AERODYNAMIC MEASURES IN PERSONS WITH VOCAL NODULES AND POLYPS

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CERTIFICATE

This is to certify that this dissertation entitled ***"Aerodynamic Measures in Persons with Vocal Nodules and Polyps"*** is a bonafide work submitted in part fulfilment of the Degree of Master of Science (Speech- Language Pathology) by student with Registration No: 12SLP010. This has been carried out under the guidance of a faculty of this institute and has not been submitted earlier to any other University for the award of any other Diploma or Degree.

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DECLARATION

This is to certify that this Master's dissertation entitled ***"Aerodynamic Measures in Persons with Vocal Nodules and Polyps" is*** the result of my own study and has not been submitted earlier to any other University for the award of any Diploma or Degree.

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CHAPTER I

INTRODUCTION

The voice is a major component of speech which is produced by the vocal folds and modified by the structures of oral cavity. Larynx is the structure which houses vocal folds and several other structures such as cartilages, muscles etc., supporting its function in the production of voice. Though the larynx is the major source of sound used for speech, it also requires the participation of respiratory system which provides air source to initiate and sustain the vibratory function of the vocal folds. This complex phenomenon of production of voice is usually studied under different branches of science like acoustics and aerodynamics.

Aerodynamics is the branch of science which deals with the motion of gases in the objects. Laryngeal aerodynamics is a sub- branch of aerodynamics which specifically deals with role of aerodynamic energy in the production of voice. Acoustics is the branch of science which deals with the study of sound. There are several models and theories proposed to understand the physiology of voice production on the basis of acoustic aspects and several assessment methods in the present scenario incorporates acoustic measurements as the major tool.

Hence, in order to understand the physiology of phonation and to differentiate normal voice with pathological voice one should have a thorough understanding of both the aerodynamic and acoustic aspects involved in the voice production.

Voice disorders can occur due to disturbance in either respiratory or phonatory systems or combined. These voice problems can show negative impact on the person's lifestyle mainly in those whose voice is essential for their occupation. Verdolini and Ramig (2001) estimated that 50- 60 % of the clinical population report social, communicative, physical, and psychological problems as a result of voice disorders.

Vocal pathologies can range from a simple form of laryngitis to a severe condition like vocal cord paralysis. But, in a typical voice clinic most widely seen conditions are benign vocal fold lesions such as vocal nodules, polyps, cyst, sulcus vocalis, vocal fold scar etc. (Colton and Casper, 1996). Vocal fold nodules are bilateral swellings on the medial surface of the vocal folds, usually symmetrical (Sataloff, 1997). They generally appear at the junction of the anterior and middle third of the vocal folds i.e. at the mid-part of the membranous vocal folds (Chagnon and Stone, 1995).Vocal nodules, appear mostly in women (Hirano 1981), and the highest prevalence seems to be in young to middle age (Herrington et al., 1988). Their incidence seems to be higher in occupations that require frequent voice use (Fritzell, 1996).

Vocal fold polyps are swellings on the middle third of the membranous part of the vocal fold, often on the free edge, and usually unilateral. They can be sessile or pedunculated, and are very mobile when pedunculated.

These conditions are majorly said to be caused by vocal abuse or misuse behaviours, mostly seen in professional voice users, also can be caused due to pollution, exposure to pharmacological agents, changes in humidity damaging the tissues of the vocal fold layers.

Traditional assessment protocol of these disorders includes stroboscopic examination, acoustic and aerodynamic measures. Each type of measure has its own advantages and disadvantages; however it provides a basic understanding about the underlying physiology.

Aerodynamics play a major role in the production of voice as the normal phonation is typically preceded by the inhalation of air to lung volumes above the resting expiratory level (REL), with normal phrases in continuos speech typically being initiated above the tidal volume (Hixon, 1983). The vocal folds are then adducted and tensed in appropriate amounts through laryngeal muscle activity for the production of voice. Aerodynamic parameters involve air volumes, airflows and air pressures at different point of time in the process of producing speech. These parameters are studied by many authors in the last few decades using different instruments and found to be effective in the assessment of voice in both normal individuals and in persons with voice disorders.

Objective aerodynamic measures include MAFR (Mean airflow rate) measured in ml/s, ESGP (Estimated subglottic pressure) in cmH_20, LAR (Laryngeal airway resistance) in cmH_20/ml/s, LAC (Laryngeal airway conductance) in ml/s/cmH_20 and many more. Subjectively aerodynamics involved in phonation can be measured using MPD (Maximum phonation duration) and S/Z ratio.

The patient having vocal fold nodules usually complains of dysphonia with or without phonaesthenic symptoms. Perceptually, the voice usually has a strained / leaky quality. Often, the voice also included perceptual features that indicate irregularities in vocal fold vibrations, such as roughness (irregular voice) as well as vocal fry (Hammarberg, 1998 & Holmberg et al., 2001).

It is generally held that an underlying component in vocal nodules or polyps is vocal hyperfunction, a hypertonic state of both intrinsic and extrinsic laryngeal musculature (Aronson, 1985), and it is assumed to result in poorly regulated laryngeal muscle tension and unbalanced aerodynamic forces (Holmberg et al., 2003). A hyperfunctional voice is produced with abnormally stiff vocal folds often in combination with increased subglottic air pressure and abnormally high vocal fold closing velocities (Hilman et al., 1990). It is believed that a primary etiologic factor in vocal nodules is trauma to the vocal tissues (Hirano et al., 1980 & Kotby et al., 1988).

Vocal fold vibration during phonation leads to impact stress during collision between the left and right vocal fold surfaces. Titze (1994) has analysed these stress forces and has determined that maximal impact stress occurs in the mid membranous vocal fold. With formation of the nodules, complete closure of the membranous glottis may be hindered, causing an increase of turbulent air through the glottis. The effort to produce voice may cause further increased muscle tension, increased subglottic pressure and heightened vocal fold collision forces, thereby trigging a" vicious circle" adding to the vocal trauma (Hillman et al., 1989).

Some studies showed that aerodynamic studies of the dysphonic voices of vocal fold nodules and polyps usually show increased glottal airflow as well as increased subglottal pressure (Tanaka and Gould, 1985) as an attempt to produce phonation in the presence of leaky glottis. Also it was stated by many authors that LAR to be high and LAC to be low in mass vocal fold lesions as the efficiency of laryngeal function is reduced due to the pathology that is present. But, the effect of vocal folds nodules and polyps in all the parameters of aerodynamic analysis of voice.

Hillman (1990) compared few aerodynamic measures between vocal nodules and polyps and reported that transglottal airpressure and maximum flow declination rate were increased in nodules and decreased in polyps comparatively in his study. The possible reason for such variations between vocal nodules and polyps is not clearly explained. However, there are no many studies supporting these findings. Cantarella et al. (2011) reported significantly low MPD values in patients with vocal nodules and polyps compared to normals. However, the validity of subjective measures like MPD, S/Z ratio is highly questionable as reported by several authors.

