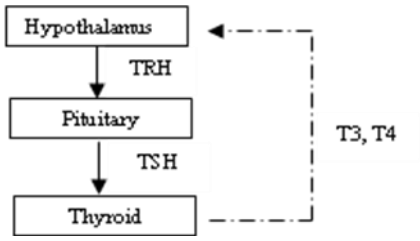

Figure 1. Thyroid Homeostasis

In secondary hypothyroidism, pituitary fails to produce normal amount of TSH even though thyroid gland is normal but cannot produce thyroid hormone in absence of proper stimuli. In a similar way when thyroid gland produces more than normal thyroid hormone is called primary hyperthyroidism and in case of pituitary tumor excess TSH stimulates thyroid gland leads to thyroid hormone in circulating blood, called secondary hyperthyroidism.

B. Disorders of Thyroid gland and Voice Dysfunction

Thyroid diseases occur in the form of abnormalities in the size and shape of the thyroid gland (goiter) and of abnormalities of thyroid secretion. The thyroid gland controls body metabolism and has a profound effect on all bodily functions. The thyroid gland is located in the lower anterior neck in close relationship to the larynx, the trachea, the esophagus, the carotid sheath structures, the sympathetic chain, the recurrent laryngeal nerve, and the mediastinal structures. Diffuse or nodular enlargement, whether benign or malignant, may cause compression or invasion of these adjacent structures. Resulting symptoms may include dysphagia, dyspnea, voice aberration, vocal cord paralysis. Because of strategic location of

thyroid gland may produce symptom complexes that divert the physician's attention away from the thyroid gland and toward the symptoms itself. Therefore, patient's history and review of symptoms should be comprehensive.

Therefore the problems related to thyroid disease create a major challenge to the diagnostic capabilities of the clinician. The patient's symptoms can be confusing and bizarre, leading the physician at times to nonspecific diagnoses, such as psychological problems with depression or anxiety, chronic fatigue syndrome, cardiac failure. The dilemma is more than simply one of hyperfunction vs hypofunction or nodular vs diffuse or benign vs malignant. The patient having either hypothyroid or the hyperthyroid, a diffuse or nodular goiter may not uncommonly be visible in the neck on simple inspection. The patient may have some aberration of the voice. The patient with hypothyroidism with myxedematous infiltration of the vocal cords will have a husky, raspy type voice. And, the patient whose recurrent laryngeal nerve is compromised by pressure or tumor infiltration will have the voice of a paralyzed vocal cord, which will be breathy, barely audible, and inefficient as far as air use is concerned. In other situations, the voice may have a guttural quality indicating obstruction of the aero digestive passageway, usually at the level of the tongue base. This would suggest a lingual thyroid that has failed to descend along normal developmental pathways.

C. Complications with Thyroid Function test (TFT)

Thyroid function tests are blood tests used to evaluate how effectively the thyroid gland is working. Thyroid function tests are used to help diagnose the overactive or underactive thyroid, evaluate the thyroid gland activity and to monitor the response to thyroid therapy. The high-sensitivity thyroid-stimulating hormone (TSH) test is the most sensitive and specific screening test for thyroid disease. A normal TSH level rules out clinical thyroid disease. Abnormal TSH levels are followed by measurements of T_3 and T_4 (preferably free T_4) to confirm the diagnosis. TFT interpretations are less straight forward in cases like familial disease, unusual pattern of TFT results and transient changes in thyroid functions.

Therefore the biggest difficulty in diagnosing thyroidal, or for any hormonal imbalance, is clinically the large normal range for TSH as long as it falls within 0.32 to 5.5 µIU/mL. This leads to a complication of every individual's normal TSH range [25].

III. PATIENTS AND METHODS

Twenty-two thyroid patients (females between ages 17 to 64 years, mean age = 37± 13 years) including eleven patients who underwent thyroid surgery and eleven thyroid patients with medication between November, 2011 and March, 2012 in the department of ENT, JSS hospital, Mysore were included in thyroid group. The patients had histories of the disease ranging from 1 week to 5 years. Thyroid function (T3, T4, TSH) was in the normal range for 50% of patients (with 18.2% in medication patients and 81.8% in patients who underwent surgery). All patients had no history of throat and vocal fold disease, head and neck surgery, or head and neck trauma except one subject. In the control group, 10 subjects (5 males, 5 females, between the ages of 24 and 60 years, mean age 32 ± 10 years) with normal voice function were included.

