ACOUSTIC AND TEMPORAL ASPECTS
OF
OESOPHAGEAL SPEECH

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To,

Aai.

Dada & Mummy

You mean the world to me

CERTIFICATE

This is to certify that the dissertation entitled "Acoustic and temporal aspects of oesophageal speech" is the bonafide work in part fulfillment for the degree of Master of Science (Speech and Hearing) of the student with the Register Number M-9120.

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CERTIFICATE

This is to certify that the dissertation entitled "Acoustic and Temporal aspects of oesophageal speech" has been prepared under my supervision and guidance.

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DECLARATION

I hereby declare that the dissertation entitled "Acoustic and Temporal aspects of oesophageal Speech" is the result of my own study under the guidance of Dr. N.P. Nataraja, Professor and Head , Department of Speech Sciences, AIISH, Mysore and has not been submitted earlier at any University for any other diploma or degree.

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CHAPTER - I

INTRODUCTION

Laryngeal cancer threatens to destroy one of the most essentially human attributes - communication through speech.

Removal of the laryngeal cancer most often asks for surgical removal of the entire laryngeal framework. Thus sacrificing the tissue essential to normal vocal function, leaving the operated individual (laryngectomee) aphonic.

The primary goal of speech pathologist working with laryngectomees is to help the patient in developing functional speech through any mode whether buccal, pharyngeal, oesophageal, electrolaryngeal or tracheoesophageal. Of these alaryngeal modes. Oesophageal speech is one of the most widely used form of alaryngeal communication.

For oesophageal speech production, the patient injects or ingests air into the esophagus by orapharyngeal trapping. The air is subsequently released and the exhalation across the pharyngeal mucosa produces sound by the apposition of the mucous membranes. The resultant sound is articulated by the reasonably intact vocal tract i.e. the tongue, lips and palate as understandable speech.

With technological advances, new techniques for voice restoration on laryngectomees have come up. These include the development of a number of mechanical devices, shunt operations (fistula techniques), surgical prosthetic approaches and reconstructive surgeries with the latest trend towards conservative surgeries or partial laryngectomies. Each of these techniques have their own drawbacks.

The mechanical devices which are popularly known as the artificial larynges are costly, difficult to maintain and lack sound projection.

The fistula techniques, link the air supply from lungs with the pharynx but these create problems of aspiration from the esophagus into the airway, tissue breakdown, infection and shunt stenosis.

Prosthetic approaches like the use of the Blom Singer valve have proved to give better intelligible speech than the other alaryngeal modes. However in India prosthetic surgery is done in very few centers and the cost and availability of the prosthesis for regular replacement is therefore a major concern. Other complications like prosthetic extrusion, leakage, tissue intolerance may keep a laryngectomized individual from benefiting with the prosthetic speech.

Neoglottic reconstructive surgeries like the epiglotohyiodopexy are complicated by serious chronic aspiration postoperatively.

The conservative surgeries are still in their infancy.

Considering all these limitations of the advanced techniques, oesophageal speech is still the only alternative available in many parts of India for rehabilitation of laryngectomees. Although the success rates for oesophageal speech vary depending on patient motivation, the availability of therapy, the results of radiation therapy and anatomic alterations, this method of sound production is convenient and can result in a high degree of intelligibility. This technique can be taught to a large number of patients with success rates generally reported as 65 to 85% (Snidecor 1975).

Satisfactory rehabilitation of laryngectomy patient requires understandable speech that is effective in all social environments. Labored monosyllabic speech is not considered successful. Oesophageal speech training is changing and when reviewed critically, indicates a need for research directed to improve the understanding of the mechanics of fluent speech, intelligibility and characteristics of the successful subpopulation of superior speakers. The present study is one such effort.

Robbins (1984) states that findings about acoustic and temporal measures are of interest because they are expected to contribute to the understanding of

a) the acoustic output of specific physiologic processes
b) the features that may contribute to variation in perceptual responses and
c) the physical properties of speech that may signal vocal deviancy.

Changes in the speech production mechanism occasioned by laryrgectomy are reflected in the acoustic characteristics of alaryngeal speech in may ways. (Weinberg 1982, Robbins, Fisher, Blom and Singer 1984, Sisty and Weinberg 1972, Weinberg 1986, Weinberg and Bennet 1972a and 1972b; Weinberg, Horii and Smith 1980). The principle factors affected by laryngectomy are those of the vibratory source (Damste 1958). Along with the alteration in the source, there is change in the vocal-cavity transmission characteristics too (Rollin 1962 and Kytta 1964).

The knowledge of acoustical and temporal properties of oesophageal speech can be interpreted to provide more insight into speech production after laryngectomy. This can be further helpful in therapy. Hence the present study was planned. A part of the study was instigated from the general observation that Marathi language utilizes a variety of aspirated sounds - Does oesophageal mode of speech, then result in any alteration in the production of the aspirated sounds in native speakers of Marathi? Some other questions which the present study tries to answer are - How do oesophageal speakers perform on temporal measure such as rate of speech and pause duration? Are they able to vary the fundamental frequency to result in a particular intonation?

Aim of the study:

The present study was undertaken to -

1) Determine the acceptability and intelligibility of oesophageal mode of alaryngeal speech.

2) Conduct an acoustic analysis of oesophageal speech to identify the parameters which are deviating from normals and the extent of their deviation

3) To understand the mechanics of fluent speech.

4) To study the importance of the various parameters contributing to the intelligibility and acceptability of oesophageal speakers so that appriate therapy programme with emphasis on the deviant parameters could be instituted for better alaryngeal speech.

Some of the acoustic, temporal and spectral parameters that were used by Robbins (1984), Sisty and Weinberg (1982) Rajashekhar (1992) have been considered in the present study along with other parameters with some modification in the definitions of the parameters used by others.

The parameters used in the present study are

Psychoacoustic

1. Acceptability of speech (ACPTL)
2. Intelligibility of speech (INTL)

Acoustic

3. Fundamental frequency in speech [Fo (SP)]
4. Frequency range in speech [FR (sp)]
5. Intonation contours for specific types of sentences i.e. declaratives and interrogatives.

Temporal

6. Vowel duration (V.D) for vowels following the initial stops viz. /e/,/ə/,/a/,/o/,/u/.
8. Voice onset time for voiceless stops (VOT)
9. Mean pause duration (MPD)
10. Rate of speech (in syllables/second) (RT)

Spectral

11. First three formant frequencies (F_1, F_2 and F_3) for the vowels /e/, /ə/,/a/,/o/,/u/, following the initial stops

Hypothesis

There is no significant difference in terms of the parameters studied between oesophageal speakers and normal laryngeal speakers.

Auxiliary hypotheses:

Hypothesis 1

There is no significant difference in terms of acceptability of speech between oesophageal speakers and normal laryngeal speakers.

Hypothesis 2

There is no significant difference in terms of intelligibility of speech between oesophageal speakers and normal laryngeal speakers.

Hypothesis 3

There is no significant difference in terms of fundamental frequency in speech between oesophageal speakers and normal laryngeal speakers.

Hypothesis 4

There is no significant difference in terms of frequency range in speech between oesophageal speakers and normal laryngeal speakers.

Hypothesis 5

There is no significant difference in terms of vowel duration between oesophageal speakers and normal laryngeal speakers.

Hypothesis 6

There is no significant difference in terms of burst duration for stops between oesophageal speakers and normal laryngeal speakers.

Hypothesis 7

There is no significant difference in terms of voice onset time for voiceless stops between oesophageal speakers and normal laryngeal speakers.

Hypothesis 8

There is no significant difference in terms of mean pause duration between the oesophageal speakers and normal laryngeal speakers.

Hypothesis 9

There is no significant difference in terms of rate of speech between the oesophageal speakers and normal laryngeal speakers.

Hypothesis 10

There is no significant difference in terms of formant frequencies between oesophageal speakers and normal laryngeal speakers.

Methodology

The voice and speech samples of the two groups viz oesophageal and normal Marathi speakers (5 each) were studied. The acoustic, temporal, spectral and Psychoacoustic parameters were analysed using a computer with the necessary software and judges. The analyzed data has been subjected to appropriate statistical treatment and results discussed.

Implications of the study:

The analysis of oesophageal speech provides some of the characteristics of this mode of alaryngeal speech and how they contribute to the intelligibility and acceptability of oesophageal speech. This enables the clinician in setting objective therapeutic goals for better intelligibility of the oesophageal speech.

Limitations of the study:

1. Only male speakers have been studied.
2. The sample size is small.
3. The study is limited to some of the acoustic spectral and temporal parameters.
4. In some key words for a few subjects the initial burst could not be inspected visually in both normals as well as oesophageal subjects.

5. The prevoicing for voiced stops in case of a few words for a few oesophageal speakers could not be accurately noted due to presence of noise.
6. Intrasubject variability was not considered.
7. Details of the total laryngectomy surgery and the duration of speech therapy could not be ascertained for each of the subjects.

CHAPTER II

"REVIEW OF LITERATURE"

"The one form of communication which people use most effectively in inter-personal relationships is speech. With it they give form to their innermost thoughts - their dreams, ambitions, sorrows and joys. Without it, they are reduced to animal noises and unintelligible gestures. In a real sense speech is the key to human existence. It bridges the differences and distances and helps to give meaning and purpose to their lives". (Fisher 1975).

Normal speech production is accomplished by generating sounds in the larynx or at various sites in the vocal tract and differentialy modifying these sounds by acoustic filtering. The normal speech production is executed by exhaling pulmonary air to provide energy to generate source sounds within the vocal tract by interrupting exhaled air with the vocal folds to produce a quasiperiodic sound or voice, in either case, pulmonary air is used to energize the source and the sound generated is differentially modified by resonant properties of the vocal tract (Weinberg 1986).

The underlying basis of speech is voice. Voice has been defined as the laryngeal modulation of the pulmonary air stream which is then further modified by the configuration of the vocal tract. (Michel and Wendahl 1971).

The production of voice depends on the synchrony between the respiratory, the phonatory and the resonatory systems. Any anatomical, physiological or functional deviation in any of these systems would lead to a voice disorder.

There are circumstances in which people must produce speech using a radically altered mechanical system. Patients who are affected by carcinoma of the larynx, having undergone total laryngectomy are in such a situation. Total laryngectomy necessitates the removal of the entire laryngeal framework. In this procedure all structures located between the hyoid bone and the upper tracheal rings are sacrificed (viz. the arytenoid cartilages, cricoid cartilages, thyroid cartilage and the posterior tracheal - anterior oesophageal wall). Figure-1 depicts the throat of a laryngectomee before and after surgery. The trachea is rotated forward and sutured to a surgically created opening. This leads to the creation of a permanent stoma on the external neck wall for respiratory purposes and results in an anatomical, but not functional separation between the pulmonary airway and the digestive tract.

Total laryngectomy always results in a sacrifice of tissue essential to normal vocal function and in considerable alteration of the anatomy and physiology of the speech mechanism. As a result, the normal processes of speech are modified to such a great extent that there is always a complete loss of ability to produce voice by conventional means. The laryngectomized person is left aphonic.

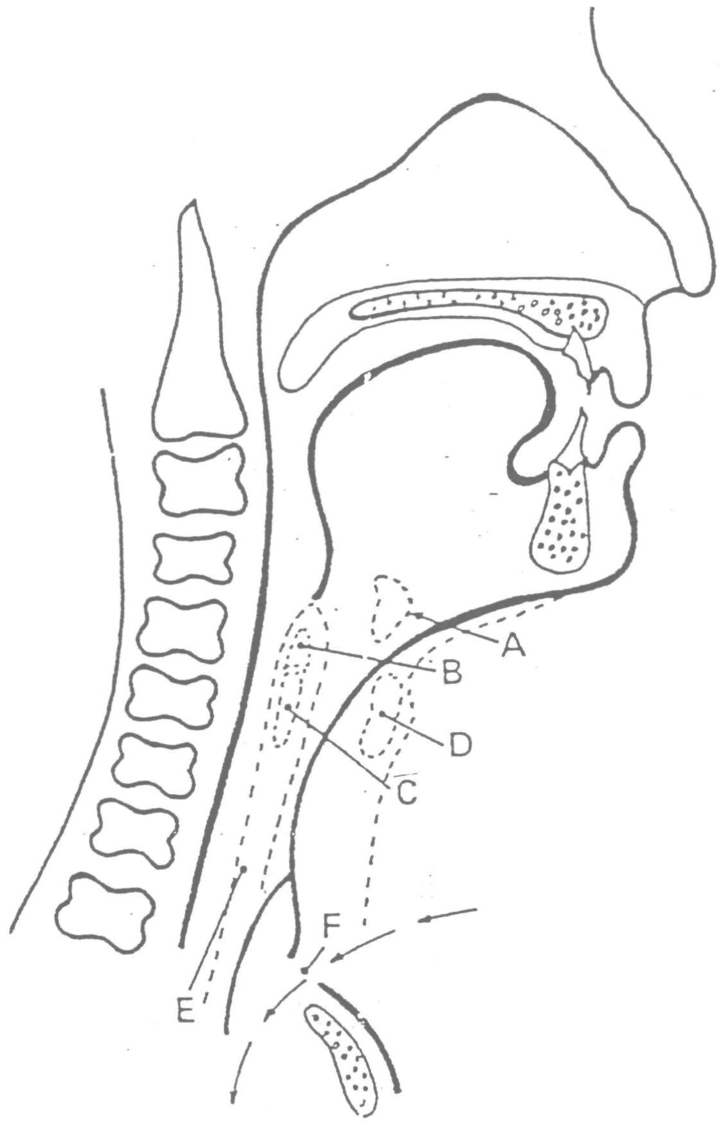


FiGURE-1

The throat of a laryngectomee, before and after surgery. The broken lines designate normal structures present before the surgical operation. The patient has had removed (A) the hyoid bone; (B) the arytenoid cartitages; (C) the cricoid cartilage; (D) the thyroid cartitage. Note (E), the posterior tracheal-anterior esophageal wall. After the operation, the residual neck and head structures of the taryngectomee are shown by the solid lines; the new tracheal opening, the tracheotomy, is seen at (F).

For the laryngectomee, the loss of voice is not just traumatic but handicapping in all faces of life. More so, when a person is dependant on his voice for his living like teachers, lawyers, politicians, sales executives etc. The laryngectomized person needs to compensate for loss of voice by using alternative methods of voicing to support speech production. Kallen (1934) refers to any kind of non laryngeal phonation - oesophageal, buccal, pharyngeal, via an electronic larynx or whatever as alaryngeal speech.

Basically there are two forms of voicing laryngectomized persons may use to support alaryergeal speech production. One form refers to extrinsic methods of alaryngeal voice and speech production. Extrinsic forms depend upon man made voicing prosthesis (artificial larynx) or surgically created structures developed specifically for the purpose of voice production (surgical/prosthetic approaches to voice restoration). The second form is an intrinsic method that relies upon intrinsic anatomical structures remaining following laryngeal extirpation (e.g. buccal speech, pharyngeal speech and oesophageal speech).

The laryngectomee - the operated individual can generate sound at three locations i.e.,

1) Within the oral cavity called "buccal speech" producing friction noises by trapping air between the tongue and cheek.

2) Within the pharyngeal cavity termed as "pharyngeal speech".

3) at the lumen of the oesophagus known as "oesophageal speech". Of the various methods of sound production available, oesophageal speech is the time honoured one. Aronson (1980) has stated that this mode of alaryngeal speech is based on the principle that when air is taken into the oesophagus, sound is produced on the release of the air by exciting the upper oesophageal tract into vibration, like belching. The main difference between normal belching and oesophageal speech according to him is that in the latter, the speaker is highly skilled and can control the initiation and prolong the oesophageal tone.

Physical requirements	Laryngeal voice	Oesophageal voice
Initiator	A moving column of air from the lungs	A moving column of air from the oesophagus
Vibrator	Vocal cords	P.E. segment
Resonator	Vocal tract	Vocal tract
Articulators	Tongue, teeth, lips, soft palate	Tongue, teeth, lips, soft palate

Table 1: Comparison of requirements to produce laryngeal voice and oesophageal voice (Edels, 1983).

Oesophageal speech is that in which the vicarious air chamber is located within the lumen of the oesophagus and the neoglottis is located above the air chamber. The site of the neoglottis is the pharyngo-oesophageal segment or junction and may contain fibers of the inferior constrictor, cricopharyngeus and/or the superior oesophageal sphincter which are predominantly located at C5 and C6 (Diedrich and Youngstrom 1966).

ORIGIN OF OESOPHAGEAL SPEECH

The introduction of oesophageal speech in the early part of 20th Century was popularised by schools of phoniatry. Simpson, Smith and Gordon (1972) reported Reprand in 1828 observed oesophageal speech in a patient with congenital glottic atresia. Singer (1983) stated that Czermack in 1859 described oesophageal speech in a case of laryngeal stenosis and there were other reports of this occurrence in cases of diptheria. Czerny (1856) in his publications referred to the technique of voice rehabilitation used by Gluck, (cited by Singer, 1983). Patients whose larynx had been displaced by acute stenosis or atresia and who had been provided with a tracheostoma learned to swallow air and to form words when it ascended. This was nothing but an early form of oesophageal speech. Gluck was therefore able to achieve a certain degree of voice restoration. Gottstein (1900) reported that gluck was the first to introduce oesophageal speech as a speech restoration method for laryngectomees in 1882 (Herrman, Hammer and Grevemeyer, 1986).

By 1922, in Prague, Seeman (cited by Singer, 1983) probably was the earliest to define the upper oesophagus as the vicarious glottis and the body of the oesophagus as the air reservoir. His early studies of the air-distended oesophagus during transnasal insufflation were important to the understanding of the mechanism of alaryngeal speech production.

GENERAL REQUIREMENTS FOR OESOPHAGEAL VOICING:

Production of oesophageal voicing necessitates use of the oesophagus as an accessory lung and the pharyngoesophageal (PE) segment as a voicing source. The PE segment which is the upper sphincter of the oesophagus, serves to divide the pharynx from the oesophagus in normals. This segment consists of the cricopharyngeus muscle, fibers of the pharyngeal inferior constructor and upper fibers of oesophageal muscle (Zaino et al 1970 as cited by Weinberg 1982). Deidrich and Youngstorm (1976) referred to this area as the site of the pseudo-glottis and used the term pharyngo-oesophagel segment to label it (Edels, 1983). The P.E. segment does undergo major morphological and functional changes as a result of laryngectomy. Laryngectomy results in a significant sacrifice of tissue critical to post surgical oesophageal voice acquisition.

Weinberg (1982) describes the oesophageal voicing as a two part process, comprising the air intake and voicing. The oesophageal speaker must cause a pressure drop across the PE segment, to effect, either air intake or voicing oesophageal speakers insufflate air into the oesophagus by means of the injection or inhalation methods of air intake.

METHODS OF AIR INTAKE

After laryngectomy, pulmonary respiration with its consequent alterations of intrathoracic pressure continues, via the tracheostoma. At rest, air at atmospheric pressure (i.e. positive pressure) continues to circulate within the nasal, oral and pharyngeal cavities. The PE segment is tonically contracted and registers positive pressure, while the oesophagus is closed down and registers negative pressure. Before sound can be produced, air must pass the P.E. segment and enter the oesophagus which will then register a positive pressure relative to that in the pharyngeal cavity. This may be achieved by either the inhalation or the injection method (Edels, 1983).

A) The inhalation technique

Inhalation method of air intake is a pulmonary activated method of air insufflation. Air is taken into the oesophagus synchronously with pulmonary inhalation. In this method, air is directed into the oesophagus by having patients inhale pulmonary air. The patient experiences a thoracic enlargement during pulmonary inhalation, which reduces the compression on all thoracic structures, including the oesophagus. This causes the magnitude of negative pressure in the oesophagus to increase from -4 mm to -7 mm to around -15 mm.

Patients are instructed either to keep their mouths open or to sniff during pulmonary inhalation.

If the cricopharyngeus opening into the oesophagus is slightly open at time of the slight increase in the size of the oesophagus, air from the hypopharynx will flow into the oesophagus. Thus air will flow from the area of positive pressure (mouth and phaynse) to the area of increased negative pressure (oesophagus) provided that the air overcomes resistance of the PE segment. With the reduction in pressure difference, the PE segment snaps shut, leaving air contained within the inflated oesophagus ready for use for voice production (Edels 1983).

B) The injection method

The injection method of air intake is a positive pressure respiratory maneuver. Basically persons using this method complete tongue compression moreuvers and or articulatory gestures to generate increased oral and pharyngeal pressure. The laryngectomee attempts to force air past the PE segment by increasing the pressure of the air within the oral/pharyngeal cavity, by shutting the escape routes for the air and then reducing the size of the air chamber. The oral exit is shut, either by sealing the lips or more commonly by tongue - tip alveolar ridge contact and the nasal exit by velopharyngeal port closure. If the air is now subjected to sufficient increased pressure, it would enter the oesophagus via the PE junction.