Need for the present study:

There are very few number of Indian studies focused on studying aerodynamic measures in hyperfunctional voice disorders. As it was reported by many studies that aerodynamic measures and voice quality may vary across ethnic groups and geographical regions (Jayakumar and Savithri, 2012), it brings the need to investigate the aerodynamic measures in different voice pathological conditions in Indian population. As vocal nodules and polyps are widely seen vocal fold pathologies, the present study made an attempt to study aerodynamic measures in patients with these disorders and thus to understand the underlying pathology of abnormal voice production. Secondly, to explore whether aerodynamic measures can differentiate between vocal nodules and polyps.

Objectives of the study:

- To obtain the air flow and air pressure values in persons with vocal nodules and polyps.
- To compare the values of air flow and air pressure measurements among vocal nodules and polyps.

CHAPTER II

REVIEW OF LITERATURE

Aerodynamic analysis of voice production includes measurements of air flow, air pressure, and their relationships during phonation. Early investigators found that aerodynamic studies are helpful in etiological classification of voice disorders (Yanagihar, 1969), While later studies showed that the diagnostic value of aerodynamic measurements is low in identifying the exact etiology, but they may point to a tendency to the "hyperfunction" or " hypofunction" styles of vocal production (Schutle, 1988). However, the main value of aerodynamic measures is to evaluate the degree of vocal dysfunction and to monitor the post therapeutic changes of voice disorders in the same patient (Hirano, 1989).

Mean airflow rate (MAFR) refers to the rate at which air passes through the glottis during phonation in one second and is measured in l/sec. It is usually expected to be low in normal individuals to sustain phonation for maximum duration by using small amounts of air through glottis.

Subglottal pressure (Ps) refers to the air pressure that is built below the vocal folds to initiate voice production. Subglottal pressure is usually not measured directly as it is invasive method where in device in inserted through trachea which makes the patient very uncomfortable. Rather, indirect measurement of subglottal measure (ESGP) can be obtained by asking the patient to produce repeated /pa/ syllables. Smitheran and Hixon first described this method in 1981. The rationale behind this method is that for the voiceless stop sound, the lips are closed and the vocal folds are open, so that pressure in the oral cavity and subglottal area are approximately equal. Some authors also prefer to use /pi/ or /bip/ syllables but, as /i/ is a tensed vowel, it may require more airpressure than used for majority of the speech sounds, hence the present study consider /pa/ syllables as the stimuli. Also Titze (1989) predicted that the largest changes in F_0 with Ps would be when the vocal folds were short and lax.

Laryngeal airway resistance (LAR) refers to the resistance provided by the vocal folds in opposing the airflow and laryngeal airway conductance and depends on glottal adductory mechanism and vocal fold tension. Smitheran and Hixon (1981) reported an overall mean LAR value of 35.7 cm H_20/L/s in adult male subjects and in adult females it was reported to be 38.3 cm H_20/L/s by Leeper and Gravis (1984). LAR is calculated as the ratio of the time- averaged transglottal pressure to glottal airflow. The application of clinical (i.e., medically non- invasive) methods for assessing LAR has been strengthened by theories describing muscular and aerodynamic factors affecting phonation. Laryngeal airway conduction (LAC) can be calculated by inversing LAR.

All these measures can be obtained simultaneously by using pneumotachograph methods of transducing oral and nasal airflow. Although there are methods available to measure parameters like ESGP directly using invasive methods, indirect methods are often used as they are more comfortable to the participants.

There are several factors which can show impact on these measures such age of the participant, gender, physical status, type of vocal pathology, type of task selected to measure, syllable rate and type of stimuli used etc. Studies which used different tasks and syllable rates to obtain aerodynamic measures are summarized in the next chapter.

Maximum Phonation Time (MPT) is also an aerodynamic measure and is a common task used in the routine clinical assessment of voice where the individual is asked to sustain phonation of vowels /a/, /i/, /u/, /s/, /z/ as long as possible after taking a deep inhalation and thus obtained value is compared to the normative data and a rough indication of respiratory or laryngeal pathology can be obtained. MPD in normal adults is expected to be 20 seconds and 10 to 15 seconds in children.

A patient with a greatly reduced vital capacity may demonstrate short maximum phonation times, short speech phrases, and a weak voice with reduced intensity due to difficulty achieving adequate subglottal pressure during speech (Koschkee & Rammage, 1997).

S/Z ratio can be obtained from maximum phonation durations of /S/ and /Z/. A 1.0 ratio suggests normal respiratory ability and the absence of a vocal cold pathology. The use of the S/Z ratio as an indicator of laryngeal pathology was first proposed by Eckel and Boone in 1981. A 1.0 ratio with reduced duration of /s/ and /z/ indicates possible respiratory inefficiency. The patient may have a reduced vital capacity or poor control of expiration. An s/z ratio of 1.2 or greater with normal duration of the /s/ production indicates possible vocal cold pathology. Unlike /s/, the voiced /z/ requires phonation. Therefore, unequal phonatory control of the /s/ and /z/ is indicative of a laryngeal pathology rather than a respiratory problem. The higher the s/z ratio is above 1.0, the greater the likelihood of laryngeal pathology.

In the past few decades, several authors studied these aerodynamic parameters in both normal and clinical population using different instruments and found these measures to be effective as the part of assessment protocol used for voice disorders.

In indian population, there are few studies done on establishing normative data for different aerodynamic measures such as MPD (Maximum Phonation Time), ESGP (Estimated subglottal pressure), MAFR (Mean airflow rate), Rlaw (Laryngeal airway resistance or LAR), LAC (Laryngeal airway conductance) but comparatively less studies were done in clinical populations.

Gopi Kishore, Sheela & Pushpavathi (2012) studied aerodynamic parameters such as ESGP, MAFR, LAR, and LAC in adult Indian population to establish normative data. 85 subjects consisting of 54 males and 31 females in the age range of 18- 40 years participated in the study. They were divided into two major groups based on age i.e., 18- 25 years and 26- 40 years and each group was subdivided into two other groups based on gender (Males and Females). None of the participant had history of voice problem. Aeroview system from Glottal enterprises was used to study the selected parameters. Participants were instructed to produce CV syllable train "papapa" at comfortable loudness and pitch with circumvented mask placed against the mouth and nose and with oral tube placed between the lips. The mean ESGP in 18- 26 years age group (first group) was 4.74 cm H_20 and 5.68 cm H_20 in 26- 40 years group (Second group). Mean MAFR in first group was 0.26 L/s and 0.25 L/s in second group. Mean LAR in first group was 0.23 L/s and 0.27 L/s in second group. Mean LAC in first group was 0.05 L/s and 0.04 L/s. Overall results indicated significant main effects of age for the parameters ESGP and

LAC. But, no significant main effects of gender were observed for the any of the laryngeal aerodynamic parameters studied.