A. Voice Acoustic Analysis and Parameters

The entire document In the medical field the voice acoustic analysis is used in diagnostic and treatment of voice disorder. The voice analysis will help the clinicians to document the status of vocal function with cycle to cycle information that is not available with stroboscopy [3]. The voice acoustic analysis began with the thyroid patients assuming a natural and comfortable position with the mouth positioned 1 cm from the microphone. The vowel /a/ was produced sustainedly at a comfortable pitch and intensity for 3 to 5 seconds. The signal was digitized, analyzed, and stored using PRAAT software.

The analysis indicators included the average fundamental frequency (F0), the F0 standard deviation (STD), the fundamental frequency perturbation (Jitter), the amplitude perturbation (Shimmer), the harmonic/noise ratio (HNR), the voice turbulence index (VTI), and the degree of sub harmonics (DSH), as follows.

1. *Fundamental frequency (F0):* Pitch or fundamental frequency is calculated by using autocorrelation method, searching for a peak in normal pitch range in speech of 50Hz to 500 Hz. This estimation is improved by the algorithm to find a period time, interpolated between the sampling instants [10, 11, 12].

2. *Jitter and Shimmer:* Jitter and Shimmer are used as indicators of harshness of voice and relative jitter and shimmer are given as a percentage that represents the maximum deviation from a nominal frequency or amplitude [13, 14, 15]. If N is the total number of Pitch periods, T be the fundamental frequency and A the amplitude of particular period then Absolute and relative jitters are calculated using (1) and (2). The absolute and relative shimmer are calculated by (3) and (4).

$$\text{Jitter (absolute)} = \frac{1}{N-1}\sum_{i=1}^{N-1}\left| T_i - T_{i+1} \right| \qquad (1)$$

$$\text{Jitter (relative)} = \frac{\frac{1}{N-1}\sum_{i=1}^{N-1}\left| T_i - T_{i+1} \right|}{\frac{1}{N}\sum_{i=1}^{N} T_i} \qquad (2)$$

$$\text{Shimmer(dB)} = \frac{1}{N-1}\sum_{i=1}^{N-1}\left| 20\log(A_{i+1} / A_i) \right| \qquad (3)$$

$$\text{Shimmer(relative)} = \frac{\frac{1}{N-1}\sum_{i=1}^{N-1}\left| A_i - A_{i+1} \right|}{\frac{1}{N}\sum_{i=1}^{N} A_i} \qquad (4)$$

3) Harmonic to Noise Ratio (HNR): HNR is used to assess vocal fold behavior and is closely related to whisperiness, harshness of voice quality [17, 18]. The HNR (dB) is estimated by frequency domain approach. As first cepstral peak correlates with overall voice quality and breathiness, and is directly proportional to average harmonic to noise ratio [16, 19].

4) Voice Turbulence Index (VTI): Voice Turbulence Index is the average ratio of spectral noise energy in high frequency range to the spectral harmonic energy [20]. VTI correlates with incomplete or loose adduction of vocal folds.

5) Degree of Sub Harmonics (DSH): DSH (%) is computed based on the algorithm used to determine pitch by sub harmonic to harmonic ratio (SHR). SHR can also be used to describe degree of irregularity or roughness that reflects the voice quality [21, 26]. According to Titze [5], sub harmonic generation can occur when there is left-right asymmetry in the mechanical properties of the vocal folds. adduction of vocal folds.

The STD, Jitter, Shimmer, HNR, VTI, and DSH were mainly related to the stability of the vocal fold vibration. The value of these indicators increased when the vocal function was abnormal [6, 7]. The voice acoustic analysis was performed before surgery in case of thyroid patients who underwent surgery and only once in case of control group.