Moolenaar-Bijl (1953), a Dutch speech therapist provided the original description of what is now known as Consonant injection. He was the first person to advance the notion that oesophageal insufflation can occur as a result of pressure build up associated with the production of certain types of consonants. These are consonants which have a facilitating effect in producing good oesophageal voice. Individual patients may have their own favorite facilitating sounds but more often than not these are plosive consonants (/p/. /b/, /t/, /d/, /k/ and /g/) or affricates containing plosives /tʃ/ or /dz/ (Boone 1980). Stetson (1937) reported that the voiceless stops /p/, /t/ and /k/ were the earliest sounds for the new laryngectomee to use. Moolenaar -Bijl (1953) reported that the same phonemes produced oesophageal speech faster in most patients. Diedrich and Youngstrom (1966) recommended the voiceless /p/ /t/ /k/ /s/ /ʃ/ and /tʃ/ phonemes as good sounds to employ in the consonant injection method of air intake. As the patient whispers monosyllabic words with a facilitating consonant before and after the vowel, he or she will sometimes spontaneously inject air into the oesophagus and produce an unplanned oesophageal voice. The production of the consonant facilitates the transfer of air into the oesophagus (Shanks 1986). This method is also known as **Dutch method.** or **plosive injection**. In this method the air intake and voice expulsion phases occur almost simultaneously.

Diedrich and Yongstorm (1977) have commented that research has shown that non vibratory i.e., voiceless sounds may be made using either

a) supra P.E. segment air or
b) air from within the oesophagus on the condition that it can be released past the P.E. segment without causing it to vibrate or
c) a combination of a) and b).

Voiceless consonants may assist air injection not only from a position of rest, but during the course of sentence production when they may occur automatically within the course of the conversation. These plosive lader sentences allow the laryngectomee to recharge his air supply while he speaks, giving him extra duration for voice production and considerably easing the flow of communication.

Weinberg and Bosma (1970) have described a second type of injection, now known as glossal press, glosopharyngeal press or tongue pump injection method. In the glossal press injection method the laryngectomees tongue tip contacts the alveolar ridge and frequently the middle of the tongue contacts the hard and soft palate. The posterior portion of the tongue makes a backward movement but does not touch the posterior pharyngeal wall. (Velopharyngeal closure is necessary). Whereas in the Glossopharyngeal press, injection method, the posterior portion of the tongue makes a backward movement and contacts the posterior pharyngeal wall (velopharyngeal port closure is necessary). Sweeping the air backwards and downwards in the pharynx, results in sufficient pressure to overcome the contraction of the PE segment for air flow into the oesophagus.

AIR RESERVOIR

Studies using radiographic techniques have confirmed the oesophagus as an air reservoir (Hodson and Oswald 1958; Schlosshauer and Mockel 1958, Kamieth 1959, Motta, Profazio and Acciarri 1959, Vtricka Svobada, 1961 as cited by Edels 1983).

The normal laryngeal speaker has an air reservoir within the lungs of between 3,500 ml and 4,000 ml of air, although not all of this is available for phonation. According to Greene (1964) about 1,500 to 2,000 ml of air is inspired during respiration for phonation. In contrast the total capacity of the oesophagus is between 60 ml and 80 ml of air when fully inflated (Vanden Berg and Moolenaar - Bijl 1959). However the oesophagus as reported by Edels (1983) is not fully inflated for phonation. Only the top one third to one half is inflated during air charging for voice production by good and superior oesophageal speakers. This amounts to only about 15 ml of air available for use after each air charge (Snidecor and Isshiki 1965). With so little air available, it is essential that the patient develops good consistency for successive attempts at recharging his oesophagus, speed in air intake, control for sound output which are linguistically acceptable.

METHOD OF VOICE PRODUCTION:

The method of voice production in oesophageal speakers has been studied by many. As air is either inhaled or injected the air pressure within the oesophagus becomes positive with respect to the atmospheric pressure. The resting oesophageal pressure is generally as -4 to -7 mm of Hg increasing to -10 to -20 mm of Hg on pulmonary inspiration, the inflated oesophageal pressure measured just after air intake is about + 25 mm of Hg (Dey and Kirchner, 1961). The air would then flow out of the oesophagus, setting the walls of the P.E. segment into vibration. The sound produced by this vibration is the basic oesophageal voice.

ANATOMICAL AND PHYSIOLOGICAL ASPECTS OF OESOPHAGEAL SPEECH/VOICE PRODUCTION:

Kirchener et al (1963) attempted to delinate the nature of change in both the structure and the function of the pharynx and oesophagus resulting from laryngectomy from cinefluorographic examinations and intraluminal pressure measurements of the pharynx. The points of attachment of a large number of extrinsic laryngeal muscles along with the cricopharyngeus muscle are sacrificed during total laryngectomy surgery. Kirchner's (1963) data provides support to the notion that the voicing source used to support oesophageal speech should be regarded as a surgical residue characterised by extensive intersubject variability. The evidence provided by Kirchner et al (1963), Diedrich (1968) and Winans, Riechbach and Walderop (1974) suggests that total laryngectomy may lead to only slight alterations in the anatomy and physiology of the oesophagus. The detachment of cricopharyngeus muscle from the larynx may account for the observations of weakened contractions of the cricopharyngcus muscle postsurgery Kirchner et al 1963; Winans et al 1974) and for depressed amplitude of peristalsis in the upper oesophagus. The function of the lower oesophageal sphincter is apparently not altered.

The PE segment does undergo major morphological and functional changes as a result of laryngeal extirpation. The observations of Diedrich (1966) and Kirchner et al (1963) reveal that some laryngectomized patients exhibit well defined, single PE segments, typically located between cervical vertebrate four and six. Some patients exhibited double and triple segments. In a small number of oesophageal speakers, no well defined PE segment was observed during voice production. This high degree of variability in the morphological characteristics of the segment serves to verify the heterogeneity in vocal attributes evident across a large sample of oesophageal talkers.

FAILURE OF DEVELOPING OESOPHAGEAL SPEECH:

Not all laryngectomees are able to acquire oesophageal speech. Various percentages of failures have been reported ranging from 43% (King et al 1968) to 98% (Hunt, 1964). Snidecor (1971) reported an acquisition rate of 60-70% but more objective specific data indicates that approximately only 29% of the laryngectomees really acquire proficiency in oesophageal communication (Gates, Ryan and Cooper 1982). The failures are attributed to

1) Lack of motivation
2) old age
3) Hearing loss
4) Dependency on mechanical device for voice production (artificial larynx).
5) Over protectiveness of the family.
6) Damage to the PE segment-hypotonicity or hypertonicity of the PE segment.
7) Stricture within the pharynx.
8) Lingual and palatal insufficiency
9) Presence of mucosal pouches at the base of tongue and within the pharynx.

ACOUSTIC CHARACTERISTICS OF STOPS:

Stops are the only kind of consonants that occur in all languages. Henton Ladefoged and Maddieson (1992) by their cross linguistic study have shown the diversity and similarity of stops in terms of manner and place of articulation.

Stops may be defined according to their articulatory and acoustic characteristics. Stop consonants are produced by occluding the oral cavity by an articulator. Air is held behind the articulator for sometime and is released. The stops are special in that they represent the nonlinearity of the speech production system. They appear to be the most highly encoded speech sounds (Day and Vigorito 1973) and they are the information bearing elements of speech.

Five qualitatively distinct segments can be identified for stop consonants:

1. A period of occlusion (silent/voiced).

2. A transient explosion (burst) produced by shock excitation of the vocal tract upon release of occlusion.

3. A very brief (0-10 msec) period of frication as articulators separate and air is blown through a narrow constriction.

4. A brief period of aspiration (2-20ms.) with in which may be detected noise excited formant transitions, reflecting shift in vocal tract response as the main body of tongue moves towards a position appropriate for the following vowel and

5. Voiced formant transitions, reflecting the final stages of tongue movement in to the vowel during the first few cycles of laryngeal vibration.

Specification of acoustic features for perception of stops has been a prominent issue in research on speech production and perception. Acoustic features are reported to vary across languages. However a lot of literature is on English stop. Among the Indian languages some studies have been done on Kannada, Hindi and Telugu stops.

The proliferation of studies on stops in both production and perception can be attributed to their special nature. Savithri (1990) states that the stops are special in that:

a) Acoustically they have been considered to contain basic properties, also characteristics of other consonants.

b) They represent the nonlinearity of speech production systems.

c) They demonstrate the redundancy of acoustic cues available to distinguish speech sounds.

d) Their perception provides best example of listener use of acoustic overlapping of phonemes in speech stream and

e) They are the information bearing elements of speech.

A major part of the present study also deals with stops.

VOICE ANALYSIS

Acoustic analysis has proven useful for the clinical assessment of laryngeal and articulatory function. Over other methods of analysis, acoustic analysis has an advantage due to its non intrusive nature and its potential for providing quantitative data with reasonable expenditure of analysis time. To understand the mechanism of voice in normal laryngeal speakers number of studies have been carried out. oesophageal speech, where the voice source is different from the laryngeal speakers also has generated a lot of interest among the researchers. Various exhaustive studies on the acoustic parameters of oesophageal speech have been carried out. However very few studies have been carried out on oesophageal speakers in the Indian population. Further investigations are yet needed. Increased understanding of speech production following removal of larynx is accomplished by uncovering relationships among acoustic properties and physiological, psychological and linguistic aspects of speech production.

Since total laryngectomy always results in a sacrifice of tissue essential to normal vocal function, investigators have assumed that the principal factors influenced by laryngectomy are those related to the voicing source. There have been a number of studies completed to specify the fundamental frequency characteristics of oesophageal speech.

Although comprehensive knowledge about articulatory changes due to laryngeal extirpation is lacking, there is experimental evidence to support the notion that laryngectomy surgery does alter articulatory behaviour. For example. Due to removal of hyoid bone, the musculature of the suprahyoid complex and the supporting musculature of the tongue is disrupted. (Weinberg 1980). In addition, the intrusion of gestures essential to oesophageal air fillings must exert disruptions in dynamics of articulatory behaviour of oesophageal speech. Thus extirpation of the larynx results in substantial changes in both phonatory and nonphonatory aspects of speech production.

The parameters considered in the present study were:-

Psychoacoustic parameters:

1) Acceptability of speech
2) Intelligibility of speech

Acoustic parameters:

3) Fundamental frequency in speech.
4) Frequency range in speech.
5) Intonation contours for specific types of sentences i.e. declaratives and interrogatives.

Temporal parameters:

6) Word duration.
7) Vowel duration for vowels following the initial stops viz (/e/; /ə/; /a/; /o/, /u/).
8) Burst duration.
9) VOT for voiceless stops.
10) Mean duration of pauses.
11) Rate of speech in syllables/second.

Spectral parameters:

12) Formant frequencies F1, F2, and F3 for the vowels /e/, /ə/, /a/, /o/, /u/ following the initial plosives.

The parameters studied were chosen for their relationship with aerodynamic and physiological characteristics of the vocal mechanism and their contribution towards perception of voice. The frequency parameters (fundamental frequency in speech, frequency range in speech and intonation contours) have been used to assess the impact of aerodynamic events on the alaryngeal vibratory source (P.E. segment). Temporal parameters (Burst duration, vowel duration, VOT, rate of speech, Mean duration of pauses) determine the effects on time achieved by the insufflated air on the P.E. segment.

The formant frequencies have been measured to obtain knowledge of the vocal tract configuration and transfer function. All these factors singly or in interaction with each other are considered to be affecting the intelligibility and acceptability of oesophageal speech.

The intonation contours have been studied to know the extent to which oesophageal speakers are able to realize linguistic contrasts like declaration and interrogation. Their is an absence of information concerning the ability of laryngectomized speakers to realize such important types of contrasts as intonation. The following review would highlight the importance of each parameter in the assessment of laryngeal and alaryngeal speakers.

I. PSYCHOACOUSTIC PARAMETERS:

a) ACCEPTABILITY OF ALARYNGEAL SPEECH:

Clinical utility of any alaryngeal voicing technique lies in the intelligibility and acceptability of speech. Experiments have been performed to specify vocal attributes which differentiate good and poor oesophageal speakers (Snidecor and Curry 1959; Shipp 1967; Hoops and Noll, 1969). The works of Shipp (1967) and Hoops and Noll (1969) have shown that variables such as rate of speech, phonation time mean fundamentals frequency and stomal noise ratings are significantly related to judgements of sp. acceptability.

Bennet and Weinberg (1972) attempted acceptability ratings of nine normal laryngeal speakers and five oesophageal speakers. The judges were asked to rate the acceptability using a 7 point (equal interval) scale (where 1 represented speech which was least acceptable and 7 highly acceptable). The normals scored a mean acceptability rating of 5.48 and the oesophageal speakers a rating of 2.54. Gates et al (1982) observed a mean speech acceptability score (1-5 scale) of 2.49, in twelve oesophageal speakers. Using a five point rating scale, Blom et al (1986) obtained mean acceptability scores of 2.49 in oesophageal speakers. Whereas Rajshekhar (1991) reported mean acceptability scores of 1.6 (1-5 scale). It was hence decided to find the effect on the acceptability of speech.

b) **INTELLIGIBILITY OF ALARYNGEAL SPEECH:**

There is experimental evidence to support the notion that total laryngectomy does alter articulatory behavior. Weinberg (1986) opines that total laryngectomy disrupts muscular support for the tongue, brings out major changes in articulatory aerodynamics and produces alterations in vocal tract morphology. In addition, the intrusion of gestures essential to oesophageal air filling must exert disruptions in dynamic articulatory behaviours of oesophageal speakers. (Hyman 1955, Shames, Font and Mathews 1963, McCroskey and Mulligan 1963, Tikotsky 1965, Sacco, Mann and Schutz 1967, Clarke and Hoops 1970, Hoops and Curtis 1971, Amster, Love, Menzel, Sandier Sculthorpe and Gros 1972, Weinberg 1980, Kalb and Carpenter 1981, Holley, Herman and Randolph, 1983) have shown that oesophageal speech is characterized by a reduction in speech intelligibility.

Information about acoustic properties of articulatory by-products in alaryngeal speech is scarce. Sisty and Weinberg (1972) have shown that formant frequency characteristics of vowels produced, by oesophageal speakers are elevated, a finding interpreted as due to the shorter than normal vocal tracts in laryngectomized patients. Christensen and Weinberg (1976) have shown that the spoken vowels of oesophageal speakers are consistently longer than those spoken by normal speakers, a finding supportive of the view that articulatory behaviour is altered.

Although varying in their methodologies and results, other studies have found mean word intelligibility scores in conventional oesophageal speakers to range from a low of 54.9% (Shames et al 1963) to a high of only 79.6% (Rajshekahar 1991). Kalb and Carpenter (1981) reported mean intelligibility scores of 78.5%. Gates, Ryan, Coper et al (1982) found mean intelligibility score of 61.4% in oesophageal speakers. Bloom et al (1986) reported intelligibility scores of 78.2% where as Hariprasad (1992) reported mean intelligibility score of 43.4% only in oesophageal speakers.

II. ACOUSTIC PARAMETERS:

a) FUNDAMENTAL FREQUENCY IN SPEECH Fo (sp)

Fundamental frequency is the lowest frequency that occurs in the spectrum of a complex tone. In human voice also, the lowest frequency in the voice spectrum is known as the fundamental frequency. "... both quality and loudness of voice are mainly dependent upon the frequency of vibration. Hence it seems apparent that frequency is an important parameter of voice" (Anderson 1961). Emrickson (1959) opines that vocal cords are the ultimate determiners of pitch and that the same general structure of the cords seem to determine the range of frequencies that one can produce. The perception of pitch and measurement of fundamental frequency are based on the systematic opening and closing of the vocal folds during the production of voiced speech signals. Hence when fundamental frequency is measured acoustically, the process is actually to count these openings and closings by some objective method.

Evaluation of the fundamental frequency in phonation may not represent the fundamental frequency used by an individual in speech. Studies have shown that the Fo in phonation and speech are different (Nataraja and Jagadeesha 1984). Hence determination of fundamental frequency in speech using an adequate speech sample becomes important. Using a reading task rather than spontaneous speech has an advantage for comparison between speakers, if the same material is used (Baken 1987).

Many investigators have studied the Fo (sp) as the function of age and in various pathological conditions (Micheal, Hollien, Moore 1965, Shipp, Huntington 1965, Bohme and Hecker 1970, Fitch and Holbrook 1970, Hollein and Shipp 1972, Murry 1978, Murry and Doherty 1980, Hudson and Holbrook 1981, Hirano 1981, Kushal Raj 1983, Gopal 1986, Natraja 1986).

The Fo(sp) is reported to decrease with age upto adolescence and increase in advanced age group (Bohme and Hecker 1970, Hollien and Shipp 1972). Nataraja and Jagadeesha (1984) measured the fundamental frequency in phonation, reading, speaking and singing in normal males and females. They observed that the fundamental frequency increased from phonation to singing with speaking and reading in between.

Studies of Fo(sp) variability in pathological cases have been carried out. Hecker and Kruel (1971) found a restricted Fo(sp) range in patients with laryngeal cancer. Murry's (1978) study supported Hecker and Kruel's (1971) findings.

The Measurement of Fo(sp) in oesophageal speakers needs to be viewed from the perspective that it could contribute to the intelligibility and acceptability of oesophageal speech and evolve setting up of therapeutic goals.

Since the total laryngectomy always results in a sacrifice of tissue essential to normal vocal function, clinicians and investigators have related the principle factors influenced by laryngectomy to the voice source.

Damste (1958) believed that the larynx of a normal speaker and the PE segment of the laryngectomee operated essentially in the same way i.e. by the Bernoulli effect. He stated that the normal vocal cords lie against one another along a rather great depth during phonation in the chest register, as it is clearly shown by frontal tomograms of the larynx. The subglottic pressure forces them apart. As soon as the air bell has passed, they close again, beginning at the bottom. This closure is effected by the elasticity of the cords as well as by the Bernoulli's effect- the decreased pressure on the medial side of the cords, when a rapid current of air passes through. Thus the air current through the glottis is modified into puffs of air. As per Damste (1958). Fundamentally this is not different for the pseudoglottis. Only the distance the air bells have to cover through the glottis is not a few millimeters but a centimeter or more.

Determination of the FO(sp) in oesophageal speakers is more difficult because of the fact that only rarely the sound signals are purely periodic. More commonly the vibrations of the PE segment are aperiodic, so that it is difficult to speak of a tone. The occurrence of a periodicity was attributed to three causes by Damste (1958).

1. To variations in subneoglottic pressure:- The volume of air in the oesophagus is small (approximately 80 cc), any fold in the mucous membrane below the level of the PE segment may easily influence the supply of air.

2. The length and elasticity of the PE Segment are not so constant and adjustable as in the normal glottis.

3) The accumulation of mucous above the mouth of the oesophagus, a handicap for most laryngectomees. The third reason is considered to be the most important. Thus the air is forced in a highly irregular way through the PE segment through varying layers of secretions. It is therefore noise that is produced rather than a tone (Perry 1989).

According to Perry (1989) there is some confusion as to whether oesophageal speech can truly be said to have fundamental frequency as it involves aperiodic sound. Often the recording is a regular note at the PE segment with aperiodic overtones. Additionally, the results of analysis using "good" oesophageal speakers may be very different from analysing those who have difficulty in producing sound (Curry and Snidecor 1961) However many investigators have used the term Fo in speech.

Few studies measuring the Fo in speech in oesophageal speakers have been carried out.

Investigator	Mean Fo (Sp) Hz
Damste (1958)	67.5
Curry and Snidecor (1961)	63.0
Hoops and Noll (1969)	94.38
Shipp (1967)	65.59
Weinberg and Bennet (1971,1974)	57.4
Torgerson and Martin (1980)	65.7
Blood (1984)	64.6
Robbins (1984)	77.1
Pindzola and Cain (1989)	84.1
Rajashekhar (1991)	90.8

Table - 2: The mean Fo(SP) in oesophageal speakers by various investigators.

Damste (1958) used 20 randomly selected subjects who read a four word sentence. The mean fundamental frequency was 67.5 Hz in these subjects. Snidecar and Curry (1959), Curry and Snidecor (1961) and Curry (1962) used the Rainbow passage for Fo (Sp) measurement. They reported a mean Fo (sp) of 63 Hz. Shipp (1967) extracted the fundamental frequency from the second sentence of the rainbow passage from the recordings of the six best oesophageal speakers. The mean of which was 94.38 Hz. Hoops and Noll (1969) extracted the Fo (sp) from the first paragraph of the Rainbow passage by the measurement of oscillogram. The Mean Fo (sp) in 22 oesophageal speakers was 65.59 Hz. Weinberg and Bennet (1971 and 1972) measured the Fo (sp) in eighteen male oesophageal speakers and reported a mean Fo (Sp) of 57.4 Hz.