In the western population there are many studies done to study aerodynamic parameters in both normal and disordered populations. Goozee et al (1998) studied the effects of age and gender on few aerodynamic measures. 56 male and 53 female normal speaking subjects participated in the study and they were divided into six age groups (20–30; 31–40; 41–50; 51–60; 61–70 and 71–80 years). Aerophone II Model 6800 (Kay Elemetrics Corp.) was used in the study and the participants were instructed to perform comfortable phonation, vocal efficiency, and running speech tasks. Mean MAFR in the age group 20- 30 years (first) was 0.52 L/s in males and 0.39 L/s in females and in the age group 31- 40 years (second) was 0.38 L/s in males and 0.5 L/s in females. Mean airpressure in the first group was 9.34 cmH_2O in males and 6.73 cmH_2o in females and in the second group airpressure values were 6.56 cmH_2O in males and 7.9 cmH_2O in females. Overall results indicated no significant age or gender effects on the selected parameters.

Solomon, Garlitz and Milbrath (2000) studied the role of respiratory and laryngeal systems in MPD task in normal population. 6 women and 6 mean with normal voice and speech participated in the study. All the participants were made to perform two tasks i.e., standard MPD task (sustained phonation) and modified MPD task (slow syllable repetition) to measure Lung volume excursion (LVE), MPD and Rlaw (Laryngeal airway resistance). Circumferentially vented pneumotachograph face mask was used to measure aerodynamic parameters. In the first task participants were instructed to take in as much air as possible and to sustain phonating /a/ and /i/ as long as possible with 3 repetitions of each vowel and no instrument was used to record this task. In the second task, participants were instructed to repeat strings of CV syllables i.e, /pa/ and /pi/ at a rate of 1.5 syllables/sec (each syllable separately and rate was trained using digital metronome). During the second task, pneumotachograph mask with oral tube was placed against the participant face with oral tube between lips to obtain kinematic, acoustic and aerodynamic measures. Mean LVE (Lung volume excursion) values found in males were 88.3 %VC for /a/ and 90.2 %VC for /i/ and in females the values were 91.8 %VC for /a/ and 89.2 %VC for /i/, Mean MPD values in females were 22.7 seconds for /a/ and 25.1 seconds for /i/ and in males 19.2 seconds for /a/ and 20.8 seconds for /i/. Mean Rlaw values in females were 41.8 L/s for /a/ and 42.0 L/s for /i/ and in females for the same measure the values were 30.2 L/s for /a/ and 27.8 L/s for /i/. Overall results revealed no systematic relation between MPD and VC for all the subjects. Rlaw was strongly correlated with MPD for men but not for women. Also found that Rlaw increased linearly as lung volume decreased for a subset of trials (32%) in all the subjects. However, the authors concluded that the laryngeal valving strategies used for MPD or modified MPD tasks are not likely to represent the strategies used during speech.

Netsell et al. (1991) studied aerodynamic parameters such as ESGP and mean volume velocity of air flow in normal adults. Participants composed of 30 adults (15 mean and 15 women) with no history of voice or respiratory pathologies. Pneumotachometer with oral anesthesia mask was used to obtain the signals. Participants were instructed to repeat a series of seven CV syllable of two types i.e., /pi/ and /pa/ separately and each type of syllable was repeated at two different rates 1.5/s and 3/sec to study the effect of type of syllable selected and also the rate at which the syllables are uttered on aerodynamic measures. Results showed that mean ESGP values for /pi/ syllable were 5.94 cmH_20 at 1.5/s rate and 6.41 cmH_20 at 3/s rate and n females for the same syllable mean ESGP values were 5.32 cmH_20 at 1.2/s rate and 5.79 cmH_20 at 3/s rate. For the /pa/ syllable, mean ESGP values were 5.89 cmH_20 at 1.5/s rate and 6.31 cmH_20 at 3/s rate in males and in females ESGP values were 5.11 cmH_20 at 1.5/s rate and 5.41 cmH_20 at 3/s rate. Mean airflow values in males were 192.93 ml/s at 1.5/s rate and 205.53 ml/s at 3/s rate for the syllable /pi/ and in females for the same syllable the values found were 127.07 ml/s at 1.5/s rate and 139.87 ml/s at 3/s rate. For the syllable /pa/ the mean airflow values found in males were 200.07 ml/s at 1.5/s rate and 207 ml/s at 3/s rate and in females the values were 136.93 ml/s at 1.5/s rate and 154.60 ml/s at 3/s rate for the same syllable. Women had greater Rlaw than men for /pi/ syllables and women also had greater Rlaw during /pi/ syllable production than /pa/. Overall results showed that syllable rate and vowel used will show significant impact on the aerodynamic measures.

Radish kumar and Bhat (2010) measured maximum phonation duration (MPD) in 60 normal adults (30 males and 30 females) in the age range of 20- 40 years. All the participants were instructed to sustain phonation of vowels /a/, /s/, /z/ as long as possible after taking a deep inhalation. Mean MPD for vowel /a/ was 18.8 s and mean S/Z ratio was 1.048.

Aerodynamic studies in vocal nodules:

Sapienza and Stathopoulos (1995) studied the effect of speech tasks on acoustic and aerodynamic measured in women with vocal nodules. 10 women with bilateral vocal nodules and 10 women with normal voice participated in the study. Aerodynamic parameters selected for the study were MFDR (Mean flow declination rate) and AC flow (Alternating glottal airflow). Pneumotachograph mask (Glottal Enterprises model MS I00 A-2) coupled with airflow and pressure transducers was used to measure the selected parameters. Participants were instructed to perform three different tasks with the pneumotachograph mask held against face such as sustained vowel prolongation (/a/), syllable repetition (/pa/) and reading (with high representation of /a/ in CVCV syllable context like /papa/). Mean MFDR values in disordered subject group were 297.53 ml/s for vowel task, 273.29 ml/s for syllable repetition task and 353.11 ml/s for reading task. Mean AC flow values in the same group were 0.245 L/s for vowel task, 0.245 L/s for syllable task and 0.215 L/s for reading task. These values were significantly higher compared to normal group. There was no significant difference found between tasks for the selected measures and the authors concluded that choice of speech task may not make an apparent difference in the objective evaluation of disordered voice.

Rammage, Peppard and Bless (1992) studied relationships of posterior glottal chink magnitude and nodule size with phonatory flow rate, resistance, and breathiness. Participants consisted of 70 women out of whom 50 had voice disorders (Bilateral vocal nodules, muscular tension dysphonia, or functional dysphonia with posterior glottal chink) and 20 had normal voice (age range- 17 to 36 years). Participants were instructed to sustain vowel phonations at habitual F_0 and effort levels. Nagashima PS-77 Phonatory Function Analyzer coupled with a face mask was used to measure phonatory air flow rate and videolaryngoscopy was performed to compare the obtained airflow rates with the vocal fold status during phonation. Results indicated a strong relationship between chink size and airflow, but no relationship was found between nodule size and airflow. Resistance and nodule size were moderately correlated.