B. Statistical Method

A *t* test was performed to analyze and compare data obtained from experimental group to data from control group, with $P<0.05$ for significant difference [8, 9]. And both groups found to be significantly different in means, as it is also clear from Table I.

C. Bio Spectral Analysis

The vocal fold vibration cannot be directly measured with non-invasive methods because the larynx is not accessible during phonation. The vocal folds are not only the source of the periodic component, but also the main source of aerodynamic turbulent noise in vocalic sounds. [22, 23, 24]. Here Abacus computer program is used to have graphical representation of numeric values of voice spectrum as shown in Fig.2. This program helps in locating anomalous frequencies present in the voice spectrum using FFT. Following are some the anomalous frequencies listed [29].

(i) Spikes: They indicate the presence of an important problem or an issue to the body. The substance may be present in large amount or that substance is blocked from being used by the body. They usually include high frequency extremes in the chart.

(ii) Stringers: They are very low frequency extremes in the chart indicating substance deficiency or a long standing condition in the body, which is correlating with toxins, chemicals.

(iii) M shaped waves : They indicates recent issues of the body.

(iv) W shaped waves : They indicates the chronic or long standing issues of the body.

(v) Truncated Up waves : They indicates information about vitamins, minerals, bone or muscle injury. They points to the potential issues but, it may be present or indication of more or deficiency of substance.

(v) Truncated Down waves : They shows an issue existed for a long time or a chronic condition.

D. Anomalous Frequency Analysis and music

The bio spectral analysis is the identification of anomalous frequencies in the voice spectrum using Abacus program. Abacus is a computer program generating graphical representation of vocal sounds with numeric values. This led to the further analysis of anomalous frequencies present in the voice spectrum. Most of the existing medical diagnostic systems like X-ray, MRI etc are based on vibrational nature of human body. This means that every human molecule, bone, muscle, organ, vitamin, mineral, enzyme and microbe has its own resonant frequency [30].

As the brain is the commanding organ in the body, all of its signals are passing through the main vagus X nerve and is passing very near to the vocal system. Therefore, here an effort is being made to extract as much of this information as possible from voice spectrum to reveal the inner happenings of human body [31]. In this study are trying to extract information about how brain is communicating and commanding with each cell to integrate the body's well being via many neurons. These pathways from brain to all body cells will be nicely revealed by expressing human voice frequencies numerically or graphically using FFT, a significant part of Abacus tool. Here beta brain waves ranging from 16 Hz to 32 Hz are, taken as main reference as a part of algorithm [32].

In view of music, voice is a mathematical representation of sounds, which is chaotic. Each word is made up of individual sound units called phonemes. And here will try to examine the chaos and disharmony of these phonemes. The body may be responding the way how the music becomes disharmony with missing of one or more tunes. At the atomic level, the biochemical reactions taking place in between molecules resulting in complex harmonics. Such harmonics here, can be tried to extract with help of voice analysis. Voice acoustic analysis which was being in the field of study, FFT is the most commonly used efficient computational algorithm to convert analog signals like recorded vocal sounds into its equivalent digital data. Points that are located high on the graph, i.e., "risers", would proportionally indicate loud and over abundant sound frequencies. Points that are low, i.e.,

"stringers", would indicate sound deficient frequencies. Fewer risers and/or stringers would indicate a more coherent vocal presentation [33, JBB, Volume #5, Issue #11 - October, 2005]

IV. RESULTS

The voice acoustic analyses of thyroid patients and of patients in the control group are shown in Table I. In comparison to the control group, the preoperative F0 levels in the thyroid group decreased significantly ($P < 0.05$), whereas the other indexes were significantly higher than those of the control group ($P < 0.05$). The Absolute Jitter, Relative Jitter (%), Absolute Shimmer (dB), HNR, VTI and DSH levels are significantly higher than those of control group. This will indicate that stability of vocal folds is affected and the presence of abnormal voice.