Torgerson and Martin (1975) determined fundamental frequency of oesophageal speech produced by laryngectomized and nonlaryngectomized male subjects. They obtained the mean FO (sp) from the second sentence of the Rainbow passage by using the Honeywell visicorder oscillograph. They observed a significant difference between the two groups in the standard deviation of fundamental frequency. The laryngectomized speakers exhibited a comparatively lower mean and standard deviation values than the non-laryngectomized speakers. They opined that the mean fundamental frequency produced following laryngeal amputation is apparently more homogeneous among the speakers and that is perhaps related to a reorientation of the pharyngeal and oesophageal musculature. Torgerson and Martin (1980) reported a mean fundamental frequency and standard deviation of 65.7 Hz and 2.06 tones in 15 oesophageal speakers. In a study by Blood (1984) the mean Fo (sp) for ten oesophageal speakers for the second sentence of the rainbow passage was 64.6 Hz with a standard deviation of 14.5 Hz.

Similarly Robbins et al (1984), who extracted the mean Fo (sp) from the second sentence of the Rainbow passage read by 15 oesophageal speakers found a mean Fo (sp) of 77.1 Hz and a standard deviation of 18.2 Hz.

Pindzola and Cain (1989) compared selected characteristics in the speech of 5 tracheo-oesophageal, 5 oesophageal and 15 normal adult speakers. The average fundamental frequency in speech for oesophageal speakers in their study was 84.1 Hz. Rajashekhar et al (1990) reported a mean Fo (sp) of 68 Hz by oesophageal made in one case of laryngectomee, Proficient in both the oesophageal and trancheo oesophageal mode of alaryngeal speech Rajashekhar (1991) in another study on 20 oesophageal speakers reported the mean Fo (sp) to be 90.8 Hz.

b) FREQUENCY RANGE IN SPEECH

The patterned variations of speech over linguistic units of different length (syllables, words, phrases, clauses, paragraphs) yield the critical prosodic features namely intonation (Freeman 1982) In other words during speech the fundamental frequency varies with time. The difference between the maximum and minimum fundamental frequency is called the frequency range in speech (Hirano 1981).

Hudson and Halbrook (1981) studied the fundamental frequency range in reading in normal young male black adults and reported a mean range of 81.95 to 158.5 Hz. Nataraja (1986) reported a mean frequency range in speech of 248 Hz in normals. Gopal (1986) from a study of normal males from 16-65 years, reported the frequency range in speech as ranging from a mean of 134 Hz (16-25 years) to a mean of 181.49 Hz (36-45 Years).

Kent (1976) states that the general conclusions about the diagnostic value of fundamental frequency variability are difficult to make because such measurements are helpful in certain pathological conditions, but not in others. Shipp and Huntington (1965) indicated that in cases of laryngitis, the voice had significantly restricted ranges than did post-laryngitis voice. Murry (1978) found reduced semitone ranges of Fo (sp) in patients with vocal cord paralysis.

Robbins et al (1984) reported a frequency range of 118.1 Hz (S.D = 43.88) and 85-9 Hz (S.D=18.88) in oesophageal and normal groups respectively during reading.

Pindzola and Cain (1989) measured the frequency range in connected speech in normal and oesophageal subjects. The normal speakers showed average frequency range of only 129 Hz whereas the oesophageal speakers had an average range of 177 Hz, which according to them was higher than expected. In their study, frequency variability probably was produced equally well by normal and oesophageal speakers. Since listeners perceived intonational contrasts effectively in both the groups.

c) INTONATION CONTOURS:

Intonation is the salt of an utterance (Delattre 1960). It is the fluctuation of voice, pitch as applied to the whole sentence. It is the melody of the sentence that is superimposed on the sentence as a whole.

Denes (1959) states that the phonemic sequence is not the only linguistic form in which information to be transmitted by speech is organized. Factors like intonation, stress and rhythm also make their contributions. Recognition of these factors provides the listener with additional information about the speaker's intention. Intonation does not change the meaning of lexical items but constitutes pant of the meaning of the whole utterance. He also writes that intonation is the linguistic form, by which the speakers emotional attributes are conveyed such as doubt, agreement, questioning, affirmation, continuing interest etc.

Bolinger (1972) states that the most important grammatical function of intonation is that of tying the major parts together within a sentence and tying sentences together within a discourse showing, in the process, what things belong more closely together than others, where the divisions come, what is subordinate to what and whether one is telling, asking or commanding.

The physiological correlate of intonation is the vibration of the vocal folds in phonation. The rate of vibration may be increased as a result of an increase in the rate of airflow through the glottis. (Caused by increased activity of the respiratory muscles producing increased subglottal pressure) and as a result of an increase in the tension of the laryngeal musculature itself, especially the vocalis muscle. Decrease in the rate of vibration of the vocal folds may be brought about by decreasing the rate of airflow and/or by relaxing the laryngeal musculature. There is some evidence that some external laryngeal muscles may be involved actively in lowering the rate of vibration of the vocal folds.

The acoustic correlate of vocal fold vibration is the fundamental frequency of the sound generated at the glottis. Intonation refers to the linguistically significant functioning of fundamental frequency at the sentence level (Lehiste 1970). According to Pike (1945) and Lado (1961) the variations in the fundamental frequency is the basis for various intonation contours.

Analytic experiments found that a simple relationship existed between intonation and fundamental frequency - a straight forward fall in frequency for a falling tone or a simple rise in frequency for a rising intonation.

Lieberman (1968) comments that although relevant phonetic or instrumental analysis are not available at present for most languages, it is possible to generalize about intonation to the extent of stating that short declarative sentences, usually end with a falling fundamental frequency contour. Detailed instrumental analyses by Jones (1909), Chiba (1935), Fonagy (1958), Hadding - Koch (1961) and Abramson (1962) show that this is the case for English, Spanish, French, Finnish, Hungarian, Italian, Thai, Japanese, Swedish and German. Thus some of the characteristics of intonation are universal.

The universal lowering of pitch towards the end of an unexcited discourse results automatically from running out of lung power. Subglottal pressure raises and lowers pitch, other things being equal. The universal raising of pitch for questions and other keyed up utterances is probably due to higher nervous tension in the body as a whole, which has a total effect of tensing the vocal cords.

To bring about different emotions like surprise, joy, anger, fear etc, a speaker uses different fundamental frequency movements i.e. uses different intonation contours. These can be described in terms of rise, fall, flat and their combinations.

In Kannada, it has been found that a listener identifies an emotion as surprise, if the final contour is rise(r) -

fall(f), as joy when it is r-f/ gradual f(gf); as anger when it is r-f/f-r/gf/gr/ slight fall (sf), as fear when it is r-f/sf/f-r, as jealousy when it is f-r/r-f/sf/gf/f-sr, as frustration when it is sf/r-f, as worry when it is r-f/sf/gf and as grief when it is r-f/sf/gf (Manjula 1979).

Nataraja (1981) studied the intonation patterns in four Indian languages (Kannada, Hindi, Tamil and Gujrati) objective analysis of intonation countours for different emotions in Kannada was in agreement with the conclusions drawn by Manjula (1979). Intonation contours of sentences spoken in Gujrati with the five emotions under study (anger, jealousy, neutral, joy and mercy) showed a general lowering of fundamental frequency by the end of the sentences. In Tamil, same intonation contours were used to express anger and mercy whereas different contours were used for the other three emotions. However, there was a general lowering of fundamental frequency, towards the end of the sentences. In Hindi, to express anger, neutral and mercy, same intonation patterns were used but to express jealousy and neutral, different patterns were used. There was an increase in fundamental frequency towards the end of the sentences. Chandrashekhar Prasad (1985) carried out objective analysis of sentences spoken with different emotions in Hindi and concluded that Hindi speakers use different intonation patterns to express different emotions.

Weinberg (1980) rightly points out that there is an absence of information concerning the ability of laryngectomized speakers to realise, the lingustically important contrasts like intonation. Studies on these aspects are awaited to throw light on the acoustic and temporal parameters used in such intonation contours and their comparability to normal intonation produced by oesophageal speakers.

As total laryngectomy leads to considerable anatomical and physiological alteration, alteration in the realization of intonation is expected. Such information will help in the development of clinical procedures and materials to enhance prosody realisation in oesophageal speakers. Therefore, it is considered that it will be interesting and useful to study intonation in oesophageal speakers.

III TEMPORAL PARAMETERS:

a). VOWEL DURATION:

Vowels are considered as carriers of speech sounds and therefore the information about the vowel duration in oesophageal speakers can contribute to the understanding of articulatory behaviour and acceptability and intelligibility of speech in laryngectomees.

Conditioning of the vowel length by voicing of a following consonant has received a considerable amount of attention in recent research (Smith 1978). Studies by Belasco (1953) House and Fairbanks (1953), Peterson and Lehiste (1960). Monsen (1978) and Mitleb (1984) have shown that vowels preceding voiced consonants in English are of greater duration than those preceding voiceless consonants. Hence the duration of the preceding vowel is often cited as an important cue to the voicing feature of final stop consonants in English. Preceding vowel duration has been called under certain conditions a primary (Klatt 1976) and even necessary (Rophael 1972) cue to the voicing distinction. Nataraja and Jagadeesha (1984) have found a relationship between fundamental frequency and vowel duration.

Information about vowel duration in alaryngeal speech is scarce. Christensen and Weinberg (1976) measured vowel durations from symmetric CVC syllables produced by ten oesophageal speakers some results of this work revealed that the durations of vowels spoken by normal and oesophageal speakers in voiced consonant contexts were comparable but were longer in voiceless consonant contexts. In addition they reported longer vowel duration in voiced as against voiceless consonant contexts. In addition they reported longer vowel duration in voiced as against voiceless consonant contexts in oesophageal speakers. Based on the results of this investigation Weinberg (1982) commented that total laryngectomy also produced changes in articulatory behaviour as evidenced by altered durational characteristics of vowels. Moreover such changes are influenced by phonetic context, indicating that phonological rules governing the durational properties of English vowels are preserved following laryngeal amputation. Weinberg (1982) presumed that the oesophageal speakers make compensatory adjustments in the timing control system in order to realize these variations in vowel length before voiced and voiceless consonants. He, thus, emphasized that only the speech apparatus and not the linguistic code, is altered in laryngectomees.

Robbins, Christensen and Kempster (1986) compared the vowel duration of fifteen oesophageal and normal laryngeal speakers on the three vowels /i/, /a/ and /u/. Oesophageal speakers exhibited longer vowel durations than normal speakers. However the difference was significant only for the vowel /a/.

Rajashekar (1991) studied the vowel durations in twenty oesophageal and twenty normal laryngeal speakers for the vowels /a/, /u/, /o/, /i/, /e/. The oesophageal speakers demonstrated longer than normal vowel durations for the long vowels /a/ and /o/, but as a whole, there was no significant difference between the oesophageal and laryngeal speakers in vowel duration. Hariprasad (1992) from his findings concluded that the vowel duration in oesophageal speakers is not significantly different from normal values although they are higher than the normal values.

b) BURST DURATION

Stops are characterized by bursts which are nothing but transient explosions. A burst represents organization of acoustic energy in the time domain and no organisation in the frequency domain (Halle, Hughes, Radley 1956). Klatt (1975) observed the burst durations in voiced stops. The burst durations successively increased from bilabials to alveolars to velars. The same ordering of burst durations was seen by Halle et al (1957, cited in Klatt 1975). Burst durations are 5 to 10 msec longer for voiceless aspirated plosives than for voiced plosives. Klatt (1975) stated that the inherent differences in burst durations for labials, dentals and velars may be explained by observing the time course of the pressure developed across the oral closure following the release. A labial release is quite rapid and the generated burst spectrum is weak in intensity because there is no resonator in front of the lips (Fant 1960 cited by Klatt 1975). Both factors contribute to the a coustic appearance of a short burst. A velar release involves the entire tongue body. The constriction increases in area more slowly due, in part to the mass involved and in part to the fact that the release vector of the tongue motion is usually not perpendicular to the long dimension of the acoustic tube formed by the vocal tract (Houde, 1967 cited by Klatt 1975). The release vector of the tongue tip for /t,d/ is more nearly perpendicular and hence the burst duration is shorter than that for velars. Savithri (1989) defined burst duration as the duration of the vertical irregular striations depicting the articulatory release. She supported the findings that bursts of voiceless stops are stronger than that of voiced stops in Kannada. Often multiple bursts are noticed for velars and bilabials. This is attributed to multiple release of a hump of articulator.

No reports on the burst duration characteristics of oesophageal speakers are available to the investigator. Since the oesophageal speakers have to use insufflated air which is much less than the normal pulmonary supply and firm articulatory maneuvers for precise articulation an alteration in the burst duration for stops is expected.

c). VOICE ONSET TIME (VOT):

Voice onset time, after stops, has attracted much attention in the past. Lisker and Abramson (1967) defined voice onset time (VOT) as the difference between the release of a complete articulatory constriction and the onset of phonation. They stated that the VOT was an useful acoustic cue of the various phonemic categories such as "voiced stop", "voiceless stop" and "voiceless aspirated stop". Lisker and Abramson (1967) further stated that normal speakers of English systematically varied VOT to distinguish pre vocalic stops /p/, /t/, /k/ from /b/, /d/, /g/. Voiced plosives in English normally have a short VOT (less than 20-30 sec and voiceless plosives, relatively long VOT (greater than 50 msec). Languages which have a two way contrast involving aspiration achieve the dichotomy by short VOT lag for unaspirated stops and long lag for aspirated. (Fischer - Jorgensen, 1954 Lisker and Abramson, 1964, Keating et al 1983 - cited in Henton, Ladefoged and Maddieson 1992). Lisker and Abramson (1971) stated that VOT is the single most effective measure for classifying stops into different phonetic categories with respect to voicing".

Gilbert and Campbell (1978) attributed the increased VOT for voiceless stop consonants to greater intra oral air pressure resulting in the increase in the air flow rate and friction at glottis. This glottal frication inhibits the vocal folds from initiating periodic vibrations during the production of voiceless stop consonants, thereby delaying VOT. It has been reported (Borden and Harris 1980, Lisker and Abramson 1964, Basu 1979, Ravishankar 1981, Sridevi 1990, Savithri, 1989) that VOT increases as the place of articulation moves backwards in the oral cavity i.e., VOT is greater in velars than alveolars and in alveolars than labials.

According to Weinberg (1982), laryngectomized patients using oesophageal speech have difficulty achieving voicing contrast between homorganic stop consonants. Christensen, Weinberg and Alfonso (1978) studied the VOT associated with production of stops in oesophageal speakers. They reported that oesophageal speakers did effect systematic variation in VOT and that the VOT values associated with prevocalic voiceless stops exhibited lag intervals which were significantly shorter than in normal speakers. They further stated that the VOT characteristics of oesophageal speakers were differentially sensitive to place of articulation.

The observation that the oesophageal speakers effected systematic variation in VOT during the production of phonetically representative speech sounds was considered, by Weinberg (1982), as intriguing due to the differences in voice producing systems of normal and oesophageal speakers. Weinberg (1982) commented that with the absence of abductor - adductor properties of the pseudoglottis in oesophageal speakers as compared to the vocal cords in normals, the differences in VOT are expected. He considers that the earlier onset of voicing associated with voiceless stops in oesophageal speakers highlighted the contribution of articulatory aerodynamic factors. Weinberg (1982) cites the earlier VOT in prevocalic stops to account, in part, for the increased vowel duration observed in oesophageal speakers by Christensen and Weinberg (1976). Weinberg (1982) concludes that oesophageal speakers were far less consistent than normals in effecting appropriate variation in the timing of voicing onset.

Robbins, Christensen and Kempster (1986) measured the VOT in voiceless consonants in oesophageal and normal speakers from the broad band spectrograms. Oesophageal speakers had short VOT's than normal speakers. The laryngeal speakers systematically varied VOT with the change of stop loci from labial to velar positions. The oesophageal speakers performed only marginally in this aspect. Klor and Milanti (1980) reported reduced VOT for prevocalic stop productions for oesophageal speakers. Based on the above mentioned studies, Robbins et al (1986) suggested that the physical. characteristics of the neoglottis exert a major influence on VOT production in alaryngeal speakers.

Rajshekhar (1991) studied VOT for voiceless stops /p/ /t/ and /k/ in oesophageal and laryngeal speakers and found a significant difference among the groups in the VOT of /p/ in the initial position, the VOT for the oesophageal speakers (29.2 msec) being greater than that for normal laryngeal speakers. The VOT in the normal speakers varied sytematically with place of articulation but the same was not demonstrated in the oesophageal group.

Hariprasad (1992) found no difference in the VOT values for /p/, /t/, /k/, /b/, /d/, /g/ in oesophageal speakers and normals.

Thus the study of VOT may be useful in determining its effect on intelligibility of speech in alaryngeal speakers, especially intelligibility of the aspirated sounds used by Marathi oesophageal speakers.

d). MEAN PAUSE DURATION (MPD)

Robbins et al (1984) determined the total pause time, total number of pauses, mean pause time, percentage of total pause time in reading for normal and oesophageal groups. All the pause time measurements were larger in oesophageal speakers compared to normals. The greater total pause time and number of pauses shown by the oesophageal speakers may be attributed to their limited air reservoir (Diedrich 1968). The increased mean pause time in oesophageal speakers has been attributed to their limited ability to sustain voicing. The oesophageal speaker produces an average of five words per air charge compared to a mean of 12.5 words per breath group produced by normal speakers (Snidecor and Curry 1959). Hence the oesophageal speaker must pause more often for air intake. Snidecor and Curry (1960) observed differential length in pauses occurring in the oesophageal speech. For example, phrase - limiting pauses (i.e. junctural pauses) were approximately 1.41 times longer than air-intake pauses. The mean duration of pauses signaling juncture in oesophageal speech was also greater than the mean duration of junctural pauses measured for normal speaker. Also it is possible that articulatory rate itself may be altered following laryngectomy. Sedory et al (1989) in a comparative study of oesophageal and tracheoesophageal speakers reported percentage of pause time, total number of pauses and mean pause length to be 29.4%, 15.8 and 484 msec respectively.

According to Hammarberg and Nord (1989) the percentage of pause time ranged between 17-40% in oesophageal speakers and 14-21% in normal speakers.

e). RATE OF SPEECH (RT)

Rate of speaking is traditionally described as the number of words spoken per minute (WPM) during a complete speech performance (Kelly and Steev 1949). This would include all pauses, intentional and unintentional and the meaningful words spoken in unit elapsed time. Rathna and Bharadwaj (1977) reported a rate of speech of 130.66 words/ minute for normals during passage reading in Marathi language. The same rate when considered in reading syllables per minute was 355 syllables/minute.

Recent investigation has indicated a relationship between syllable duration and speaker intelligibility. Even laymen seem to link up unintelligibility with rate of speech though it is often mentioned in the converse relationship.

Snidecar and Curry (1959, 1960) have demonstrated that the rate of speech of oesophageal speakers is markedly reduced. The rate of speech of superior oesophageal speakers in their study ranged from 85 to 129 words per minute with a group average of 113 WPM. The assumption has always been that the decrement in the rate of oesophageal speech is due to the increase in the amount of time spent in silent pauses. This increase in silent pause results from the oesophageal speaker's limited ability to sustain voice. Hoops and Noll (1969) reported a mean rate of speech of 114.3 WPM in twenty two oesophageal speakers, whereas Filter & Hyman (1975) from a study of twenty oesophageal speakers reported a rate of only 100.1 WPM.

Robbins et al (1984) reported that rate of speech in normals and oesophageal speakers was 172.8 (SD = 23.3) and 99.1 (SD = 24.8) respectively. According to Robbins et al (1984) the significantly slower rate of oesophageal speech reflected the use of restricted amount of air trapped in the oesophagus for phonation compared to the use of large respiratory volumes in the laryngeal group.

Pindzola and Cain (1989) found a rate of speech of 93.8 WPM in oesophageal speakers, which was significantly different from normal speakers (WPM = 158.8). Rajashekhar (1991) reported that normal speakers (WPM = 99.1) averaged 39 WPM higher than the oesophageal speakers (WPM = 60.3).

In general, the review of literature shows that oesophageal speakers produced speech at a slower rate than the normal speakers.

Syllable/second

Syllable/second being an indirect measure of the rate of speech has been reported by some investigators. Filter and Hyman (1975) have reported a rate of speech of approximately

2.25 syllables/second for good oesophageal speakers. Sedory et al (1989) reported 2.86 syllables/sec (SD = 0.52).