Mamdouh and Eman Saed (2006) studied few aerodynamic parameters in patients with vocal nodules. Two group of subjects participated in the study where group one composed of 35 adult female patients with bilateral vocal nodules and group two composed of 35 adult female subjects with normal voice. Aerophone II was used to study aerodynamic measures such as phonation quotient (PQ), mean flow rate (MAFR), subglottic pressure (Psub) and glottal power (GP), maximum phonation time (MPT) and glottal resistance (GR), vital capacity (VC), sound pressure level (SPL) or glottal efficiency (GE). Participants were instructed to repeat strings of syllables /i:pi:pi:/ with the face mask and oral tube between the lips. Mean MPT values found were 13.02 seconds in clinical group 26.41 seconds in control group. Mean MAFR values seen were 0.233 L/s in clinical group and 0.113 L/s in control group. Mean ESGP values seen were 10.07 cmH_20 in clinical group and 7.56 cmH_20 in control group. Mean glottal resistance values seen were 32.17 cmH_20 in clinical group and 73.89 cmH_20 in control group. Compared to control group, vocal fold nodules caused statistically highly significant increase in: phonation quotient (PQ), mean flow rate (MAFR), subglottic pressure (Psub) and glottal power (GP) and statistically highly significant decrease in: maximum phonation time (MPT) and glottal resistance (GR). There were no statistically significant differences in vital capacity (VC), sound pressure level (SPL) or glottal efficiency (GE).

Holmberg and Hillman (1999) studied few aerodynamic measures to discriminate speakers with vocal nodules from normal speakers. A total of 26 women participated in the study among whom, 14 had bilateral vocal nodules and 12 with normal voice.

Rothenberg mask was used to measure airflow and airpressure measurements with oral tube placed between the lips and participants were instructed to produce strings of CV syllables /papapa/ at comfortable pitch and loudness. Selected aerodynamic measures included subglottal pressure, average airflow. Mean subglottal pressure found in control group was 6.0 cmH_20 and 10.5 cmH_20 in clinical group. Mean average flow values were 0.14 L/s in control group and 0.29 L/s in clinical group. Overall results revealed that subglottal pressure and airflow values were high in vocal nodules compared to normal. Authors have attributed these results to the reason that speakers with nodules may be compensating for the nodules by increasing the subglottal pressure, resulting in relatively good acoustics but increased air flows.

Aerodynamic studies in vocal polyps:

Hillman et al. (1990) studied acoustic and aerodynamic measures to compare and contrast vocal function among participants under four different hyperfunctioally related vocal fold lesions such as nodules, polyps, polypoid degeneration, or contact ulcers. Aerodynamic measures included transglottal pressure and average glottal airflow and acoustic measures included vocal intensity and F_0. Participants were instructed to produce five repetitions of the syllable /pae/ at two different conditions (normal loudness and louder than normal). Rothenberg mask was used to obtain the signals for required measures and a microphone was connected to the mask to obtain acoustic signals. Results indicated that selective acoustic and aerodynamic measures are useful to differentiate voice of three vocal fold lesions studied. Specifically to compare vocal nodules and polyps from the results, transglottal airpressure and maximum flow declination rate were increased in nodules and decreased in polyps comparatively. Authors concluded that the selected parameters can be helpful in understanding the underlying mechanism associated with different hyperfunctioally related vocal fold lesions.

Cantarella et al. (2011) studied few acoustic and aerodynamic indices in discriminating normal voice from benign vocal fold lesions. Clinical group composed of 53 subjects affected by benign organic dysphonia (24 patients with vocal fold polyps, 15 with cysts, 11 with Reinke's edema, and 3 with nodules) and control group composed of 39 subjects with normal voice. Some of the aerodynamic measures taken for this study were Maximum Phonation Time (MPT), Oral airflow (cc/s), Subglottic pressure (hPa). Pneumotachograph face mask was used to measure these parameters where in the subject was instructed to repeat series of CV syllables /papapa/ with oral tube placed between lips. Mean values seen in clinical group were MPT-11.52 seconds, oral airflow-213.70cc/s, and subglottal pressure- 12.05 hPa. There was a significant difference of all the measures between clinical and control groups.

Tanaka and Gould (1985) studied ESGP and MAFR measures in both normals and clinical population. Two group of subjects participated in this study, group one composed of 10 normal and adult subjects and group two composed of 10 adults with different vocal pathologies such as vocal nodule, polyps, and Reinke's edema etc., Body plethysmography was used to measure selected parameters. Participants were seated in an airtight box with a mouthpiece and clip placed on the nose then they were instructed to sustain vowel /a/ for few seconds at comfortable loudness and pitch level. Mean MAFR in subjects with vocal nodules was 0.258 L/s and mean SGP was 8.3 cm H_2O. These measures suggested an aerodynamic‑biochemical classification based on vocal fold lesion type associated with low vocal efficiency. Firstly, a large glottal chink (RLN paralysis) associated with high MAFR value. Secondly, mass on vocal folds (vocal nodule, vocal polyp and Reinke's edema), associated with a high level of MAFR and ESGP values. Thirdly, highly stiffened vocal fold (Glottal cancer), associated with high SGP value.

Al- Malki (2012) studied aerodynamic measures in subjects with vocal polyps. Two group of subjects participated in the study. Group one consisted of 31 adult patients with unilateral or bilateral vocal polyps and group two consisted of 30 normal adult subjects. Aerodynamic measures selected for the study were phonation quotient (PQ), mean flow rate (MAFR), subglottal pressure (Psub), and glottal power (Pg), glottal resistance (Rg), vital capacity (VC) or glottal efficiency (Eg) and maximum phonation time (MPT). Aerophone II (Model 6800, Kay Elemetrics Corp., Lincoln Park, NJ, USA) was used to study the selected measures and the participants were instructed to repeat strings of syllables /i:pi:pi:/ with the face mask and tube inside the oral cavity. Results revealed that, compared to control group, vocal fold polyps caused statistically highly significant increase in: phonation quotient (PQ), mean flow rate (MAFR), subglottal pressure (Psub), and glottal power (Pg) and statistically highly significant decrease in: maximum phonation time (MPT) and glottal resistance (Rg). There were no statistically significant differences in vital capacity (VC) or glottal efficiency (Eg). Author of this study concluded that aerodynamic analysis of voice can be can be one of the essential investigative tools in assessment of vocal polyps.