TABLE I
COMPARISON OF VOICE ACOUSTIC ANALYSES OF THYROID PATIENTS WITH PATIENTS IN CONTROL GROUP (MEAN±STANDARD DEVIATION)

Analysis Indicators	Thyroid Cases (n=22)	Control Group (n=10)
f0 (Hz)	434.402428 ± 48.652572	476.212969 ± 34.175376
STD f0 (Hz)	143.642469 ± 16.626601	120.688003 ± 26.340734
Absolute Jitter	0.001081 ± 0.000465	0.000559 ± 0.000246
Relative Jitter (%)	0.346857 ± 0.105360	0.221841 ± 0.096679
Absolute Shimmer (dB)	5.526725 ± 0.812011	4.379583 ± 2.881662
Relative Shimmer (%)	0.070454 ± 0.012263	0.061628 ± 0.024056
VTI	0.566231 ± 1.073825	0.027599 ± 0.021987
HNR (dB)	0.109083 ± 0.020929	0.092278 ± 0.022616
DSH (%)	0.204605 ± 0.081710	0.111878 ± 0.081020

The second method i.e., Bio acoustic voice analysis will focus on the internal architecture of voice spectrum involving the investigation of anomalous frequencies. Fig.2 shows the voice spectrum of the Thyroid patient (Green) with age 26 and compared with that of normal one with age 27. For simplicity of explanation spectrum of 0 to 10 Hz is taken. The spectrum of Thyroid patient has one clear stringer touching -33 dB of energy, tow moderate M waves falling between -44 dB to -8 dB and two upper truncation from -12 dB to -6 dB. The M shaped and Truncated up waves indicates more recent issue with patient that is correlating with her symptoms like having thyroid swelling since two months. The TFT test shows very high TSH value of 150.3 microIU/ml and very low T4 value of 3.4 microIU/ml. This abnormal TFT condition is revealed by the presence of more prominent stringers in the spectrum. Whereas the spectrum of normal group (Red) shows the absence of any of the anomalous frequencies with the presence of normal harmonics. This means that presence of anomalous frequencies in the spectrum is indicating the disturbance in the harmonic status of the body. In this prospectus study the spectrum of only two cases is described.