Total duration

Total duration has been used as another measure of rate of speech. The total duration (time) required to read the second sentence of the Rainbow passage by oesophageal speakers ranged from 5.47 to 6.27 secs (Snidecor and Curry 1959, Shipp 1967, Weinberg and Bennett 1972, Torgerson and Martin 1980). Using fourteen model sentences as speech stimuli, Baggs and Pine (1983) found a greater mean duration (3.02 sec) in oesophageal speakers than in laryngeal speakers (1.95 sec). According to Robbins et al (1984) a total duration of 34 sec in case of normals, and 62.5 sec in oesophageal speakers were required to read the paragraph. They stated that the WPM and total duration for the paragraph reading were inversely related for both the groups. The normal speakers produced the greatest number of WPM in the shortest duration of total reading time whereas the oesophageal group produced the fewest number of WPM in the longest duration of total reading time.

III SPECTRAL MEASURES

FORMANT FREQUENCIES:

Fant (1957) defines a formant as a single energy maximum. Spectrally, vowels are characterized by well defined formants with high F_1 for /a/, high F_2 for /i/ and /e/ and closer F_1, F_2 for /u/ and /o/.

It is generally accepted that the frequencies of the first two formants are the most important features in the recognition of vowel sounds (Dellattre, Liberman and Cooper 1952; Peterson and Barney 1952, Pols, Van der Kamp and Plomp 1969). According to Angelocci, Kopp and Holbrook (1964), the formant frequency patterns of vowels, especially, the position of the second formant frequency is an important acoustic correlate of the vowel quality and its phonemic identity. The position of the third formant provides less information with respect to vowel differentiation than the first and second formants. Relative formant positions for a particular vowel are similar for men, women and children, but the natural resonant frequencies are higher for smaller vocal tracts. The differences in the frequencies of formants is not simply related to change in length, however, because the larger vocal tracts of men have a relatively larger ratio of pharyergeal area to oral cavity area compared to women and children. Levitte (1978) suggested that the vowels are differentiated by the ratio of the first and second formant frequencies i.e. the F_2/F_1 ratio.

The literature on oesophageal speech presents a contradictory picture in terms of the effects of laryngectomy on vocal tract transmission characteristics Damste (1958) suggested that "the rest of the vocal tract (the pharyngeal and oral cavities) behaves substantially the same in both normal and oesophageal speech and hence phonetic events in this region undergo no change". His conclusions were based on studies of German and Dutch speaking oesophageal speakers (Shilling and Binder 1926, Beck 1931, Luchsinger, 1952 as cited in Damste 1958) which demonstrated little difference between the vowel formant frequencies of normal and oesophageal speakers. In contrast the studies of Rollin (1962) on English speaking laryngectomees and Kytta (1964) on Finnish speaking laryngectomees showed that vowel formant frequencies for oesophageal speakers were generally higher than those for normal speakers.

Sisty and Weinberg (1972) have shown that removal of the larynx does alter vocal cavity transmission characteristics. They observed that the average vowel formant frequency values associated with oesophageal speech were elevated, and interpreted this to support the view that laryngectomees exhibited a reduced vocal tract length. Further, they observed that the changes in formant frequency from vowel to vowel were systematic and were essentially the same for normal and oesophageal speakers. Rajshekhar (1991) supported Sisty and Weinberg's findings by showing significant differences between normal laryngeal speech and oesophageal speech for F_1,F_2,F_3 (/a/ and /i/), F_1(/u/), F_1, F_3 (/o:/) and F_2, F_3 (/e/). Hariprasad (1992) found higher formant frequencies than in normals in the oesophageal speakers for the vowels /i/, /e/, /a/, /o/, /u/. However, significant difference among the groups was found only for vowel /o/.

The information about the formant frequencies for vowels in oesophageal speech is valuable in understanding the physiology of speech production and in documenting changes in the vocal tract function in oesophageal speakers. Hence these were included in the present study.

CHAPTER - III

METHODOLOGY

The present study was aimed at comparing oesophageal speech and normal speech on the following acoustic and temporal parameters.

Psychoacoustic measures

1) Acceptability of speech (ACPTL)
2) Intelligibility of speech (INTL)

Acoustic measures

3) Fundamental frequency in speech Fo(sp)
4) Frequency range in speech FR(sp)
5) Intonation contours for specific types of sentences i.e., declaratives and interogatives.

Temporal measures

6) Vowel duration for vowels following the initial stops (V.D.)
7) Burst duration (B.D)
8) Voice onset time for voiceless stops (VOT)
9) Mean pause duration (MPD)
10) Rate of speech (syllables/second) (RT)

Spectral Measures:

11) Formant frequencies (F1, F2, F3) for the vowels /e/, /ə/, /a/, /o/, /u/ following the initial plosives.

SUBJECTS:

Two groups of five male speakers participated in this investigation. The control group comprised of five male oesophageal speakers in the age range of 52 to 76 years (M = 64.6 years). All these subjects had undergone total laryngectomy. The mean time postlaryngectomy that the subjects as a group began to produce oesophageal was reported as 2.4 months and it ranged from one month to five months. All the subjects in the group had received speech therapy to produce oesophageal speech. (The exact duration of speech therapy could not be ascertained). Details of the cases are presented in Table 3. No attempts have been made to relate the number of years of experience of the subjects with any of the parameters studied. They reported to have normal hearing for speech, no neurological impairment and no history of any other speech problem.

SL. No.	Age (yrs)	Surgical procedure	Time since laryngectomy for oesophageal speech acquisition (mths)	experience in using oesophageal speech (yrs)
1.	76	T.L	2	19
2.	68	T.L	4-5	12
3.	61	T.L	1	4
4.	66	T.L	1½	25
5.	52	T.L	2½	2

Table 3: Details of oesophageal subjects.

T.L. Total laryngectomy.

The other group of speakers comprised of five normal laryngeal speakers, matched for age, sex and education with the oesophageal speakers. They reported to have normal hearing for speech, no neurological impairment and no history of any speech problem.

Another group of five listeners participated in this investigation. The group of listeners comprised of three females and two male adults unfamiliar with oesophageal speech. They were native speakers of Marathi. The age of the listener's ranged from 20 to 27 years (m = 24 yrs).

MATERIAL

1) Word list:

Twelve meaningful Marathi words (list presented in Appendix I) with twelve stops (/p/, /p^h/, /b/, /b^h/, /t/, /t^h/, /d/, /d^h/, /g/, /g^h) in initial positions were selected. These words as embedded in the sentence "mi mh nto...." formed the test material for spectral analysis of the words. These words were selected with due attention to their frequency of occurrence in Marathi i.e. the frequency of occurrence of these words were high in Marathi.

2) Passage:

A passage of 150 words was specially constructed using the most familiar words in Marathi. In the passage also embedded were specific declarative and interrogative sentences. (Passage presented in appendix 11).

DATA COLLECTION:

All the speakers were first familiarized with the material.

A) The words were visually presented (written on cards) one at a time and the subjects were instructed to utter them, embedding in, the carrier phrase in a natural manner into the microphone (cardioide-unidirectional) kept at a distance of 10 cms from the mouth. Three repetitions were recorded for each stimulus word. The best of the three recordings were used to obtain the following parameters:

a) Vowel duration for vowels following the initial stops.
b) Burst duration
c) Voice onset time for voiceless stops
d) Formant frequencies F_1, F_2 and F_3
e) Intelligibility of speech.

B) Recordings were obtained of each subject reading the passage at his comfortable loudness and rate. These recordings were used for the measurement of -

a) rate of speech
b) mean duration of pauses
c) fundamental frequency in speech

d) frequency range in speech

e) intonation contours for specific sentences

f) Acceptability of speech

ACOUSTIC ANALYSIS:

The analysis principally involved the following equipment.

1) Tape deck to play the recorded speech samples

2) Antialising filter (low pass filter having cut-off frequency at 7.5 KHz)

3) A-D/D-A converter (sampling frequency of 8/16 KHz - 12 bit)

4) Personal computer (AT intel 80386 microprocessor with 80837 numerical data processor).

5) Software (developed by voice speech systems, Bangalore) for spectrographic, intonation, frequency and duration analysis.

6) Amplifier and speaker.

PROCEDURE FOR ANALYSIS OF DIFFERENT PARAMETERS:

Part I Digitization

A) The key words containing stop consonants /p/ /p^h /, /b/, /b^h/ /t/, /t^h/, /d/, /d^h/,/k/, /k^h/, /g/, /g^h/ in initial

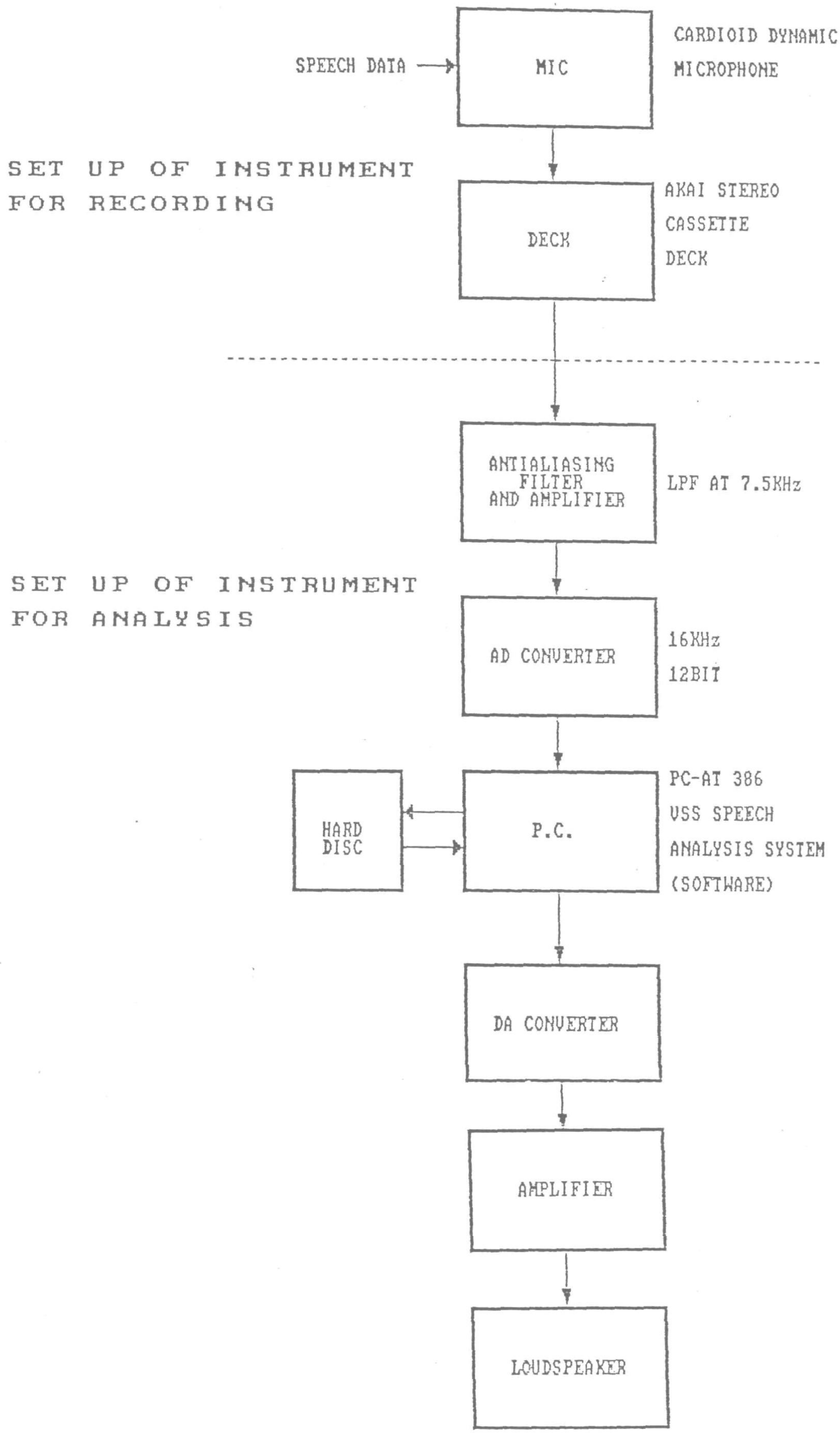


FIG-2: BLOCK DIAGRAM OF THE SYSTEM FOR RECORDING & ANALYSIS position for all the ten subjects were extracted from the sentences using editing programme. Block diagram of the equipment is shown in Fig 2.

Details of editing

1) Display was obtained on the screen

2) Boundaries were marked by listening and adjusting.

3) Each demarcated portion was saved as a separate file on magnetic floppies. Digitization was carried at a sampling rate of 16000 Hz. Thus a total of 360 tokens (12 x 3 x 10) were collected.

B) A representative speech sample of the passage with two interrogative and two declarative sentences embedded in it was selected and then digitized at the sampling rate of 4000 Hz using a PC/XT with a 12 bit A/D and D/A converter.

Equipment: same as in part 1-A

Procedure: same as in part 1-A

The programme SPECTROGRAM was used to obtain a wide band spectrogram (300 Hz filter) display. The following parameters were measured from the spectrographic analysis of digitized samples of the key words.

a) Vowel duration for vowels /e/, /ə/, /a/, /o/, /u/ following the initial stops.

b) Burst duration for the stops.

c) Voice onset time for voiceless stops /p/, /pʰ/, /t/, /tʰ/, /k/ and /kʰ/

d) Formant frequencies F_1,, F_2 and F_3 for the vowels /e/, /ə/, /a/, /o/, /u/

a) **VOWEL DURATION (V.D)**

The vowel duration (msec) for each vowel following the initial stop in all the 12 words spoken by each subject was measured from the spectrogram display. The measurement criteria for vowel duration were based on suggestions by Peterson and Lehiste (1960) i.e. the vowels were identified on the spectrogram and the duration from the onset of phonation indicated by the initial periodic striations of the first formant to the last vertical striations associated with the second formant were considered as duration for each vowel.

b) BURST DURATION (B.D)

Burst duration in msec for each word initial stop was measured from the wide band spectrogram display by moving the time cursor from the onset of the burst to its offset.

c) VOICE ONSET TIME (VOT)

Voice onset time (VOT) in msec for words beginning with voiceless stops /p/, /p^h /, /t/, /t^h /, /k/, /k^h/ were measured using the definition given by Lisker and Abramson (1967) i.e. the time interval between the burst (or brief interval of high intensity noise) that marks release of the stop closure and the onset of quasiperiodic pulsing that reflected laryngeal vibration was the VOT.

d) FORMANT FREQUENCIES (F_1, F_2, F_3)

The first three formants for each vowel following the initial stop were measured (in Hz) directly from the spectrogram display with sectioning on the screen of the computer. Formant frequency estimates were made by measuring the midpoint of the visible dark bands of energy appropriate to the first three vowel resonances (also the peak on the sectioning spectrogram). The measurements were made at a comparatively steady state portion of the vowel.

From the digitized representative speech sample of the passage, the two interrogative and two declarative sentences were sliced and later analysed using the programme 'INTON'. From the representative paragraph as a whole and from the sliced sentences, the following parameters were measured.

a) Fundamental frequency in speech [Fo(sp)]

b) Frequency range in speech [FR(sp)]

c) Intonation contours

d) Mean pause duration

a) FUNDAMENTAL FREQUENCY IN SPEECH [Fo(sp)]

Programme 'INTON' based on the LPC autocorrelation method to obtain the fundamental frequency was used. Readings of mean fundamental frequency of speech for the four digitized sentences were averaged for each subject. Thus the mean fundamental frequency of speech was obtained for all the subjects of the two groups.

b) FREQUENCY RANGE IN SPEECH [FR(sp)]

The difference between the maximum and minimum fundamental frequency in the utterance of the test sentence, provided the frequency range in speech for that sentence. The frequency ranges for all the four sentences were obtained. The maximum and the minimum among the four values provided the frequency range in speech for that subject. Thus the frequency range in speech for all the subjects of the two groups were obtained.

c) Intonation contours:

Using the programme INTON, the display for each of the two interrogative and two declarative sentences was obtained on the screen. See Figs. 3, 4 & 5. The overall intonation

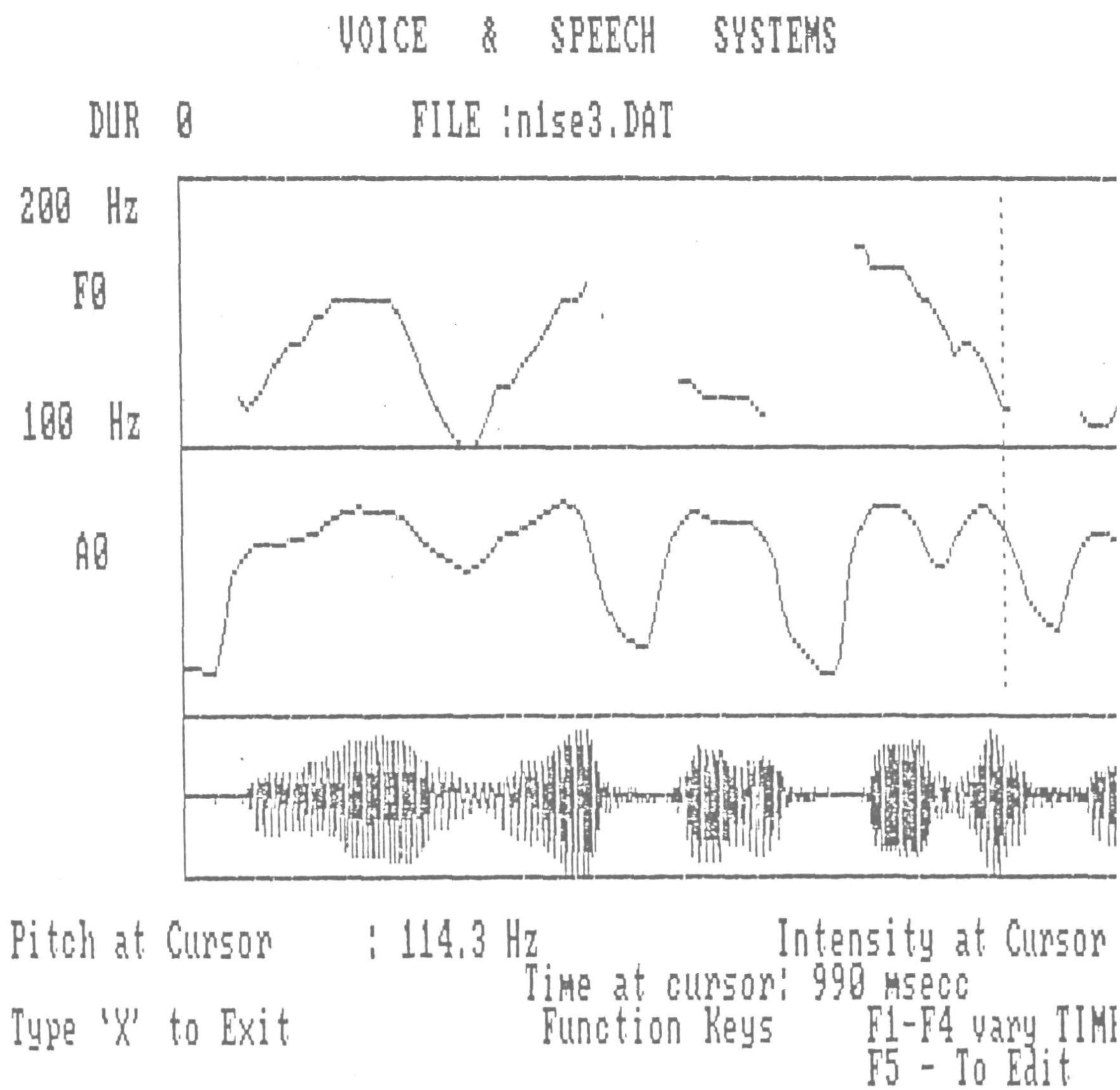


Fig - 3 : Display of intonation countours used by a normal subject for sentence - 3.