Aerodynamic measures in monitoring clinical progress:

Holmberg et al. (2002) studied aerodynamic measurements in patients with vocal nodules who underwent behaviorally based voice therapy programme to find changes in voice compared to baseline and across voice therapy. Participants included 10 women with bilateral vocal nodules. All the participants were undergoing behaviorally based voice therapy programme. Participants were instructed to repeat strings of /pae/ syllables and sustain /ae/ phonations in two loudness conditions: comfortable loudness and loud voice. Circumferentially vented mask was used for recording the task along with differential transducers and recordings were done before the initiation of the voice therapy (baseline) and then subsequently after each therapy phase (total of five therapy assessments). Analyses of variance showed that there were no significant differences between baseline values and values obtained during therapy. Mean transglottal airpressure found was 11.0 cmH_20 at comfortable loudness and 15.5 cmH_20 at loud voice. Mean AC flow found was 0.31 l/sec at comfortable loudness and 0.45 l/sec at loud voice (Averaged across the Three Baseline Assessments). Authors concluded that aerodynamic measures are effective in reflecting the presence of vocal pathology to a higher degree than the acoustic spectral measures and thus are helpful in comparing nodule and normal voice production.

Chen et al. (2007) studied the effectiveness of resonant voice therapy in teachers with different vocal pathologies using perceptual, acoustic, aerodynamic and functional measurements. Participants consisted of 24 fulltime female teachers among whom 4 had muscular tension dysphonia, 6 had vocal nodules and 14 had chronic chorditis. All the participants were instructed to perform both sustained phonation tasks and syllable repetition tasks (/pi/) to measure aerodynamic parameters such as maximum phonation duration in seconds (MPD), airflow rate in cc/s and phonation threshold pressure (PTP) in cmH_20. Airflow and airpressure measures were obtained using Aerophone II (Kay Aerophone 2, 6800; Kay Elemetrics Corporation). Mean MPD was 17.17 s before therapy and 18.65 s after therapy. Mean airflow rate was 99.75 cc/s before therapy and 113.40 cc/s after therapy. Mean PTP was 7.04 cmH_20 before therapy and 5.42 cmH_20 after therapy. Results revealed a significant difference in PTP before and after therapy but no difference found in MPD and airflow measurements before and after therapy. Authors concluded that aerodynamic measures along with acoustic and functional measures can help in providing evidence to study the effectiveness of any treatment programme in voice disorders.

Treole and Trudeau (1997) studied the changes in sustained production tasks among women with bilateral vocal nodules before and after therapy. 13 adult female subjects participated in the study whose age range was between 20 – 50 years and all the subjects were diagnosed with bilateral vocal fold nodules. All the subjects underwent structured voice therapy program which included tension identification and relaxation training as well as training of efficient respiratory behaviors. All the subjects were instructed to sustain vowels /a/, /i/, /u/, /ae/ and also /s/ and /z/ to calculate s/z ratio at comfortable level as long as possible and these tasks were performed by them both before and after voice therapy. Mean phonation duration for all the vowels was 17. 15 seconds before therapy and 14.03 seconds after therapy. Mean s/z ratio before was 1.44 and 1.13 after therapy. Results indicated that there was no significant difference in MPD or S/Z ration before and after treatment. Authors also reported that, females with vocal nodules demonstrate measurements before therapy similar to measures considered to be normal in persons without vocal nodules. Authors concluded that these kinds of subjective measurements may not be sensitive to study the changes occurring in voice after treatment.

Woo et al. (1994) in their study measured acoustic, aerodynamic and stroboscopic findings before and after microlaryngeal phonosurgery to compare the vocal quality and status in two conditions. Participants composed of 50 adult subjects with a variety of benign vocal fold lesions including vocal nodules, polyps, Reinke's edema, sulcus vocalis underwent microlaryngeal phonosurgery. Aerodynamic measures included mean airflow rate (ml/sec) which was measured using high-frequency hot film anemometry unit (TSI 1054A) through which the subject was asked to sustain a comfortable modal "ee", a high-pitched "ee," low-pitched "ee", and a loudest comfortable modal "ee." and maximum phonation time (s) was also obtained before and after the participants undergoing phonosurgery. Preoperative mean MAFR was 158.08 ml/s and 132.16 ml/s postoperatively. Preoperative MPT was 10.26 s which was reduced to 9.70 s postoperatively. MPT did not show difference in both the conditions but difference was noted in MAFR values. Authors concluded that improved understanding of vocal function after phonosurgery can help to refine surgical principles and techniques.

In summary, majority of studies showed aerodynamic measures helpful to differentiate vocal nodules, polyps with normal voice and the common findings in both vocal nodules and polyps were increased ESGP, MAFR and decreased Rlaw, MPT measures. These findings can be attributed to the incomplete closure of vocal folds and vocal fatigue due to the pathology present.

CHAPTER III

METHOD

Participants: Two groups of subjects participated in the study. Group I consisted of 12 patients with vocal nodules in the age range of 20- 41 years and Group II consisted of 7 patients with vocal polyps in the age range of 20- 45 years.

Inclusion criteria: All the subjects were diagnosed with either vocal nodules or polyps by an experienced otolaryngologist using stroboscopic examination.

Extracted and derived measures included:

- ✓ Estimated Subglottic Pressure (ESGP)
- ✓ Mean Airflow Rate (MAFR)
- ✓ Laryngeal Airway Resistance (LAR)
- ✓ Laryngeal Airway Conductance (LAC)
- ✓ Maximum Phonation Time (MPT)
- ✓ S/Z Ratio

Utterance design:

The utterances used in this study were the single syllable /pa/. Previous studies majorly used either /pi/ or /bip/ as the stimulus. Smitheran and Hixon (1981), and Rothenberg (1982) suggested the above mentioned stimulus respectively. Since /i/ is a tensed vowel it may lead to excess of subglottal pressure than used for other sounds, hence /a/ is considered to be a vowel suitable to measure the normal amounts of subglottal pressure used for speech. It is reported in several studies that syllable rate between 2.5 to 4 sylables/s is more appropriate in measuring airflow and airpressure measurements.

Instrumentation: The Aeroview 1.4.4 version (Glottal Enterprises Inc, Syracuse, NY) was used to measure selected aerodynamic measures i.e., ESGP, MAFR, LAR & LAC. The Aeroview is a software based device with an external module and calibration unit connected to it. It consists of mask handle for using oronasal mask (also called as pneumotachograph mask) to which oral tube is attached, PT- 2E wideband model airflow transducer and PT- 25B airpressure transducer coupled with the oronasal mask, manual flow and pressure calibrators. Low pass filtering for airflow was set at 500 Hz as per the manufacturers recommended.