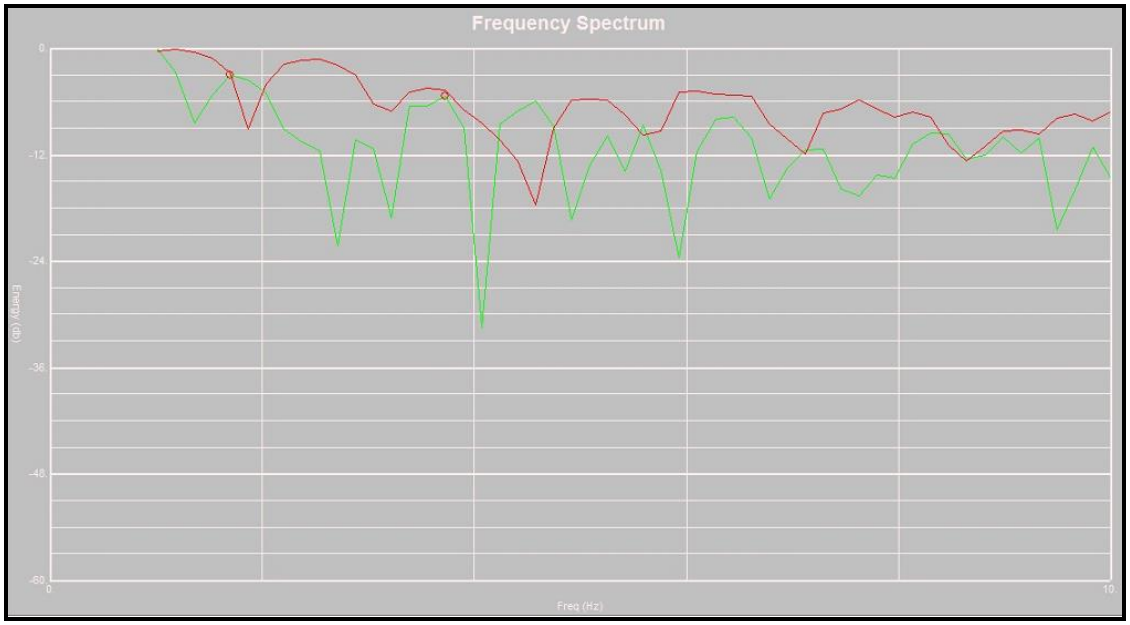

Figure 2. Voice Spectrum

V. DISCUSSION

The voice acoustic abnormal objective voice acoustic analyses are more common in women [3, 4, 6]. In this study the results of voice acoustic analyses of thyroid patients were significantly different from the results of the control group. However, the F0 levels of thyroid patients were significantly lower than the control group levels, and the indexes for the stability of vocal fold vibrations were significantly higher than the normal control group. This demonstrates the presence of an abnormal voice in the experimental group. The possible reasons for decrease in F0 are the emotion and behavioral conditions that affect the human acoustic voice and acoustic detection. And the identification of anomalous frequencies in the spectrum is useful in not only categorizing thyroid patients with TSH levels along with primary classification of pathological voices.

VI. CONCLUSION

This prospective study reveals the preoperative voice acoustic measures were abnormal in female thyroid patients. Performing routine voice acoustic analyses has proved to be especially important in female patients, and it can be helpful in diagnosing preoperative voice disorders without obvious subjective symptoms. Even though the voice acoustic analysis has significantly classify among Thyroid and normal groups but with its less focus upto cellular level, may not further helpful in differentiating among TFT groups or in diagnosing specific voice disorders like Hashimotos thyroiditis. But the spectral analysis gives more insight at cellular level with the future scope of developing unique patterns for specific diseases with voice disorders. This is may be more useful in initial assessment of voice disorder like Hashimotos thyroiditis. And this will be more helpful for patients who are reluctant to existing TFT and costlier medical diagnosis systems are concerned.

REFERENCES

[1] Journal of Bio Acoustic Biology, Volume -5, Issue-11, October, 2005

Article in a journal:

[2] Matthias Fröhlich, Dirk Michaelis, Jan Lessing, Hans Werner Stru-be, Eberhard Kruse "Breathiness measures in acoustic voice analysis",in "Advances in Quantitative Larungoscopy, Voice and Speech Research". Proceedings of the 4th International Workshop. 2000, p. 63-71.

Article in a conference proceedings:

[3] Cummings: Otolaryngology:" Head & Neck Surgery", 4th ed. Mosby.Inc,2005

[4] Cuie Li, Zezhang Tao, Jining Qu, Tao Zhou, and Fei Xia, " A Voice Acoustic Analysis of Thyroid Adenoma Patients after a Unilateral Thyroid Lobectomy", Journal of Voice,April, 2011, in press.

[5] Xuejing Sun and Yi Xu, "Perceived Pitch of Synthesized Voice with Alternate Cycles", Journal of Voice,2002, Vol. 16, No. 4, pp. 443–459.

[6] Alexander Stojadinovic,, Ashok R. Shaha, Robert F. Orlikoff, Aviram Nissan, Mary-Frances Kornak, "Prospective Functional Voice Assessment in Patients Undergoing Thyroid Surgery", Annals Of Surgery,Vol. 236, No. 6, 823–832,2002 Lippincott Williams & Wilkins, Inc.

[7] Serdar Akyildiz , Fatih Ogut , Mahir Akyildiz , Erkan Zeki Engin "A Multivariate Analysis of Objective Voice Changes After Thyroidectomy Without Laryngeal Nerve Injury", Arch. Otolaryngol Head amd Neck Surg./VOL 134 (No. 6), June 2008

[8] Thomas C. Purnell , "A Modest Introduction to Statistics and Acoustic Experimentation", University of Wisconsin, Madison Spring, 1998, rev. Fall 2004 .

[9] HarveyM otulsk, "Intuitive Biostatistics", Oxford Press, 1995.

[10] Lawrence R. Rabiner, "On the use of autocorrelation Analysis for pitch detection", IEEE Transactions On Acoustics, Speech, and Signal Processing, Vol. ASSP-25, No. 1, Feb. 1977.