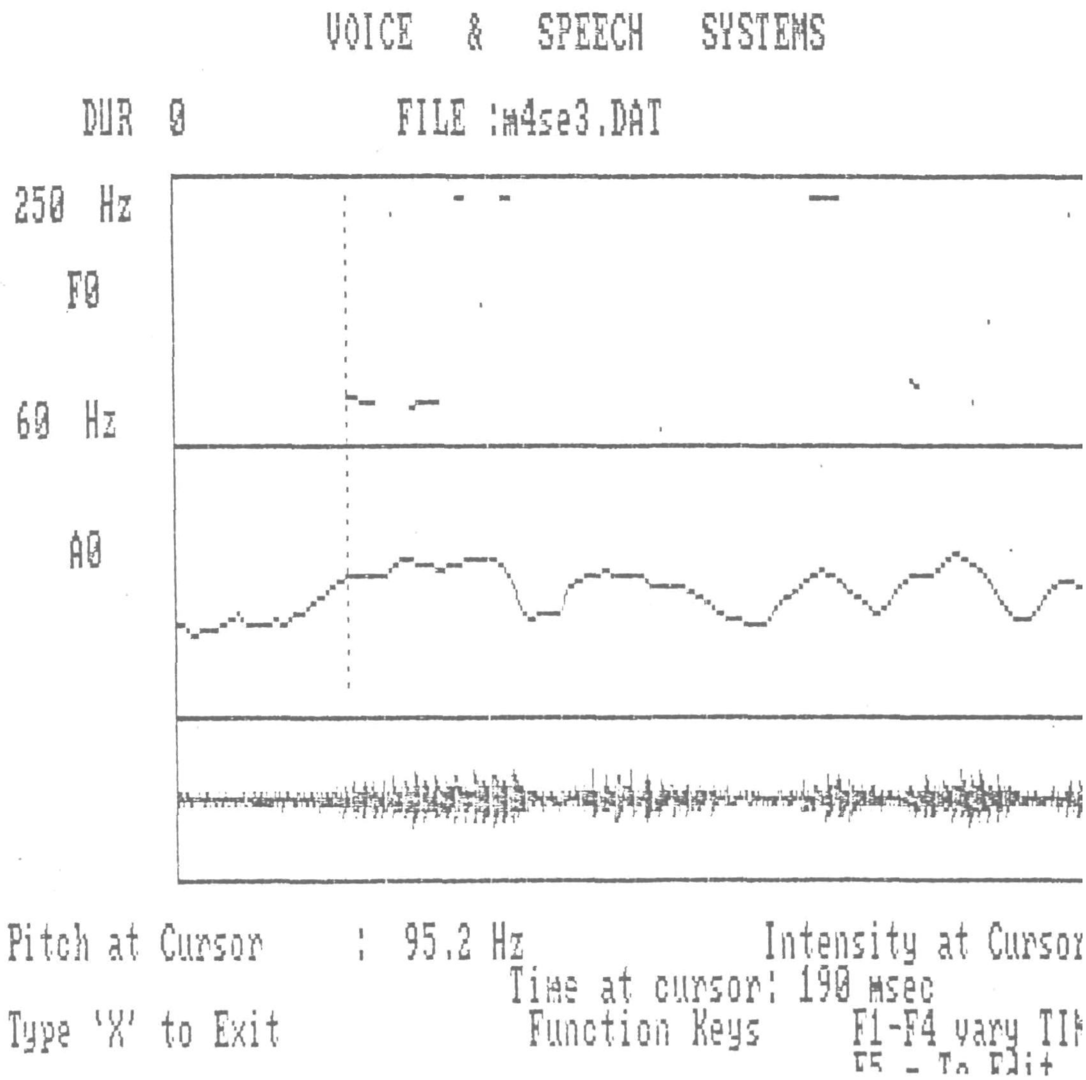


Fig - 4 : Display of intonation contours used by a poor oesophageal speaker for sentence - 3.

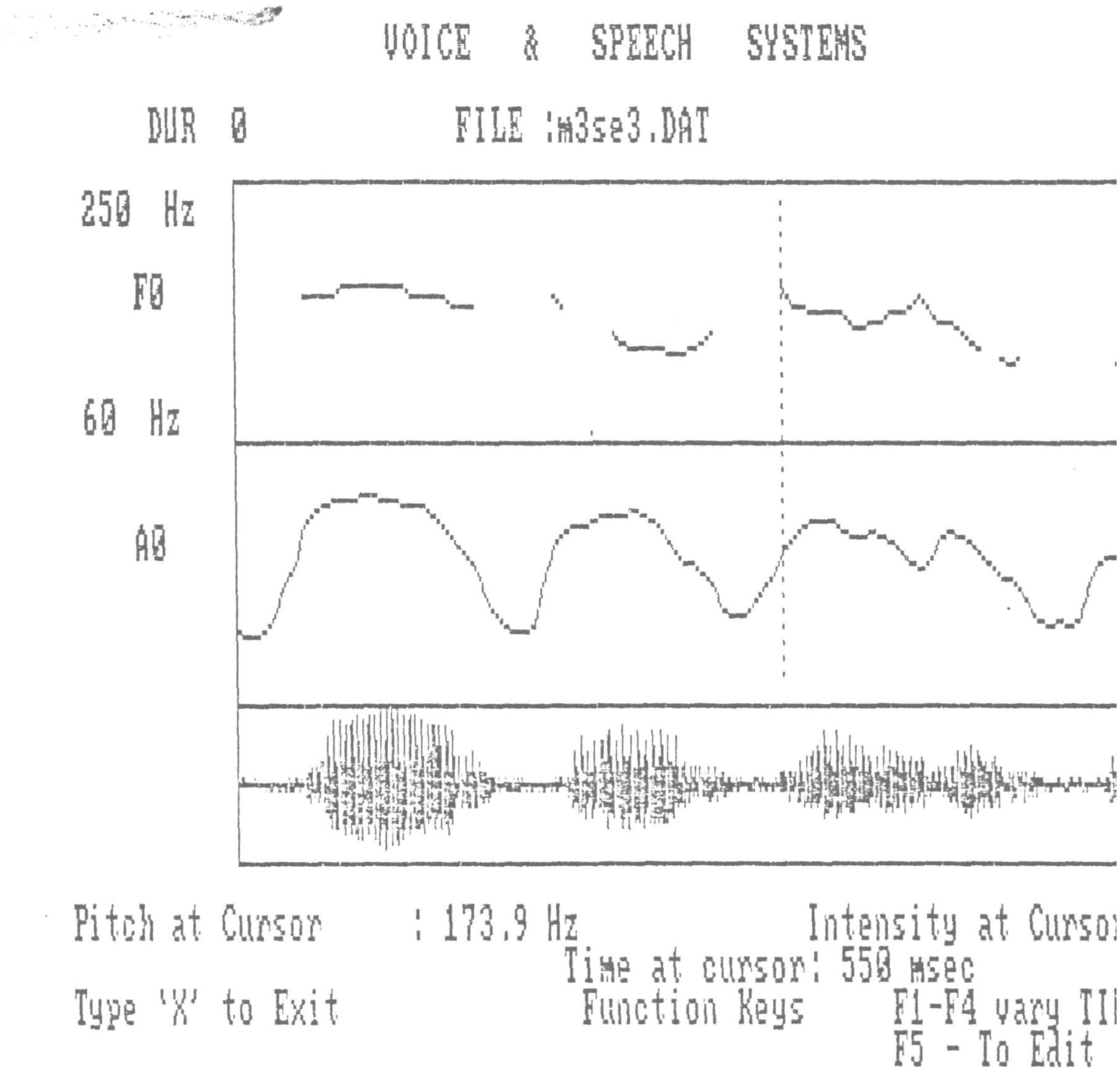


Fig - 5 : Display of intonation contours used by a good oesophageal speaker for sentence - 3.

pattern was noted as the curve depicting changes in the fundamental frequency of speech. The rises and falls were noted in terms of fundamental frequency for the highest and lowest points in the contour. Thus readings of changes in fundamental frequency in speech were obtained, along with the printouts of intonation contours for the speech samples of all the subjects.

d) MEAN PAUSE DURATION (MPD)

The number of pauses and the total duration of pauses for the entire representative sample were measured by moving the cursor on the speech waveform displayed on the monitor. The periods of silence were visually determined by the experimenter. A pause was marked when there was more than 200 msec of continuous silence. The criterion for determining a pause was similar to that used in other studies to exclude stop-closure durations from being interpreted as pauses (Lisker 1957, Robbins, et al, 1984).

The mean pause duration (msec) was computed by dividing the total pause time by the total number of pauses for each of the speech sample.

Other parameters studied in the present study were -

a) Rate of speech (RT)

b) Intelligibility of speech (INTL)

c) Acceptability of speech (ACPTL)

a) RATE OF SPEECH

The time needed to read the entire passage of 150 words (282 syllables) was measured using a digital stop watch and the speech rate was extrapolated as syllables per minute for each of the subjects.

b) INTELLIGIBILITY OF SPEECH (INTL)

Five native speakers of Marathi served as the judges. The 12 key words beginning with the plosives /p/, /p^h /, /b/, /b^h, /t/, /t^h/, /d/, /d^h/, /k/, /k^h/, /g/ and /g^h/ were selected as the material for intelligibility testing. These word lists were played at comfortable loudness levels to the listeners from a tape recorder in noise free environments. The judges were requested to write down the words as they heard them and not as what they thought the word could be. For totally unintelligible words, they were asked to draw blanks. As the order effect could not be controlled while preparing the material, listener's bias was guarded against by not allowing them to look at their previous responses i.e., each sample was heard separately. The inter judge reliability for all the five judges for the two groups was determined by correlation. The intelligibility score was computed as percentage [(number of words correctly identified - 12) x 100] intelligibility scores provided by all the five judges were averaged and that was considered as the intelligibility score for each subject.

c) ACCEPTABILITY OF SPEECH (ACPTL)

Judges used for intelligibility also served as judges for acceptability. A paragraph from the recorded speech material of each subject was played using a tape recorder in noise free conditions and the acceptability was rated on a five point scale (one being the least acceptable and five the most). The judges were requested to rate the speech of the samples they heard on a five point scale as follows:

5 = Normal (totally acceptable)

4 = Acceptable (quality sounding different but yet perfectly understandable)

3 = Slightly unacceptable (along with different quality, some other problem which makes the speech unclear but yet understandable)

2 = Unacceptable (Too much difficulty in understanding but can still follow a little).

1 = Totally unacceptable (can not understand anything at all)

The interjudge reliability for all the five judges for the two groups was determined by correlation. The mode (most frequently occurring) of the ratings made by all the five judges was taken as the acceptability score for that subject. Thus the acceptability for the subjects of both the groups was determined.

Thus all the twelve parameters were measured. This is the first study using Marathi speaking laryngectomees.

CHAPTER IV

RESULTS AND DISCUSSION

The present study was undertaken to compare the speech produced by laryngectomees with oesophagus as a source of sound production and normal speakers with larynx as the source of sound production in terms of the following acoustic and temporal parameters.

Psychoacoustic measures

1) Acceptability of speech (ACPTL)
2) Intelligibility of speech (INTL)

Acoustic measures

3) Fundamental frequency in speech Fo(sp)
4) Frequency range in speech FR(sp)
5) Intonation contours for specific types of sentences i.e., declaratives and interogatives.

Temporal measures

6) Vowel duration for vowels following the initial stops (V.D.)
7) Burst duration for stops (B.D)
8) Voice onset time for voiceless plosives (VOT)
9) Mean pause duration (MPD)
10) Rate of speech (syllables/second) (RT)

Spectral Measures:

11) Formant frequencies: first three formant frequencies (F_1, F_2, F_3) for the vowels /e/, /ə/, /a/, /o/, /u/ following the initial stops.

PSYCHOACOUSTIC MEASURES:

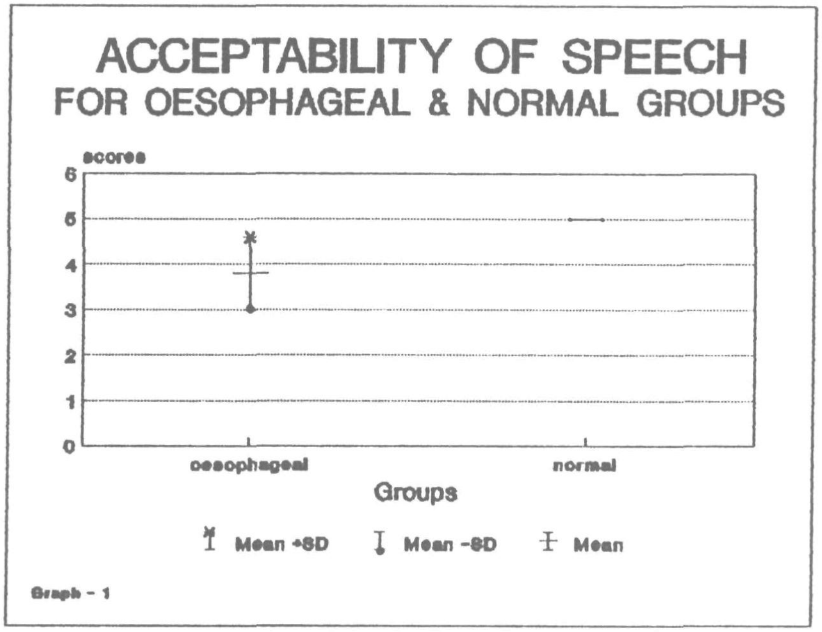
1) Acceptability of speech (ACPTL)

A five point scale with one being the 'least acceptable' and five being the 'most acceptable' was used to rate the acceptability of speech of subjects of both the groups. Five judges rated the acceptability of the speakers individually. Table 4a and graph - 1 depict the judgements on the acceptability ratings of the two groups. The oesophageal speakers had a mean rating of 3.8, which was lower than the average of the normal group (mean of 5). However, the range of acceptability rating for the oesophageal group revealed that few oesophageal subjects, were rated as good as normal laryngeal subjects.

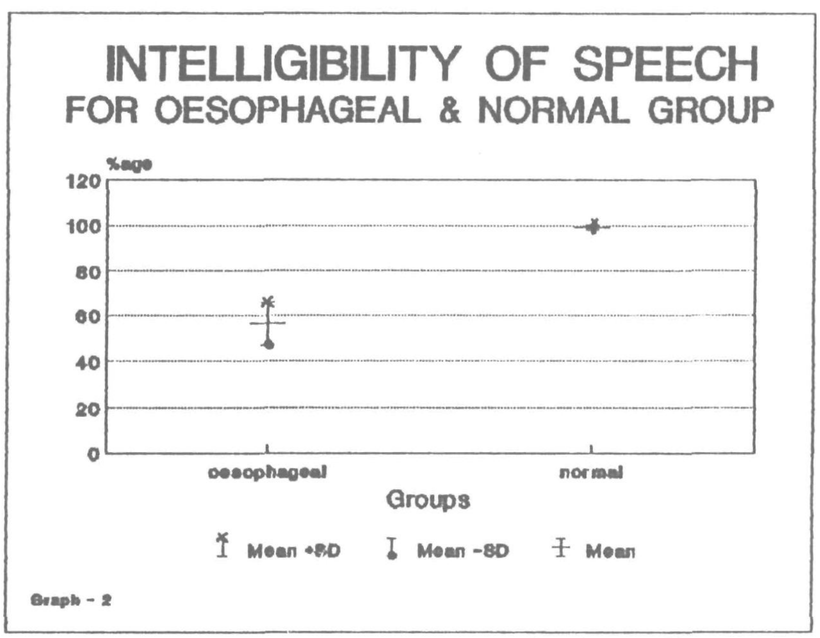
Group	Mean	S.D	Range
Oesophageal	3.8	0.836	3-5
Normal	5	0	0

Table 4a - The mean, S.D. and range of acceptability rating for oesophageal and normal groups.

Graph - 1. Showing mean and range of acceptability of speech for oesophageal and normal groups.



Group - 2. Showing mean and range of intelligibility of speech for oesophageal and normal groups.



The mean acceptability rating of oesophageal speakers in this study was higher than Gates et al (1982), Blom et al (1986) and Rajshekhar (1991), who used a five point scale similar to the one used in the present study.

The acceptability rating for oesophageal speakers ranged from 3 to 5 with a mean of 3.8. Normals obtained a mean acceptability rating of 5. It can be observed that the mean values are different for each group.

Investigator	ACPTL (OESO)
1. Bennett and Weinberg (1972)	2.54 (1-7 scale)
2. Gates et al (1985)	2.49 (1-5 scale)
3. Blom et al (1986)	2.49 (1-5 scale)
4. Rajashekar (1991)	1.6 (1-5 scale)
5. Present study (1993)	3.8 (1-5 scale)

Table 4b: The acceptability ratings of oesophageal speakers by various investigators.

Further, the Wilcoxon matched pairs test depicted significant differences between the oesophageal and normal groups on a one-tail test (Table 4c) in terms of acceptability of speech.

	Z score	Probability	Significance
ACPT L	- 1.826	0.0344*	S

Table 4c. Results of the Wilcoxon matched pairs test.

Thus the oesophageal group showed lower acceptability rating than the normal group various studies as shown in Table 4b, show the acceptability as varying from 2.54 to 1.6, whereas the result of the present study has shown a rating of 3.8 which is much higher than the previous studies. This indicates that either the subjects were more proficient or the judges were not strict.

Shipp (1967) and Hoops and Noll (1969) have indicated that the rate of speech, phonation time, high mean fundamental frequency and stomal noise were related to the judgements of speech acceptability in alaryngeal speakers. Trudeau (1987) commented that speaker proficiency had a significant effect on judgements of acceptability. The judges who rated the acceptability of the three groups in the present study attributed the rate of speech, pause duration, pitch fundamental frequency, clarity of words, extraneous noise and voice quality as factors influencing their judgement of acceptability. They found high correlation between acceptability and Fo in phonation (0.98) 2) MPD in phonation (0.99) 3) Alpha ratio (0.95) 4) Beta ratio (0.95) 5) Gamma ratio (0.98) 6) Rate of speech (0.92) and 7) intelligibility (1.00).

The hypothesis stating that there is no significant difference in terms of acceptability between oesophageal and normal larynggeal speech is rejected. The alternate hypothesis stating that the rating for oesophageal speech is lower than that for normal laryngeal speech is accepted.

2) Intelligibility of speech (INTL)

Group	Mean	S.D	Range
Oeophageal	56.4%	9.32%	45% - 67%
Normal	99.2%	1.09%	98% - 100%

Table 5a - The mean, S.D. and range of intelligibility of speech for oesophageal and normal groups.

Table 5a and graph - 2 present the mean intelligibility scores in percentage computed from the scores of five judges, for oesophageal and normal groups. The oesophageal speakers received lower intelligibility scores than the normal laryngeal speakers.

The Wilcoxon matched pairs test revealed significant difference between the oesophageal and normal groups at 5% level of significance on a two tailed test (Table 5b).

	Z score	Probability	Significance
ACPTL	- 2.0226	0.043	S

Table 5b. Results of Wilcoxon matched pairs test ($p < 0.05$).

Studies have found mean word intelligibility scores to range from 43.4% to 79.6% (Shames et al 1963, Kalb and Carpenter 1981, Mitzell et al 1985, Gates et al 1982, Blom et al 1986, Rajashekhar et al 1990, Rajashekhar 1991, Hariprasad 1992) although varying in their methodologies. In the present study the mean intelligibility score of oesophageal group was higher than that reported by shames et al (1963) and Hariprasad (1992) but was lower than that reported by other investigators (Table - 5c).

Investigator	Oesophageal group
1. Shames et al (1963)	54.9%
2. Kalb and Carpenter (1981)	78.5%
3. Gates et al (1982)	61.4%
4. Blom et al (1986)	78.2%
5. Rajashekhar et al (1990)"	70.0%
6. Rajashekhar (1991)	79.6%
7. Hariprasad (1992)	43.4%
8. Present study (1993)	56.4%

Table 5c- The intelligibility ratings of oesophageal speakers by various investigators.

* - One dual mode speaker.

Weinberg (1986) opined that total laryngectomy results in major changes in articulatory aerodyanmics and produced alteration in vocal tract morphology. Further, he considered the intrusion of gestures essential to oesophageal air filling to exert disruptions in dynamic articulatory behaviours in oesophageal speakers. Though various studies have reported a reduction in speech intelligibility in oesophageal speakers (shames et al 1963, Gates et al 1982, Blom et al 1986, Rajashekhar et al 1990, Rajashekhar 1991, Hariprasad 1992) the nature of articulatory performances in them is not well understood.

Rajashekhar (1991) using canonical discriminant analysis found that thirteen parameters contributed significantly to the differences in oesophageal and normal speakers in terms of acceptability and intelligibility. These were.

1. Fundamental frequency
2. Frequency range in speech,
3. Extent of fluctuation of fundamental frequency.
4. Speed of fluctuation of fundamental frequency,
5. Extent of fluctuation in intensity
6. Maximum phonation duration.
7. Rate of speech,
8. Spectral parameters,
9. Formant frequencies.

In the present study, the hypothesis stating that there is no difference between the oesophageal and normal speakers in terms of intelligibility is rejected.

Thus the results of the present study clearly indicated that the oesophageal group is less intelligible than the normal group.