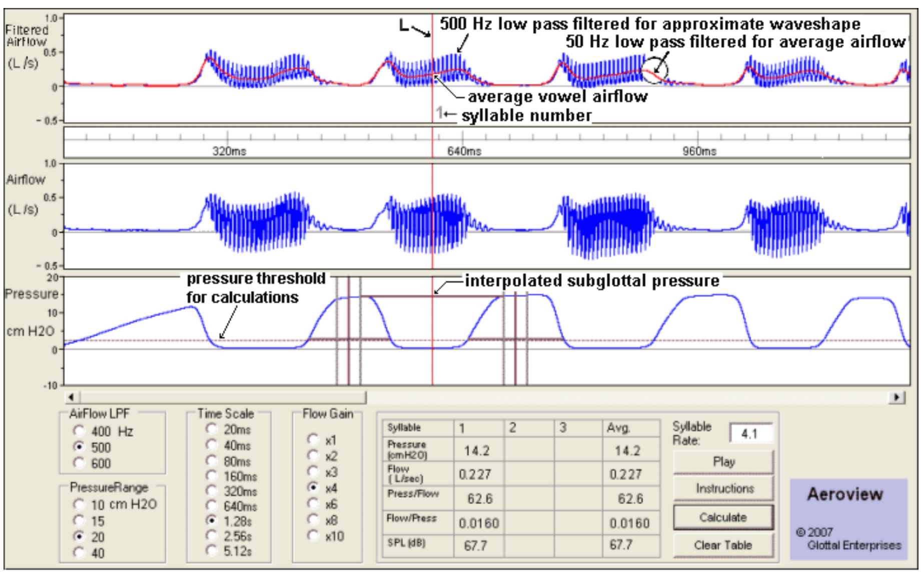

Figure: 1. Aeroview screen view of measuring airflow and pressure in normals.

Procedure:

The study was carried out in two phases.

Phase I**:** Estimating ESGP, MAFR, LAR & LAC

Phase II**:** Estimating MPD, S/Z ratio

Phase I: All the samples were obtained in a lab with low level of environmental noise. The pneumotachograph mask and oral tube were cleaned and calibration was before every recording. The participants were seated comfortably and procedure was briefly explained. The participant was instructed to hold the mask against the face with oral tube lightly held between lips and by not blocking its opening with any oral structures has to produce strings of /pa/ syllables for 5 to 7 times at a rate of 2.5 to 4 syllables/s at comfortable pitch and effort levels. Initially examiner demonstrated the task to make the subject understand how to maintain the syllable rate in required amounts and then they were asked to practice it for few trials before the actual recording.

The sample collection was done in three trials were performed by each participant and the wave which has good morphology and acceptable rate was taken for analysis. During analysis, the first and last peak was not considered and the region where the peaks are consistent was selected for analysis. Values are obtained by placing two cursors on consecutive peaks and a total of 6 peaks are measured to obtain 3 values for each measure and thus a mean value was obtained for each parameter. Similar procedure was followed for two more trials. This repeated trials were performed to measure inter- trial reliability of the selected measures.

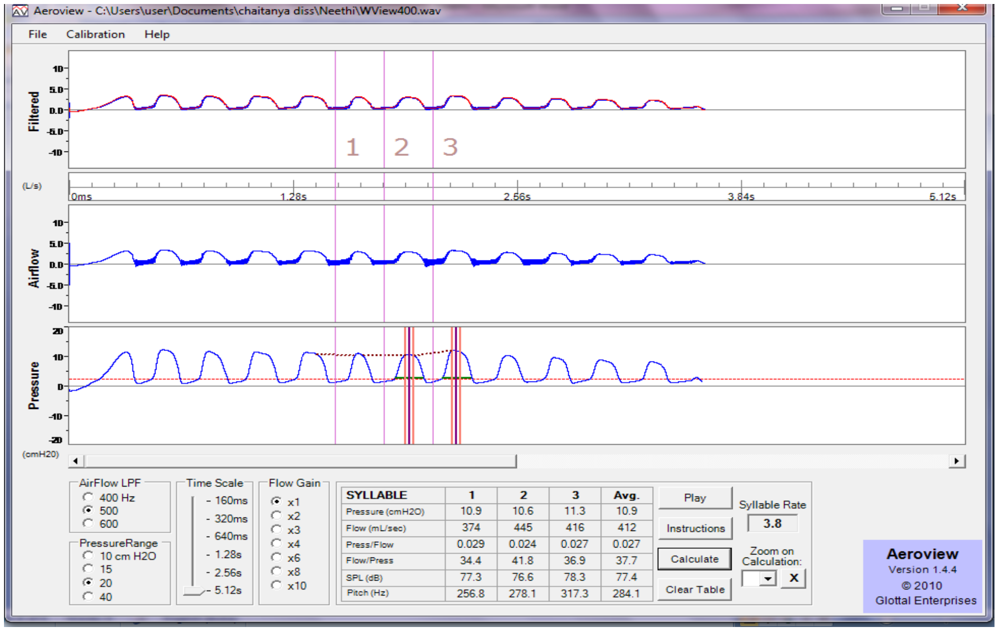

Figure 2: Aerodynamic measures obtained from the subject with vocal nodules.

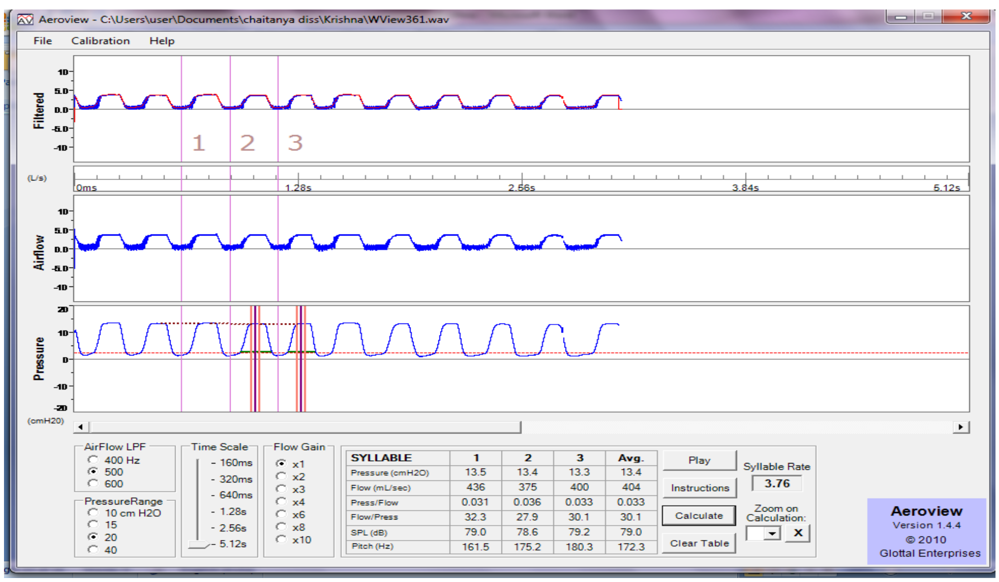

Figure 3: Aerodynamic measures obtained from the subject with vocal polyps.

Phase II: Computerised Speech Lab (Model 6500, NY) was used to record MPD and S/Z ratio tasks. Participants were instructed to take in breath as much as possible and to sustain phonation of /a/, /i/, /u/, /s/, /z/ maximally at comfortable pitch and loudness levels. The microphone was placed 10 cm away from the mouth. Three trials were taken for each sound and duration was taken from the trial with maximal duration. S/Z ratio was calculated by using the maximum durations of /s/ and /z/ phonemes.