[11] Kavita Kasi, "Yet another algorithm for Pitch detection", Old Dominion University, 2002.

[12] Johan Liljencrants."Algorithm to find a period time, interpolated between the sampling instants", STL-QPSR 1/91, 1991.

[13] Mireia Farrús, Javier Hernando, Pascual Ejarque, "Jitter and Shimmer Measurements for Speaker Recognition", TALP Research Center, Department of Signal Theory and Communications,Universitat Politècnica de Catalunya, Barcelona, Spain.

[14] Steven Bielamowicz,Jody Kreiman,Bruce R. Gerratt, Marc S. Dauer,Gerald S. Berke, "Comparison of Voice Analysis Systems for Perturbation Measurement", Journal of Speech and Hearing Research, Volume 39, 126-134, February 1996.

[15] Miltiadis Vasilakis, Yannis Stylianou," Spectral jitter modeling and estimation", Biomed. Signal Process. Control,2009 .

[16] Asako Masaki, "Optimizing Acoustic and Perceptual Assessment of Voice Quality in Children with Vocal Nodules",MIT,2009.

[17] Francois Severin, Baris Bozkurt, Thierry Dutoit, "HNR Extraction in Voiced Speech, oriented towards voice quality analysis",TCTS Lab,Faculté Polytechnique de Mons,Belgium.

[18] Peter J. Murphy and Olatunji O. Akande," Quantification of glottal and voiced speech harmonicsto-noise ratios using cepstral-based estimation", Department of Electronic and Computer Engineering University of Limerick, Limerick, Ireland.

[19] Peter J. Murphy and Olatunji O. Akande," Noise estimation in voice signals using short-term cepstral analysis", J. Acoust. Soc. Am. 121 (3), March 2007.

[20] M. Ayhan Congologlu1, Tumer Turkbay, Muzeyyen Ciyiltepe, Ibrahim Durukan, Burak Dogangun, Murat Yuce," Immediate Effects of Methylphenidate on Vocal Acoustic Parameters in Children with Attention Deficit Hyperactivity Disorder", Bulletin of Clinical Psychopharmacology, Vol: 19, N.: 4, 2009.

[21] Xuejing Sun,"Pitch determination and Voice quality analysis using Sub harmonic to Harmonic ratio", Northwestern University, USA.

[22] Ingo R. Titze," The physics of small-amplitude oscillation of the vocal folds",Journal of Acoustic Society of America,83(4),April 1988.

[23] Ingo R. Titze, Hanspeter Herzelb, Patrick Mergella, "Irregular Vocal Fold Vibration-High Speed Observation and modeling", J. Acoust. Soc. Am. 108 (6), December 2000.

[24] Sylvain Lamesch, Boris Doval, Michèle Castellengo, "Influence of the vowel on phonetograms and glottal parameters in the two main laryngeal mechanisms", LAM – IJLRA.

[25] Alan Christianson, "Achieving Balance in the Thyroid", Endocrinology, 10 August,2011.

[26] Yen-Liang Shue," The Voice Source in Speech Production: Data,Analysis and Models",university of california, 2010.

[27] Ramnath Takiar, Deenu Nadayil, A Nandakumar, " Projections of number of cancer cases in India (2010-2020) by Cancer groups", Asian Pacific Journal of Cancer Prevention, Vol 11, 2010.

[28] www.business-standard.com/article/current-affairs/india-has-1-8-mn-cancer-patients-but-only-one-oncologist-to-treat-every-2-000-114052401140_1.html, Sushmi Dey, New Delhi, May 24, 2014.

[29] " Basics of Bioacoustics", Sherry Edards

[30] Oschman, James L., 2000. Energy Medicine: The Scientific Basis. Churchill Living stone, an imprint of Harcourt Publishers Limited.

[31] Garfield-O'Brien, Lauren K, R.N., 1997. Bio-Resonance Therapy.

[32] Journal of Bioacoustic Biology, Vol9, No 10, 2009

[33] Journal of Bioacoustics Biology, Volume 5, Issue 11 - October, 2005