ACOUSTIC MEASURES:

3) Fundamental frequency in speech [Fo(sp)]

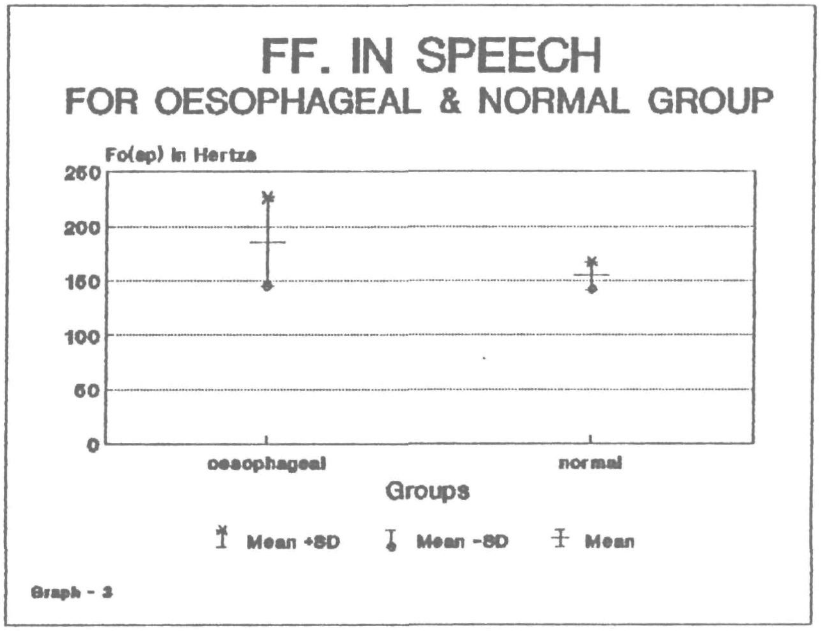
The findings of fundamental frequency in speech for the oesophageal and normal groups of the present study are given in Table 6a and graph - 3.

Group	Mean (Hz)	S.D. (Hz)	Range (Hz)
Oesophageal	185.94	41.55	135-239
Normal	154.4	12.7	138-167

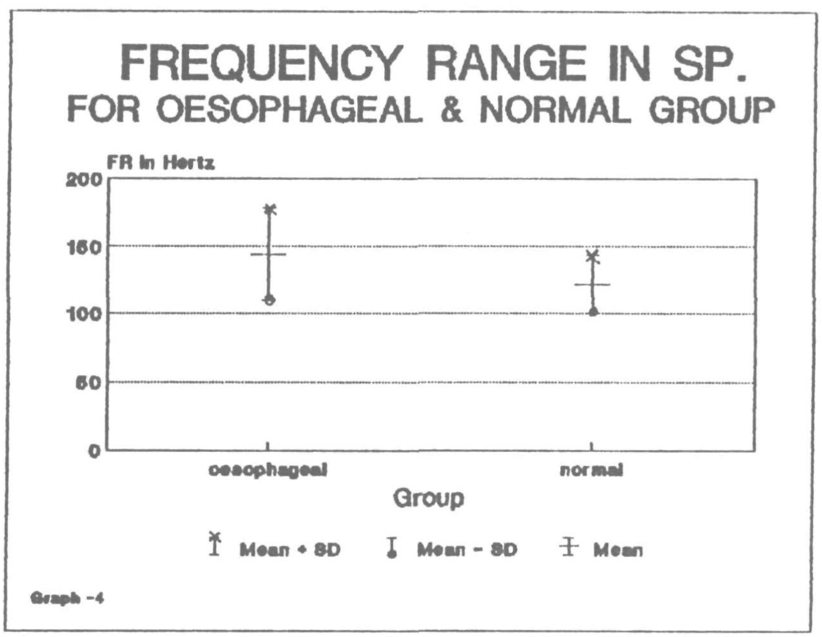
Table - 6a The mean, S.D and range of fundamental frequency in speech (Hz) for oesophageal and normal groups.

The mean fundamental frequency in speech of the oesophageal group (185:9 Hz) was greater than that of the normal group (154.4) which is surprising. However the oesophageal group showed a greater variability (S.D. 41.55 Hz) as compared to the normal laryngeal group (S.D. 12.7 Hz). The lower limit of the range of fundamental frequency in speech for oesophageal group approximated the value shown by normal laryngeal speakers. The findings of this study however did not correspond with the reports of other investigators (Table 6b).

Group - 3. Showing mean and S.D. of fundamental frequency in speech for oesophageal and normal groups.



Group - 4. Showing mean and S.D of frequency range in speech for oesophageal and normal groups.



From Table - 1 it is clear that the oesophageal speakers of the present study have had longer periods of practice in oesophageal speech ranging from 2 years till 25 years. The acceptability rating for these speakers has also been high compared to the other investigators. Hence the findings of this exceptionally high Fo in speech can be attributed to the proficiency of speakers of the present study. Cases with newly acquired oesophageal speech may not reveal the same.

Investigator	Mean [Fo) sp)] (Hz) in oesophageal group
1. Damste (1958)	67.5
2. Curry and Snidecor (1961)	63.0
3. Shipp (1967)	94.38
4. Hoops and Noll (1969)	65.59
5. Weinbert and Bennet (1971,1974)	57.40
6. Torgerson and Martin (1980)	65.70
7. Blood (1984)	64.60
8. Robbins et al (1984)	77.10
9. Pindzola and Cain (1989)	84.10
10. Rajashekhar et al (1990)	68.00
11. Rajashekhar (1991)	91.80
12. Present study (1993)	185.90

Table - 6b. The mean [Fo(sp)] (Hz) in oesophageal speakers by various investigators.

Wilcoxon matched pairs test indicated no significant difference between the oesophageal and normal groups (Table 6c).

Parameter	Z value	Probability	significance
Fo (sp)	1.483	0.138	NS

Table 6c: Results of Wilcoxon test for Fo(sp).

The hypothesis stating that there is no significant difference in terms of fundamental frequency in speech between oesophageal and normal laryngeal speech is accepted.

4. Frequency range in speech [FR(sp)]

The mean and S.D. along with range of frequency range in speech, measured from the analysis of four sentences spoken by the oesophageal and normal speakers are presented in Table 7a and Graph - 4.

Group	Mean (Hz)	S.D. (Hz)	Range (Hz)
Oesophageal	144.2	34.5	93 - 179
Normal	122.0	21.7	100 - 150

Table - 7a: The mean, S.D and range of frequency range (Hz) in speech for oesophageal and normal groups.

The study of Table 7a and Graph - 4 indicates that the frequency range in speech was slightly higher in the oesophageal group than the normals.

Studies have found the mean frequency range values to range from 59 Hz to 177 Hz in oesophageal speakers (Table 7b).

Investigator	Mean [(Fo)sp] (Hz) in oesophageal speakers
1. Filter and Hyman (1975)	80.0 Hz
2. Robbins et al (1984)	118.0 Hz
3. Pindzola and Cain (1989)	177.1 Hz
4. Rajashekhar (1991)	59.6 Hz
5. Present study (1993)	144.2 Hz

Table 7b - The mean frequency range in speech for oesophageal speakers as reported by various investigators.

The Wilcoxon matched pairs test showed no significant difference between the oesophageal and normal groups frequency range in speech.

Parameter	Z value	Prob	Significance
FR (sp)	.9438	0.345	NS

Table 7c - results of Wilcoxon test for FR (sp).

Hence the hypothesis stating that there is no difference in terms of frequency range in speech between oesophageal and normal laryngeal speech is accepted.

These results are in agreement with Pindzola and Cains's (1989) study stating that the frequency variability was produced equally well by normal and alaryngeal speakers. Since listeners perceived intonational contrasts effectively in both the groups.

5) Intonation contours:

As stated in methodology only 4 sentences representative of two types of expressions have been selected. The objective analysis of intonation for each of the two interrogative and two declarative sentences was carried out using the programme INTON. A difference of 20 Hz or more between two levels was considered adequate for the production of 'rise' or 'fall'. Any change of less than 20 Hz was considered as 'flat'.

Sentence 1: 'baba, tumhi, tipuce pʰʊkət̥ goḍwe gata aṇi
madzʰ jawar ṭika kərṭa əSə ka?

One of the two interrogative sentences with an interrogative word "ka' (why) in its terminal part was analysed. Table 8A-1 shows the frequency variations (in Hz) in the sentence 1 by normal laryngeal speakers. Table 8B-1 shows the same by oesophageal speakers.

	baba	tumhi	tipuce pʰʊkəṭ	goḍwe gata	aṇi	madzʰ -jawər	tika-kərta	ə
1.	116-160 (44) R	135-200 (65) R	200-115 (85) F	151-114 (37) F	119.4-148 (29) R	118-160 (42) R	- F	1
2.	118-160 (42) R	138-200 (62) R	190-133 (57) R	154-118 (36) F	118.0-168 (14) Fl	118-160 (42) R	- F	1
3.	125-200 (75) R	160-191 (31) R	235-182 (53) F	153-114 (39) F	143.0-160 (17) Fl	125-200 (75) R	160-121 (39) F	2
4.	111-174 (63) R	133-210 (72) R	129-190-117 (59-73) R	190-129 182-121 FRF	121.0-174 (53) R	121-182 (61) R	174-108 (66) F	2
5.	105-174 (69) R	133-210 (77) R	148-121-190-167 (27-69-23) FRF	182-121 (61) F	121.0-174 (53) R	125-182 (57) R	182-117 (65) F	2

Table 8A-1 Frequency variation in uttering sentence 1 by normal speakers.

R - Rise; R - Fall; Fl - Flat; ( ) - amount of change in frequency in Hz.

	baba	tumhi	tipuce pʰʉkəṭ	goḍwe gata	aṇi	madzʰ jawər	ṭika -kərta
1.	125 Fl	117.6-143 (25) R	180-105 (75) F	153-100 (53) F	105.0-129 (24) R	133-181 (48) R	166-125 (41) F*
2.	190-167 (23) F	210-173-200 (37-27) F-R	200-190-222 (20-32) R-F	190-235-190 (45-45) R-F	190.0-210 (20) R	181-235 (54) R	222-160 (62) F
3.	125-154 (29) R	129-160 (31) R	154-89 (65) F	93-160-83 (67-77) R-F	154.0-121 (33) F	121-133 (12) Fl	160-78 (82) F*
4.	200-210 (10) Fl	133-160 (27) R	200-235 (35) R	137-235-210 (98-25) R-F	190.0-222 (32) R	154-235 (81) R	210-143-190 (67-47) F-R
5.	190 Fl	181-8-143 (39) F	143-160 (17) Fl	168 Fl	114-250 (136) R*	167 Fl	No tracing obtd

Table 8B-1 Frequency variation in uttering sentence 1 by oesophageal speakers.

* - Intermittent change in frequency.
R - Rise; R - Fall; Fl - Flat; ( ) - amount of change in frequency in Hz.

Thus the most common pattern of frequency variation seen in normal speakers for the interrogative sentence - 1. (with an interrogative word embedded in it) was

R - R - F - F - R - R - F - F

(59Hz) (62) (67) (43) (44) (55) (57) (71)

and the one obtained from oesophageal speakers was

Fl - R - F - R F - R - R - F - F

(28) (70) (70-49) (28) (61) (62) (57)

The comparison of the above two patterns revealed that oesophageal speakers use almost the same intonation patterns as normal laryngeal speakers, if not identical. Identifying the intonation contours in sentences spoken by oesophageal speakers was difficult because of the highly discontinuous and intermittent frequency tracings. It was evident that the continuous change in frequency was greater in normal speakers than oesophageal speakers. However with intermittent phonation they could achieve a comparable amount of change in frequency as normals. A great amount of variability was seen among the oesophageal speakers with some showing very well formed patterns where as others showing very diffused patterns.

Sentence 2: beṭa, ṭIpu kuṭ^{h}e ahe? was the second

interrogative sentence with an interrogative word embedded in it. Table 8A-2 and 8B--2 show the frequency variation (in Hz) in uttering the sentence 2 by normal and oesophageal speakers respectively.

Sub. No.	beṭa	ṭIpu	kuṭ^{h}e	ahe?
1	108-147-100 (39-47) R-F	125-100 100-125 (25) (25) F - R	170-125 (45) F .	154-125 (29) F
2	112-148-117 (36-31) R-F	167-121 170-148 (46) (22) F - F	154-125-200 (29) (76) F - R	154-121-148 (33 - 27) F - R
3	148-125 (23) F	182-154-235 (28) (81) F - R	154-235-190 (81) (45) R - F	222-154 (68) F
4	129-174 (45)	160-138-222 (22) (84) F - R	235-160 210-235 (75) (25) F - R	235-143 (93) F
5	129-182 (53) R	160-138-222 (22 - 84) F - R	222-148 210-235 (74 - 25) F - R	235-143 (93) F

Table 8A-2: Frequency variation in uttering sentence 2 by normal laryngal speakers.

R - Rise; R - Fall; Fl - Flat; ( ) - amount of change in frequency in Hz.

Sub. No.	beṭa	ṭIpu	kuṭʰe	ahe ?
1	148.1 114-160 (46) Fl - R	200-182 108-200 (18) (92) Fl - R	121-190-125 (69) (65) R - F	148-190-160 (42-30) R-F
2	222 167-222 (55) Fl - R	174 210-182 (28) R - F	167-200 (33) R	222-210 (12) Fl
3	154-167 143-160 (13) (17) Fl Fl	100-118-95 (18) (23) Fl - R	167-138 (29) F	153-111 (42) F
4	222-235 210-95 (115) R F	210-143 210-200 (67) (10) F - Fl	108-200-111 (92-89) R- F	210-83 (127) F*
5	160-235 181-267 (75) (86) R R*	200-181 (19) Fl	No tracing obtained	250-167* (83) 250-160-235 (90-75) F* F - R

Table 8B-2: Frequency variation in uttering sentence 2 by oesophageal speakers.

R - Rise; R - Fall; Fl - Flat; ( ) - amount of change in frequency in Hz.
* - Intermittent change.

The most common form of frequency variation seen in normal speakers while uttering sentence 2 was

R - F-R - F-R - F
(43) (24-68) (59-42) (71)

The patterns found in the utterances of the oesophageal speakers were highly variable. With some approximation, the most common pattern for oesophageal speakers can be traced as

Fl-R - Fl-F/Fl-R - R-F - F*
(50) (23)/(92) (80-77)
* - intermittent change.

Comparison with the normal pattern revealed that the oesophageal speakers used variable patterns like Fl-R/R-F/Fl-F/F-Fl/Fl. (See Table 8B-2) instead of the pattern F-R used by majority of normal laryngeal speakers. Similarly instead of F-R as seen in normals on the 3rd word -kut e, the oesophageal speakers used patterns like R-F/R/F. However the termination of the sentence was marked by a distinct fall in both the groups, the change being continuous in normals and intermittent in oesophageal speakers.

Sentence 3 : **"mi he paise deto".**

was one of the two declarative sentence. Table 8A-3 shows the frequency variation (in Hz) in uttering the sentence 3 by

Sub. No.	mi	he	paise	deto
1	114-154-100-154 (40-54-54) R-F-R	124-112 (12) Fl	174-114 (60) F	108-182 (74) R
2	148-167-133-160 (19) (39) (27) R-F-R	148-125 (23) F	200-114 (86) F	122-100 (22) F
3	167-210 (43) R	178-143 (35) F	168-182-129 (14-53) Fl-F	114-103 (11) Fl
4	133-200 (67) R	138-129 (9) Fl	182-200-160 (18 - 40) Fl-F	138-133 (5) Fl
5	133-190 (57) R	138-125 (13) Fl	182-200-160 (18-40) Fl-F	135-133.3 (2) FL

Table 8A-3: Frequency variation in uttering sentence 3 by normal laryngeal speakers.

R - Rise; R - Fall; Fl - Flat; ( ) - amount of change in frequency in Hz.

Sub. No.'	mi	he	paise	deto
1	111-220-105-174 (109-115-69) R-F-R	121-220 R	154-103-148-11 (51-45-37) F-R-F*	210.5
2	182-222-210 (40 - 12) R-Fl	-	210-190-210-5 (20 - 20) F - R	210-235 (25) R
3	167-160 (7) Fl	167-125 (4.2) F*	167-143-167-118 (24-24-49) F-R-F	118-103 (15) Fl
4	89-222-87-235 (133-135-148) R-F-R	235-160 (75) F	235-105-91 (130-145-159) F R-F	222-250 (28) R*
5	-	286-267(19) F*	235.3 -	266-235 (31) F

Table 8B-3: Frequency variation in uttering sentence 3 by oesophageal speakers.

R - Rise; R - Fall; Fl - Flat; ( ) - amount of change in frequency in Hz.

normal laryngeal speakers. Table 8B-3 shows the frequency variation for the oesophageal speakers.

From tables 8A-3 and 8B-3 it is evident that the commonest pattern used by normal speakers for sentence 3 was

R / RFR - Fl/F - Fl-F/F - Fl.
(56)(29-44-40) (29) (44)/(73)

and that used by oesophageal speakers was

RFR - F - F-R-F - R
(121-125-108) (45) (37-34-43) (26)

A greater variability was seen in the oesophageal group. The scatter made the identification of patterns difficult. The rise and falls were intermittent.

Comparison of the common patterns revealed that both the groups began with a rising intonation on the word /mi/ and ended with a fall on the word /paise/. The terminal part showed flat intonation in majority of normal speakers whereas majority of the oesophageal speakers used rising intonation. However some of the normal subjects also used rising or falling intonation and few of the oesophageal subjects used flat and falling intonation (see table 8A-3 and 8D-3) was the

Sentence 4: **"tjace don sark^{h}e b^{h}ag kər"**

other declarative sentence used in the present study. Tables 8A-4 and 8B-4 show the frequency variations (in Hz) in uttering the sentence 4 by the normal speakers and the oesophageal speakers respectively.

Sub. No.	tjace	don	sarkʰe	bʱag	kər
1	124-114 154-114 (10) (40) Fl - F	114-154 (40) R - Fl	154-111 154-114 (43 - 40) F - F	103-160 (57) R	142-106 (36) F
2	166-133 154-167 (33-13) F-Fl	200-129 190-148 (71-61-42) F - R - F	154-129 (25) F	200-111 (89) F	118-129 (11) Fl
3	160-143 200-143 (17 - 57) F - F	174-210-190 (36-20) R - F	143-138 190-143 (5) (47) Fl - F	143-143 Fl	143-133 (10) Fl
4	129-138 167-138 (29) Fl - F	138-200-174 (62 - 26) R - F	121-190 210-125 (69 - 85) R - F	148-138-148 Fl	148-105-1 (43) F - Fl
5	129-138 174-143 (31) Fl - F	125-200-154 (75-46) R - F	121-190 210-121 (69 - 89) R - F	138-148 Fl	148-114 (34) F

Table 8A-4: Frequency variation in uttering sentence 4 by normal laryngeal speakers

R - Rise; R - Fall; Fl - Flat; ( ) - amount of change in frequency in Hz.

Sub. No.	tjace	don	saṛkʰe	ɓʰag	kər
1	133-154 133-174 (21-21-41) R-F-R *	133-154 (21) R	182-154 (28) F	154-125 (29) F	111-1 Fl
2	182-222-108 (40-144) R-F*	182-235-222 (53-13) R - Fl	210-148-222 (62-74) F-R	182-190-100 (8-90) Fl-F	200 -
3	148-166-148 (18-18) Fl	167-89-143 (78-54) F - R	160-148 (12) Fl	87-167-129 (80-38) R-F	133-100 (33) F
4	235-267-222 (32-45) R - F *	235-250-105 (15 - 45) Fl *	154-235-210 (81-25) R - F *	267-308-286 (41-22) R-F*	267-286-1 (19-138) Fl-F
5	-	222.2	-	-	286-267 (19) Fl

Table 8B-4: Frequency variation in uttering sentence 4 by oesophageal speakers.

R - Rise; R - Fall; Fl - Flat; ( ) - amount of change in frequency in Hz.
* - Intermittent change. Scatter seen in utterances by oesophageal speakers.

Two of the oesophageal speakers showed complete scatter of frequency making it extremely difficult to identify the intonation patterns . For the sentence 4 normal speakers too showed, good amount of variability in the patterns with the common most pattern being

Fl-F - R-F - R.F/F - Fl - F/Fl.

Inspite of the scatter, the most common pattern seen in the oesophageal speakers was -

RF - inconsistent - F — RF - Fl.

Thus the oesophageal speakers used rising intonation at the beginning of the utterance where as normal laryngeal speakers used either flat or falling intonation (see table 8A-4 and 8B-4). On the second word rise-fall pattern was used by majority of normal speakers but by none of the oesophageal speakers. They showed great variability by using either R/R-Fl/F-R/Fl patterns. For the third word of the utterance -sark e' the normal speakers as well as oesophageal speakers showed great variability. The fourth word of the sentence was produced with a flat intonation by majority of normal speakers where as the oesophageal speakers used intonations of the pattern F/Fl-F/R-F.