Statistical analysis: The aerodynamic measures obtained from both the groups were subjected to appropriate statistical analysis using SPSS software (17.0 version). Both descriptive and inferential statistics were performed. Descriptive statistics included mean, standard deviation, minimum and maximum values. Inferential statistics included MANOVA to identify any significant difference between two groups for all the paramaters and one-sample T test was used to compare the data from the present study with established Indian norms. Normality was also measured using one sample Kolmogorov Smirnov test.

CHAPTER IV

RESULTS AND DISCUSSION

The present study aimed at measuring aerodynamic parameters in persons with vocal nodules and polyps and comparing the same. The aerodynamic measures addressed in this study were ESGP, MAFR, LAR, LAC, MPD & S/Z ratio and thus obtained values are tabulated and subjected to analysis using SPSS software 17.0 version. Following statistical methods were performed to meet the objectives:

I. Cronbach's alpha to measure inter-trial reliability.
II. Descriptive statistics to obtain mean, standard deviation, minimum and maximum values for all aerodynamic measures.
III. MANOVA to compare the aerodynamic parameters between the groups.
IV. One- sample 't' test to compare the data from the current study with already established norms for the same aerodynamic measures.

I. Reliability measures:

Inter- trial reliability

Reliability was calculated for the repeated trials performed by the participants for the given task. The inter- rater reliability was determined by using Cronbach's alpha. The alpha values found were above 0.9 for all the parameters which indicated good reliability between trials. Table 1 shows alpha value for the aerodynamic parameters.

Parameter	Cronbach's Alpha
ESGP (cm H20)	0.98
MAFR (ml/s)	0.98
LAR(cmH20/ml/s)	0.96
LAC(ml/s/cmH20)	0.96
SPL (dB)	0.98
Pitch (HZ)	0.99

Table 1: *Reliability measures for the aerodynamic parameters*

II. Descriptive statistics for vocal fold nodules and polyp groups:

Descriptive statistics were estimated to compare mean, SD, minimum and maximum values between the groups for each parameter studied and the values are given in the Table 2.

There were no notable differences seen when mean, SD, min, max values of all parameters were compared between the groups. However, the mean values for ESGP, MAFR are slightly higher in vocal polyps compared to vocal nodules (Figure 4). This can be attributed to the reason that in vocal polyp, the extent of glottic chink is more compared to nodules as the mass formed by the polyps is usually bigger than the nodule resulting in reduced laryngeal resistance and increased glottal air leakage. Hence, we can assume that size of the mass lesions can result in such variations, although the severity was not controlled in the study. Mean comparison also showed LAR was found to be higher in nodules compared to polyps.

Parameters	Vocal nodules				Vocal polyps			
	Mean	**SD**	**Min**	**Max**	**Mean**	**SD**	**Min**	**Max**
ESGP (cmH_20)	9.24	2.36	6.25	12.83	9.74	2.33	7.37	12.90
MAFR (ml/s)	412	189	78	203	480	191	289	778
LAR (cmH_20/ml/s)	0.026	0.011	0.01	0.05	0.022	0.005	0.01	0.03
LAC (ml/s/cmH_20)	46.54	21.80	20.66	79.40	46.35	12.94	35.45	70
SPL (dB)	79.2	4.2	73.10	85.10	79.05	3.12	72.65	82.40
Pitch (HZ)	207	75	107	296	206	37	167	256
MPD /a/ (s)	10.0	3.7	4.8	16.1	9.5	3.4	4.8	14.1
MPD /i/ (s)	11.2	3.4	7.0	17.5	10.8	3.1	5.7	14.1
MPD /u/ (s)	10.7	3.6	6.3	16.6	11.3	3.8	5.7	17.3
/S/ (s)	9.5	2.7	6.3	15.4	11.1	4.7	7	19
/Z/ (s)	10.1	3.2	6.1	17.9	9.7	3.3	5.8	15
S/Z Ratio	0.96	0.25	0.61	1.37	1.16	0.31	0.55	1.46

Table 2. *Mean, SD, Min, Max values for both the groups*

Tanaka and Gould (1985) reported increased glottal airflow as well as increased subglottal pressure in vocal nodules and polyps as an attempt to produce phonation in the presence of leaky glottis. In the study done by Mamdouh and Eman Saed (2006) vocal fold nodules caused statistically highly significant increase in mean flow rate (MFR), subglottic pressure (Psub) and statistically highly significant decrease in maximum phonation time (MPT) and glottal resistance (GR). Holmberg and Hillman (1994) also reported the same.

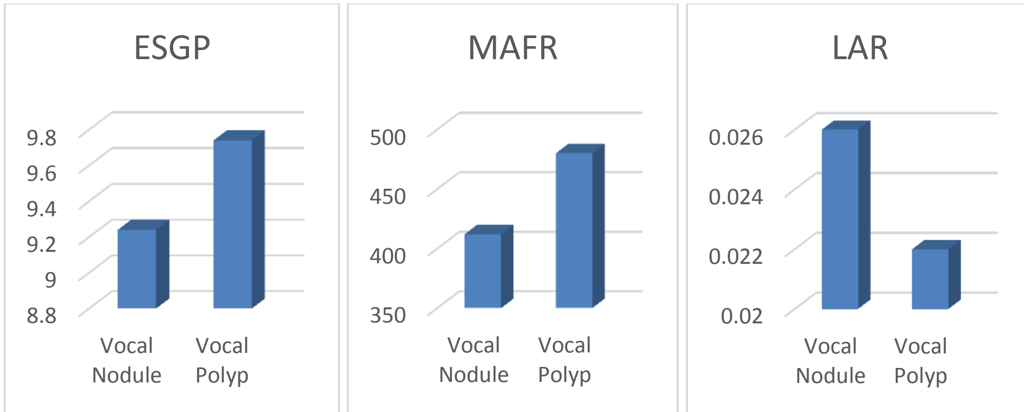

Figure 4: Mean comparison between the groups for ESGP, MAFR & LAR

In contrast to the present findings, in the study done by Hillman et al. (1990) transglottal airpressure and maximum flow declination rate were increased in nodules and decreased in polyps comparatively. However, the tasks used were different in both the studies.

Since vocal fold nodules and polyps do not alter pulmonary function, and since the glottal gap caused by these mass lesions is not large enough to waste expiratory airflow, SPL and pitch values are not much deviated from normal values and also there were no differences found between two groups for these parameters.

MPD and S/Z ratio values did not show any specific trend when comparing between the groups where mean values for /a/ & /i/ were high in vocal nodules and mean value of /u/ is high in vocal polyps compared to vocal nodules. S/Z ratio was found to be within normal range in both the groups.