[3]The intonation patterns used by normals and oesophageal speakers however were in agreement on the final word of the sentence. Both the groups used either flat or falling intonation on this terminal part.

Thus comparison of intonation contours for specific sentences uttered by oesophageal and normal laryngeal speakers showed that although oesophageal speakers can produce the intonation patterns like normals, they showed great amount of variability in the use of intonation patterns for the sentences under study. The change in frequency was intermittent (or discontinuous) for most of the oesophageal speakers identify the intonation patterns. Thus oesophageal speakers too try to achieve intonation contrasts as normal speakers but they fall short in terms of controlling the change of frequency adequately.

Thus these results point out the trend of intonation in oesophageal speakers. A detailed study is essential to draw conclusions with greater confidence.

TEMPORAL MEASURES:

6) Vowel duration:

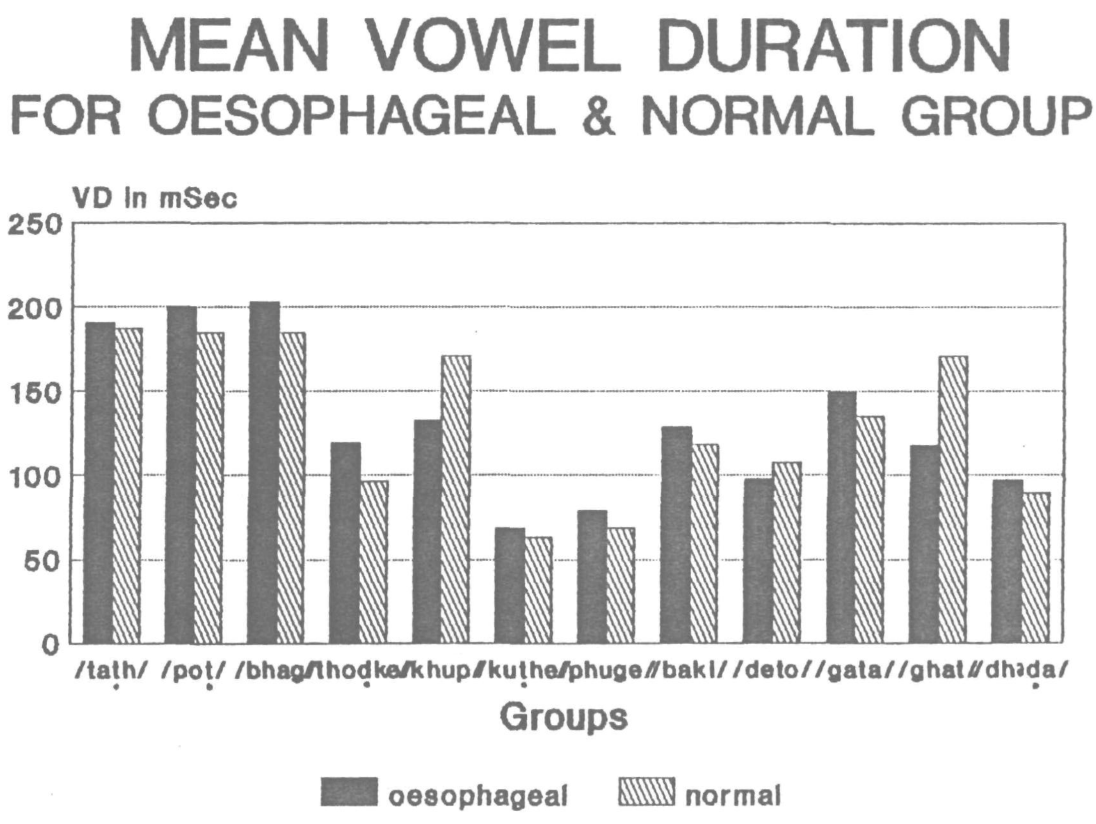
Vowel durations were measured far the vowels following the initial plosives for all the twelve words from the spectrographic displays. The mean S.D.. and range for vowel durations for oesophageal and normal groups are given in Table 9a and Graph - 5.

Scrutiny of the Table - 19 indicate slightly higher mean vowel duration in oesophageal speakers when compared to normal laryngeal speakers. This supports the findings of

Parameter duration	Oesophageal group			Normal group		
	Mean	S.D.	Range	Mean	S.D.	Range
tat^h	190.65	84.50	103.32-317.68	187.60	50.09	123.6 -240
poṭ	200.38	87.72	111.88-335.92	184.89	39.08	136.8 -241
b^{h}ag	202.77	67.77	137.34-315.04	184.64	39.08	115.2 -208
t^{h}oḍke	119.05	33.51	84.48-168.60	96.18	17.517	69.54-111.8
k^{h}up	132.21	28-56	92.23-162.00	170.80	44.44	111.75-236
kuṭ^{h}e	68.16	12.24	54.28- 84.64	63.23	21.42	46.92-100.4
p^{h}uge	79.06	18.17	59.40-100.80	68.94	33.69	23.69-117.0
baki	128.74	43.06	87.36-179.00	118.61	15.65	101.25-141.78
deto	97.49	30.78	64.35-136.40	107.06	23.85	84.59-146.50
gata	149.34	43.90	103.49-203.40	135.30	18.10	113.85-162.75
g^{h}at	117.62	62.90	102.96-260.82	170.42	55.21	110.90-231.20
d^{h}oḍa	96.73	10.69	86.35-112.66	89.18	46.14	47.04-151.20

Table 9a: The mean, SD and range of vowel duration for oesophageal and normal groups.

Group - 5 Showing mean, vowel duration for vowels following the initial stops for oesophageal and normal groups



Graph - 5

	Volume duration for	Z value	Probability	Significance
1.	/tat^{h}/	- 0.674	0.5002	NS
2.	/pot/	0.134	0.8927	NS
3.	/b^{h}ag/	0.135	0.8930	NS
4.	/t^{h}odke/	1.213	0.2250	NS
5.	/k^{h}up/	- 2.022	0.0430	S
6.	/kut^{h}e/	0.6742	0.5002	NS
7.	/p^{h}uge/	0.135	0.893	NS
8.	/baki/	0.404	0.686	NS
9.	/deto/	- 0.944	0.345	NS
10.	/gata/	- 0.404	0.686	NS
11.	/g^{h}at/	0.404	0.686	NS
12.	/d^{h}ada/	0.135	0.893	NS

Table 9b: Results of Wilcoxan test for vowel duration.

Christensen and Weinberg (1976). However statistical analysis using the Wilcoxon test revealed no significant difference between the two groups in terms of vowel duration. Statistically significant difference was observed only for the vowel /u/ preceded and followed by the consonants (k^h /and/p/ respectively. The oesophageal speakers showed smaller mean vowel duration than the normals. This discrepancy can be attributed to an extreme value of 236 msec in the normal laryngeal group. Table -9b depicts the results of the Wilcoxon test for vowel duration.

Thus the hypothesis that there is no significant difference in terms of vowel duration between oesophageal and normal laryngeal speech is accepted.

The results of the present study therefore. support the findings of Robbins et al (1986) Rajashekhar (1991) and Hariprasad (1992) that the normal speakers did not differ significantly from oesophageal speakers in terms of vowel duration.

Weinberg (1982) has commented that total laryngectomy produced changes in articulatory behaviour as evidenced by altered durational characteristics of vowels.

Vowel duration is also considered to be contributing to the intelligibility of speech. To improve the intelligibility of speech, it is often suggested clinically, to prolong the vowels. Such a compensation may be taking place in oesophageal speakers.

From the above findings, it can be concluded that the vowel duration in oesophageal speakers is not significantly different from normal values although higher than normal values.

7) Burst Duration:

Table 10a and Graph - 6 depict the mean, S.D. and range of burst durations for the twelve word initial stops (/p/, /p^h/, /b/, /b^h/, /t/, /t^h, /d/, /d^h/, /k/, /kh/, /g/, /gh/) for oesophageal and normal groups. As shown by the review of literature, burst durations for bilabials were seen to be the shortest and for velars, the longest in normals. The oesophageal speakers also followed the some trend, but all the burst durations values were greater than in normals.

Table 10b gives the results of Wilcoxon matched pairs test for significance of burst duration values of oesopheageal speakers as compared to normal speakers.

Significant differences between the normal and oesophageal group for burst duration were found for the stops /p/, /t^h / and /g^h / using two tail distribution. Using a one tail distribution significant differences were noted for the burst durations of /p/, /b/, /b^h/, /t^h/, /k^h/, /g/ and /g^h/. Thus seven out of twelve burst durations for oesophageal speakers were significantly greater than for normal speakers.

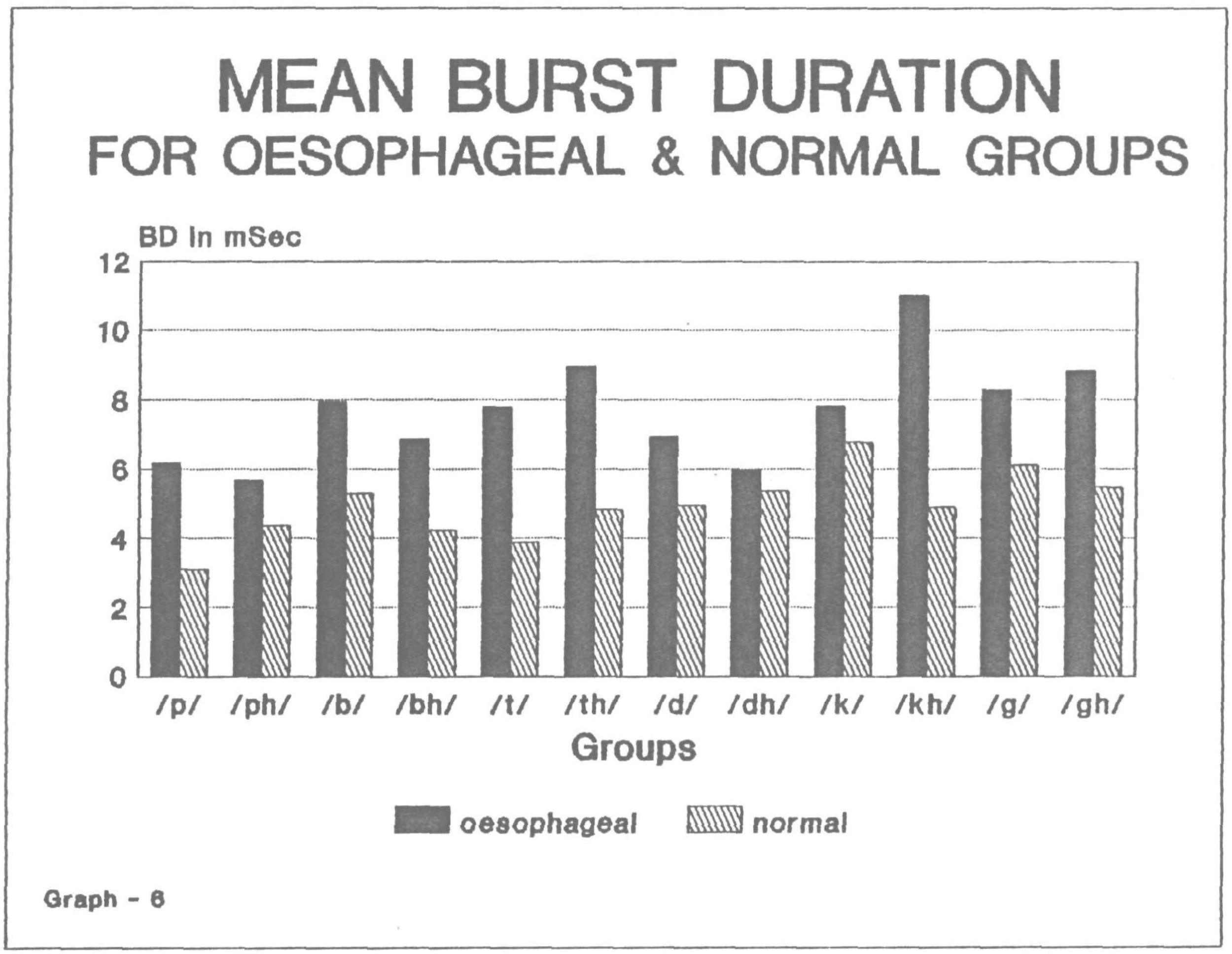
Parameter burst duration	Oesophageal group			Normal group		
	Mean	S.D.	Range	Mean	S.D.	Range
/P/	6.1782	4.909	2.187-14.4	3.094	0.7868	1.90-4.00
/pʰ/	5.6876	1.974	3.99 - 8.928	4.351	1.1995	2.52-5.76
/b/	7.929	5.343	4.32 -17.19	5.285	2.046	3.2 -8.46
/bʰ/	6.8494	3.046	3.78 -10.71	4.232	0.6472	3.5 -5.00
/t/	7.803	4.959	4.455-16.2	3.87	0.906	3.24-5.4
/tʰ/	8.9662	3.584	5.67 -14.985	4.83	1.317	3.15-6.3
/d/	6.916	2.209	4.2 - 8.96	4.966	1.114	3.79-6.57
/dʰ/	5.953	1.964	3.696- 8.50	5.372	1.153	4.2 -7.08
/k/	7.828	2.270	5.1 -11.115	6.768	1.951	4.8 -9.45
/kʰ/	11.018	3.626	5.589-15.12	4.9	0.5338	4.2 -5.5
/g/	8.299	1.585	6.468- 9.792	6.12	1.557	4.32-8.5
/gʰ/	8.847	3.54	5.175-13.86	5.478	0.785	4.92-6.72

Table 10a: The mean, SD and range of burst duration for oesophageal and normal speakers.

Burst duration for	Z value	Probability	Significance
1. /p/	2.022	0.043	S
2. /pʰ/	1.213	0.225	NS
3. /b/	1.753	0.401	S
4. /bʰ/	1.753	0.401	S
5. /t/	1.483	0.138	NS
6. /tʰ/	2.022	0.0431	S
7. /d/	1.483	0.138	NS
8. /dʰ/	0.135	0.893	NS
9. /k/	0.6742	0.5002	NS
10. /kʰ/	2.023	0.043	S
11. /g/	1.753	0.401	S
12. /gʰ/	2.0227	0.043	S

Table 10b: Results of Wilcoxon test for burst duration.

Graph - 6 Showing mean burst durations for stops for oesophageal and normal groups.



This for the present study, the hypothesis that there is no difference in burst durations for oesophageal speakers and for normal laryngeal speakers is rejected for the stops in general.

Lack of sufficient intra oral breath pressure may be compensated by increased duration of the burst.

8. Voice onset time (VOT)

The mean, S.D. and range of VOT values for /p/, /p /, /t/, /t^h/, /k/ and /k+/ measured from spectrographic display of the test words in oesophageal and normal groups are presented in Table 11a and Graph - 7 mean voice onset times for the aspirated voiceless plosives were greater than their unaspirated counterparts for both normals as well as oesophageal speakers, however the difference in VOT values of the aspirated and unaspirated voiceless stops was much less in the oesophageal speakers, compared to the normal laryngeal speakers. The VOT values for aspirated voiceless stops (/p^h/, /t^h/ and /k^h/) in the oesophageal groups were much less compared to the VOT values for aspirated voiceless stops (/p^h/, /t^h/ and /k^h/) of the normal speakers.

The results of the Wilcoxon test of significance for VOT values are shown in Table 11b. The test showed significant difference between the oesophageal and normal laryngeal speakers for VOT values of the aspirated voiceless stops /p^h/ and /k^h/ and did not reveal any significant difference in VOT values for /t^h/, /p/, /t/ and /k/.

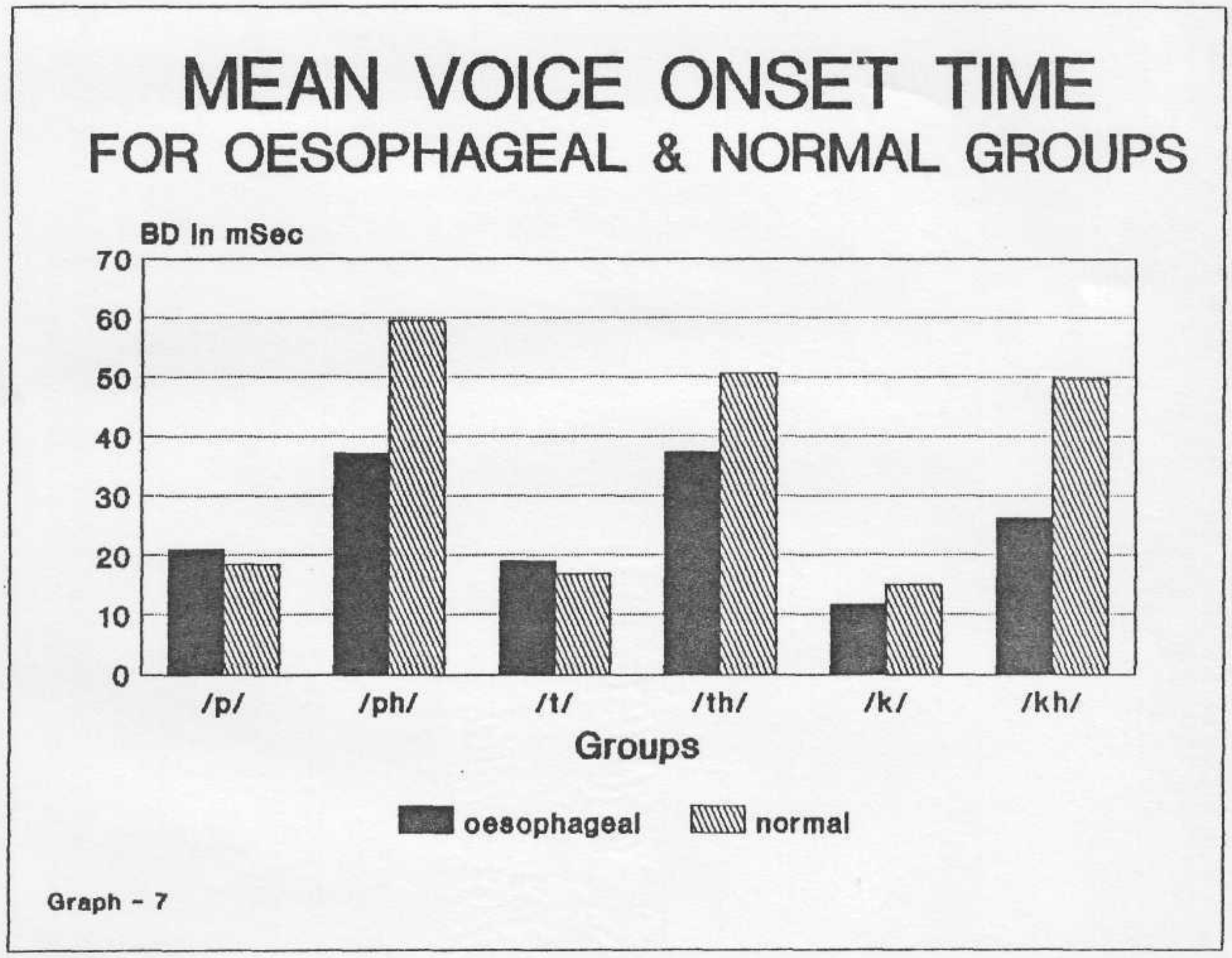
Parameter VOT	Oesophageal group			Normal group		
	Mean	S.D.	Range	Mean	S.D.	Range
/p/	20.8	5.983	13.85-28.80	18.48	11.53	8.1 -37.40
/Pʰ /	37.02	16.61	20.75-56.74	59.37	10.44	47.33-74.30
/t/	18.939	12.44	6.237-39.52	16.856	6.717	9.18-25.20
/tʰ/	37.153	18.406	12.94-56.30	50.574	9.364	40.3 -60.42
/k/	11.77	6.310	5.1 -20.2	15.072	5.88	11.34-25.50
/kʰ/	26.196	11.722	13.1 -44.28	49.65	14.28	34.96-69.36

Table lla: The mean, SD & range of VOT for voiceless plosives for oesophageal and normal group.

VOT	Z-value	Probability	Signature
/p/	0.674	0.5002	NS
/pʰ/	-2.023	0.043	S
/t/	674	0.5002	NS
/tʰ/	-1.213	0.225	NS
/k/	0.6742	0.5002	NS
/kʰ/	-2.0226	0.0431	S

Table l1b: Result of Wilcoxon test for VOT of voiceless plosives.

Graph - 7 Showing mean voice onset time values for voiceless stops for oesophageal and normal groups.