III. Comparison of aerodynamic parameters between the groups:

Kolmogorov- Smirnov Test was performed to check normality and the results indicated that all the values were falling in normal distribution. Hence, MANOVA was done to compare the aerodynamic parameters between two groups. Table 3 shows the results of MANOVA. Result showed overall no significant difference between two groups.Absence of statistical difference between the two groups in the present study may indicate that only aerodynamic value not able to differentiate the vocal nodule from the polyp.

Parameter	df	F	p
ESGP (cm H20)	1	12	0.72
MAFR (ml/s)	1	1.15	0.30
LAR (cm $H_2$0/ml/s)	1	1.60	0.22
LAC (ml/s/ cm $H_2$0)	1	0.25	0.62
SPL (dB)	1	0.22	0.64
PITCH (Hz)	1	0.04	0.84
MPD /a/ (s)	1	0.00	0.96
MPD /i/ (s)	1	0.01	0.92
MPD /u/ (s)	1	0.20	0.66
/S/ (s)	1	0.41	0.53
/Z/ (s)	1	0.02	0.86

Table 3. F- Value, p- value of the *MANOVA result between the groups.*

The possible reason can be compensatory strategies used to overcome excessive airflow leakage via glottic chink can be similar in both the groups. In the study by Rammage, Peppard and Bless (1992) a strong relationship between chink size and airflow was found i.e., airflow increased significantly along with the chink size, but no relationship was found between nodule size and airflow. Resistance and nodule size were moderately correlated in the same study.

IV. ***Comparison of present findings with established Indian norms:***

As there is no significant difference found between two groups (vocal nodule and polyp), combined mean values from both the groups in the present study has been taken to compare with the normative data established from Indian study with same parameters in the age range of 18- 40 years. Table 4 shows mean values obtained from the present study and mean values from other Indian studies for the selected aerodynamic parameters using one- sample t test.

Parameter	Current Study	Gopikishore et al. (2012) (18- 40 years)	*t* value	*p value*
ESGP(cmH20)	9.40	5.21	7.74	0.00*
MAFR (ml/s)	446	255	4.24	0.00*
LAR(cmH20/ ml/s)	0.025	0.025	0.23	0.98
LAC(ml/s/cmH20)	46.47	48.94	-0.57	0.95
Parameter	**Current Study**	**Samuel et al., (2011) (20- 40 years)**	***t* value**	***p value***
MPD (Mean)	10.81	23.1	-16.18	0.00*
S/Z	1.03	1.1	-0.91	0.37

Table 4. *Comparison of present findings with established Indian norms (t & p values).*

The comparison showed significant increase in ESGP, MAFR & MPD measures in the clinical group. This can be attributed to the reason that the phonatory glottal gap that results from mass lesions leads to excessive air leakage (Al- Malki, 2006).

Since vocal fold mass lesions hinders proper acoustic signals because of the glottal air leak, the patient with vocal fold nodules or polyps tries to “compensate” for this by increasing Psub. This can explain the highly significant increase in ESGP in clinical group compared to normals.

The increase in MAFR, ESGP and the associated decrease in MPD due to vocal fold nodules and polyps are in agreement with the findings documented by other studies. Hillman et al., (1989) also reported that in benign vocal fold lesions the effort to produce voice may cause further increased muscle tension, increased subglottic pressure and heightened vocal fold collision forces, thereby trigging a" vicious circle" adding to the vocal trauma.

But, LAR and LAC measures did not show significant different between clinical group and normal due to the reason that in both the studies pressure- flow values were increasing linearly and thus obtained ratios did not show much difference. However, in persons with vocal fold nodules and polyps the LAR is expected to be low and LAC is expected to be high compared to normal as the vocal pathology leads to reduced efficiency in laryngeal function. Mamdouh and Eman Saed (2006) from their study reported that persons with vocal nodules had low laryngeal resistance compared to controls.

Since MPD task is considered as a preliminary method of identifying vocal pathology the MPD values from the present study were compared with the already established Indian norms in the age range of 20- 40 years. MPD values were much lesser in the patients group compared to normal, because vocal nodules or polyps hinder complete co-optation of vocal folds during phonation which leads to formation of phonatory glottal gap, causing "air leak" during phonation. Cantarella et al (2011) reported significantly low MPD values in patients with vocal nodules and polyps compared to normal. Surprisingly S/Z ratio values were within normal limits even in patient group along with normal; however the comparison of durations of /s/ and /z/ in would have shown significant decrease in clinical group compared to the normative data.

CHAPTET V

SUMMARY AND CONCLUSION

The present study aimed at measuring aerodynamic parameters in persons with vocal nodules and polyps and to compare the same between those groups. Two groups of subjects participated in the study. Group I consisted of 12 patients with vocal nodules and Group II consisted of 7 subjects with vocal polyps. All the subjects were diagnosed by an experienced otolaryngologist using stroboscopic method.

The aerodynamic parameters measured in this study were ESGP, MAFR, LAC, LAR, MPD & S/Z ratio. The study was conducted in two phases. In phase I, participants were instructed to repeat strings of /pa/ syllables with a pneumotachograph mask placed against their face with oral tube placed lightly between the lips using Aeroview instrument. In the phase II, the participants were instructed to phonate vowels /a/, /i/, /u/ as long as possible after taking a deep breath and also sustained phonation of /S/ and /Z/ was also measured to calculate S/Z ratio using CSL instrument.

Results showed that no significant difference found between the two groups of participants for any of the selected parameters. However, there is a slight increase in ESGP and MAFR in vocal polyp group compared to vocal nodules which can be attributed to size of the mass lesion.

Overall findings from the present study indicated that the organic manifestations of vocal hyperfunctional disorders can cause abnormally high values for the aerodynamic measures of MAFR & ESGP compared to normal. However, as there is no notable difference found for any of the parameters studied between vocal nodules and polyps, aerodynamic measures may not be much helpful to differentiate these pathologies. It can also be stated that the underlying mechanisms causing these abnormally high values can be similar in both the conditions (mass formation leading to glottic chink) though they differ in histopathology. But, these measures can be helpful to understand the underlying physiology in the mass lesions.

The abnormal increase in some aerodynamic measures in vocal nodules and polyps can be attributed to three reasons majorly. Firstly, a large glottal chink associated with high MAFR value. Secondly, mass on vocal folds (vocal nodule, vocal polyp), associated with a high level of MAFR and ESGP values. Thirdly, increased tension of the vocal folds, associated with high SGP value. As stated by Chen et al. (2007) aerodynamic measures along with acoustic and functional measures can help in providing evidence to study the effectiveness of any treatment method in voice disorders

Future Directions

- ✓ Future studies can focus on studying these measures in a well-controlled group of participants where inclusion criteria can consider matching the severity, age, gender, onset and nature of the lesions strictly among the participants and also by including more number of subjects.
- ✓ Also factors such as syllable rate, pitch and loudness levels should be strictly controlled as they can show considerable impact on aerodynamic measures.
- ✓ Future studies can mainly focus on using aerodynamic or acoustic measures to establish selected treatment methods based on the physiological changes observed in different vocal pathologies.

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