Hence the hypothesis that there is no significant difference in the VOT values for voiceless stops in oesophageal and normal speakers is rejected for the voiceless aspirated stops /p^h/ and /k^h/ and accepted for /t^h/, /p/, /t/ and /k/. The oesophageal speakers thus showed reduced VOT values for /p^h/ and /k^h/ compared to normal laryngeal speakers.

Weinberg (1982) considered the earlier onset of voicing in voiceless stops in oesophageal speakers to highlight the contribution of articulatory aerodynamic factors. He further attributed the shorter VOT in prevocalic stops in the oesophageal speakers to account in part for the increased vowel duration in oesophageal speakers. Reduced VOT values for oesophageal speakers have also been reported by other investigators (Christensen et al 1978, Robbins et al 1986, Klor and Milanti, 1980). The present study partly supports these findings and partly supported the findings of no significant difference between the oesophageal and normal groups by Hariprasad (1992). It however contradicts the findings of greater mean VOT values in oesophageal group than normals (Rajashekhar 1991).

Variation in the values of VOT may be because of factors such as age of the speakers and consonant environment of the material in a given language. It is reported that in a (longer) sentence context, beyond one or two syllables directly associated with the stop, also influence the VOT in stop sounds. There is a demonstrable sensitivity to such suprasegmental semantic importance and utterance length (Umeda 1977, Wisker and Abramson 1967).

Robbins et al (1986) attributed the short VOT values in oesophageal speakers to the influence of the physical characteristics of the neoglottis in oesophageal speakers.

The reduced VOT values for aspirated stops in oesophageal speakers may contribute to the unintelligibility of words starting with or embedding aspirated stops and thus result in poor intelligibility scores compared to normals.

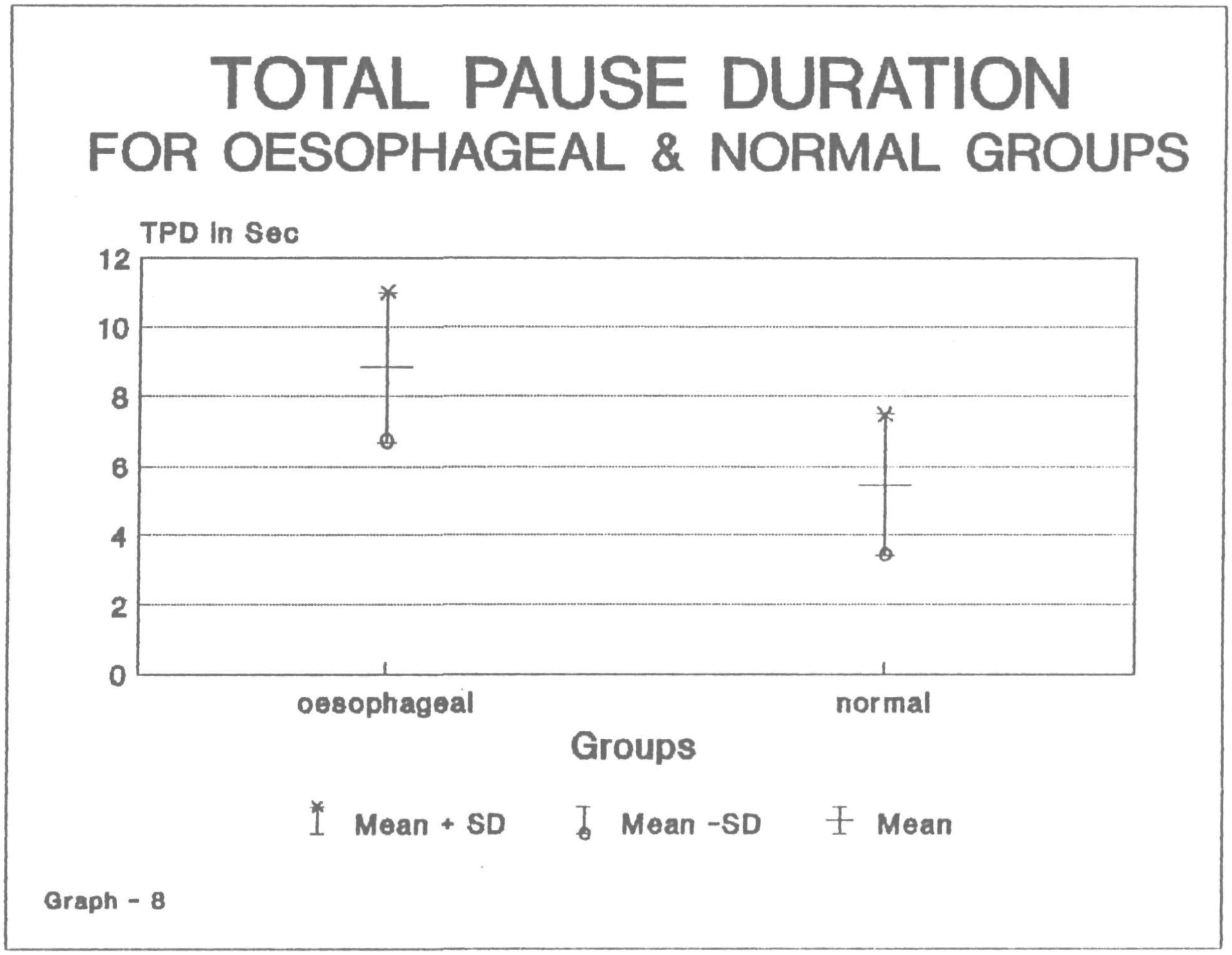
9) Mean Pause Duration: (MPD)

The number of pauses and the total duration of pauses for a representative speech sample of the passage were measured by moving the cursor on the speech waveform displayed on the monitor. The mean pause duration (msec) was computed by dividing the total pause duration by the total number of pauses for each of the speech sample.

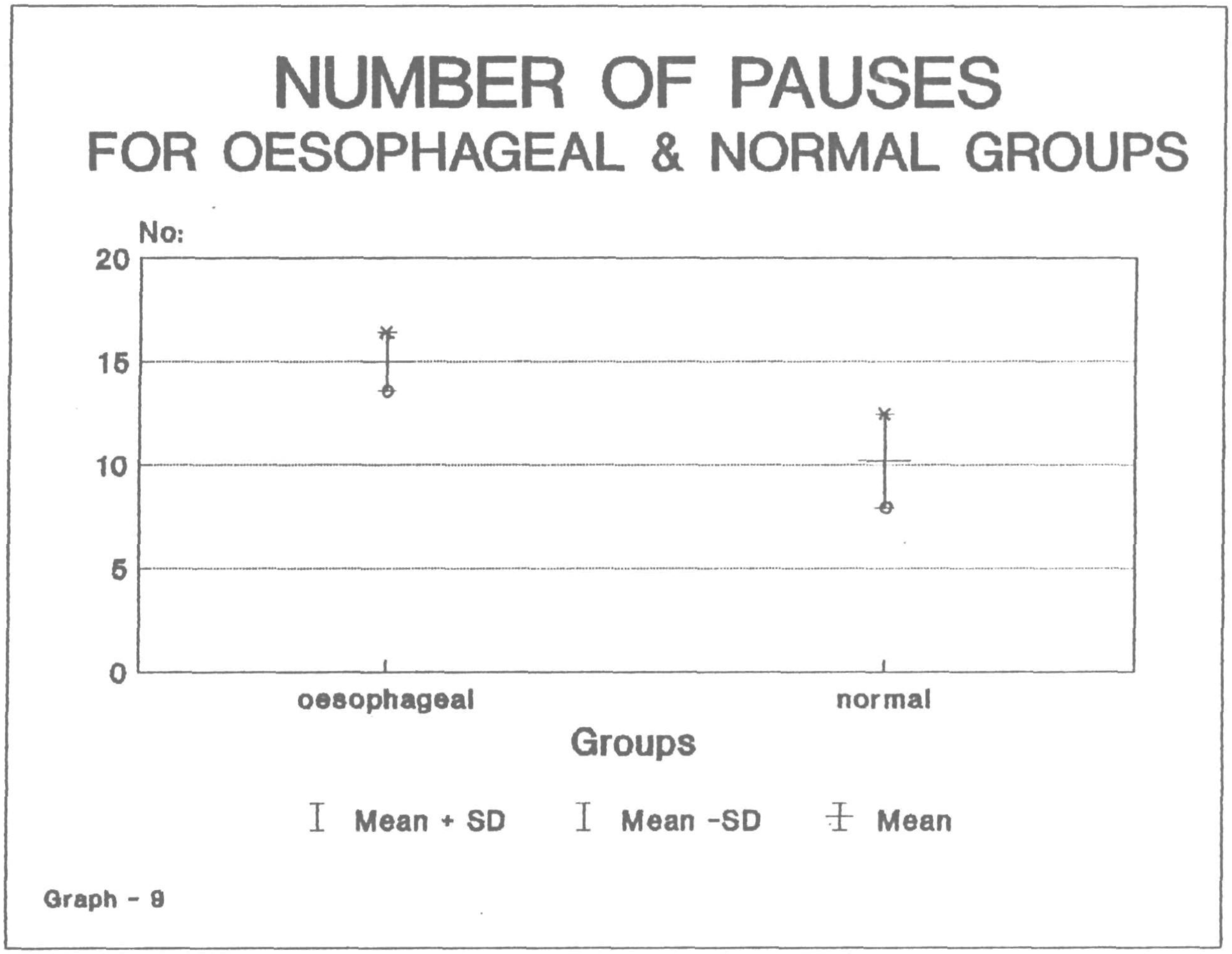
The mean S.D. and range of total pause duration, number of pauses and mean pause duration are presented in table and Graphs 8, 9, 10.

As evidenced from Table 12a, the total pause duration and mean number of pauses were much higher in the oesophageal group than the normals. However few of the oesophageal

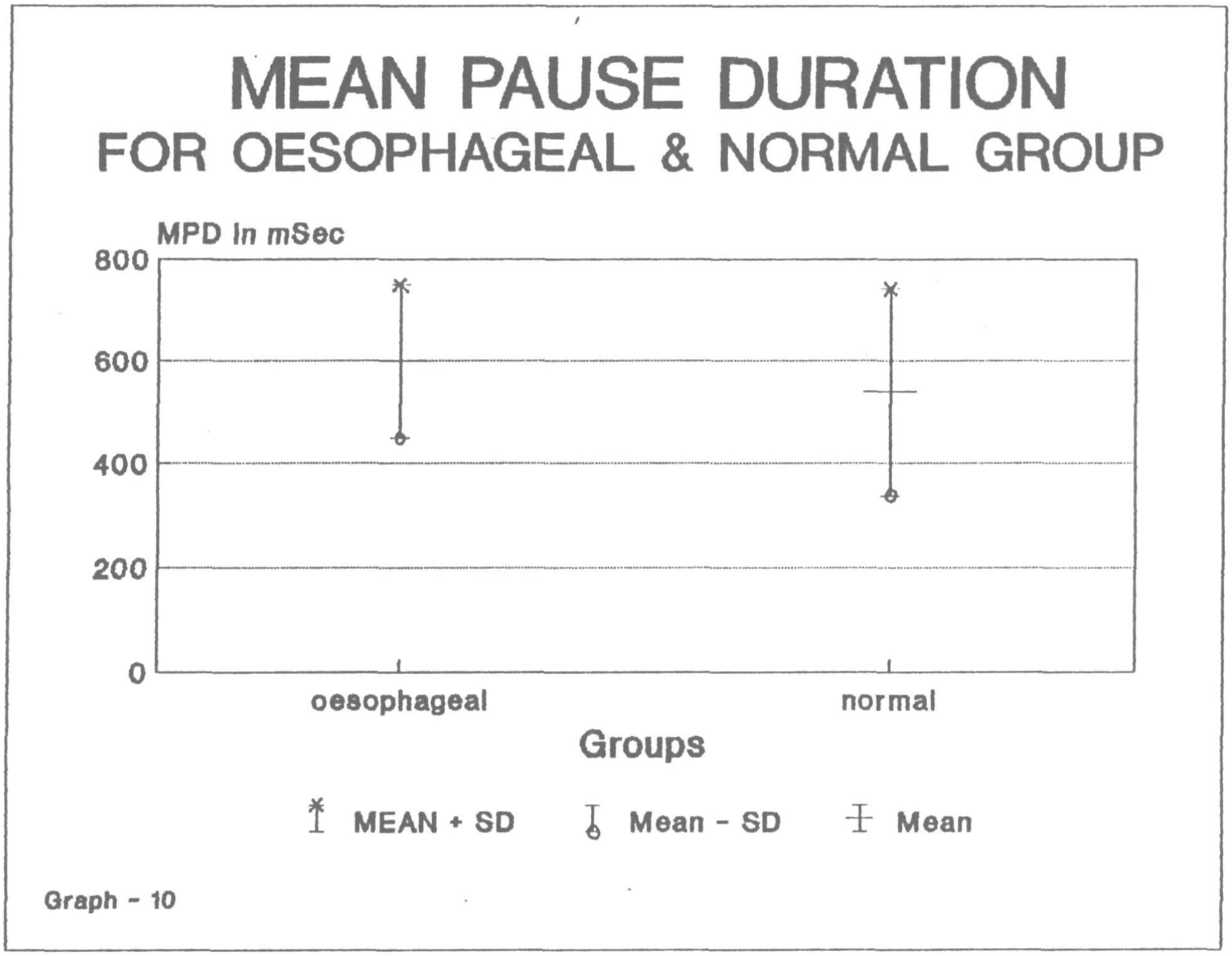
Graph - 8 Showing mean and S.D. total pause duration for oesophageal and normal groups.



Graph - 9 Showing mean and S.D. of number of pauses for oesophageal and normal groups.



Graph - 10 Showing mean and S.D. of mean pause duration for oesophageal and normal groups.



Parameter	Oesophageal			Normal		
	Mean	S.D.	Range	Mean	S.D.	Range
Total pause duration (msec)	8844.75	2145.2	6363.75 -11740.2	5446.3	2063.4	3821.25 -79546.5
Number of pauses	15	1.41	13-16	10.2	2.28	8-14
Mean pause duration (msec)	599.34	149.40	471.7 -787.2	539.31	201.2	382.1- 882.9

Table 12a: The mean, S.D. and range for total pause duration, number of pauses and mean pause duration in oesophageal and normal speakers.

speakers did approximate the normal values. The mean pause duration in oesophageal speakers was found to be higher than that of normal speakers.

The Wilcoxon test for significance showed significant differences between oesophageal and normal speakers at 0.05 level of significance on a one tailed distribution for total pause duration and number of pauses. However there was no significant difference between the oesophageal and normal groups on mean pause duration. The results of the Wilcoxon test are given in Table 12b.

Thus the hypotheses that there is no difference between oesophageal and normal speakers in terms of total pause

Parameter	Z. value	P	significance
Total pause duration	1.753	0.0401	S
No. of pauses	1.753	0.0401	S
Mean pause duration	6742	0.5002	NS

Table 12b: Results of Wilcoxon test for total pause duration number of pauses and mean pause duration.

duration and number of pauses are rejected. The alternate hypotheses that total pause duration and number of pauses are greater in oesophageal speakers than normal speakers are accepted. The hypothesis that there is no significant difference between the mean pause duration of oesophageal speakers and normal laryngeal speakers is accepted.

The present study thus supports the findings of Robbins et al (1984) who found total pause time and total number of pauses to be greater in oesophageal than in normal laryngeal speakers. Diedrich (1968) attributes the greater total pause time and number of pauses shown by oesophageal speakers to their limited air reservoir. Although the present study found the mean pause duration in oesophageal speakers to be greater than that of normals these results were not statistically significant. Hence the present study cannot support Robbins et al (1984) finding of greater mean pause duration in oesophageal speakers.

10) Rate of speech:

The rate of speech was expressed in terms of syllables per second (RT) in the present study. The mean S.D. and range of speech rate for the two groups are given in table 13a and graph 11.

Group	Mean	SD	Range
oesophageal	2.78	0.384	2.356 - 3.23
normal	3.59	0.161	3.3 - 3.71

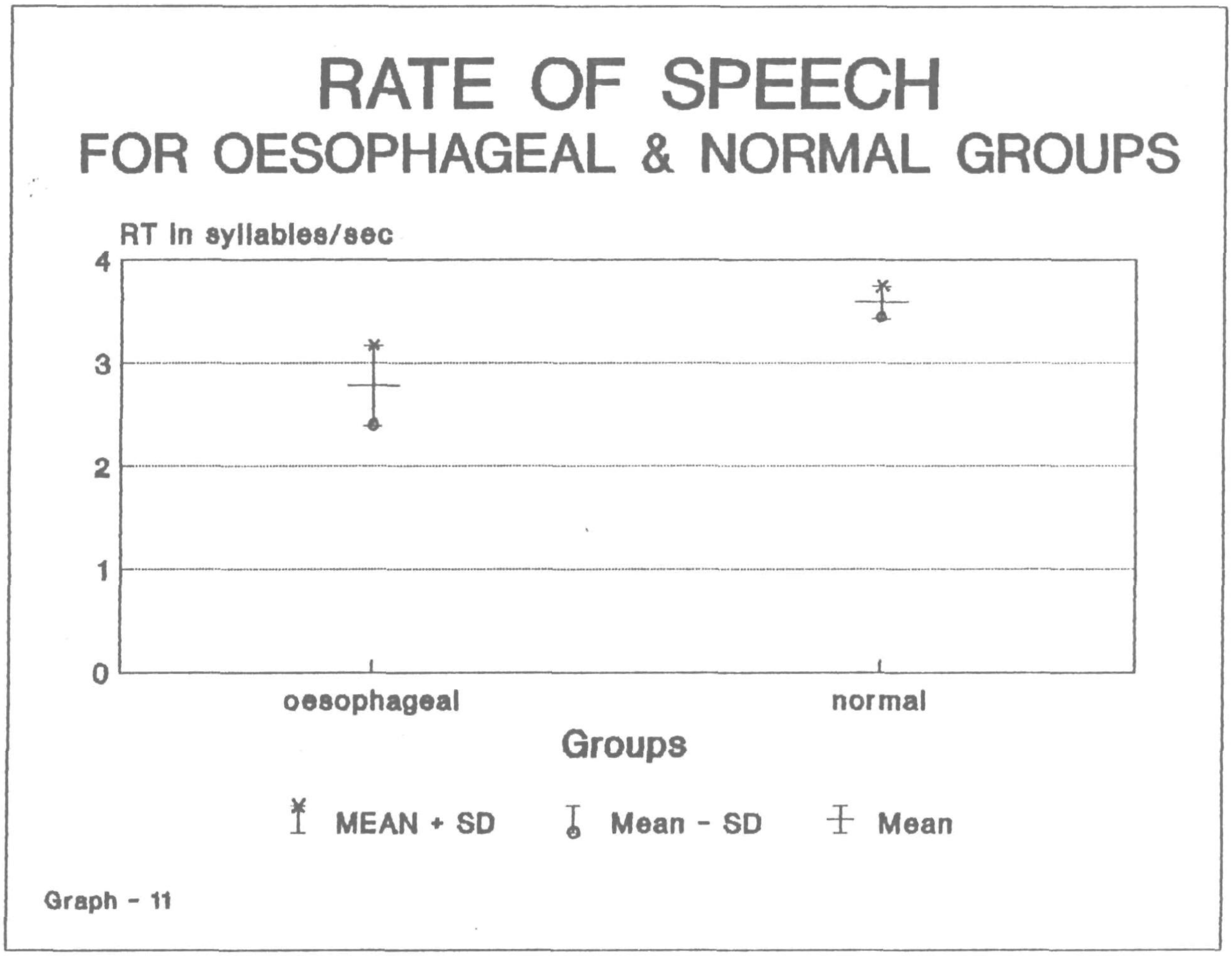
Table 13a: The mean, S.D and range of rate of speech (RT) in syllables/sec for oesophageal and normal groups.

The mean rate of speech in the oesophageal group was less than the values obtained for the normal group. However the oesophageal group showed larger variability with few oesophageal subjects almost approximating the normal values as evident from the upper limit of the range of rate of speech in oesophageal group (3.23 sps). The average rate of speech in normals was greater than the oesophageal group by 0.81 sps.

The Wilcoxon matched pairs test (Table 13b) demonstrated significant differences between the oesophageal and normal groups in the rate of speech.

Hence the hypothesis stating that there is no significant difference between the oesophageal and normal groups in the rate of speech was rejected.

Graph - 11 Showing mean and S.D. of rate of speech for oesophageal and normal groups.



Parameter	Z. value	P	Significance
Rate of speech (RT)	-2.023	0.043	S

Table 13b: Results of Wilcoxon test for rate of speech.

Robbins et al (1984) stated that the slower rate of oesophageal speakers indicated limited volume of insufflated air in the esophagus in contrast to the entire pulmonary volume available for the laryngeal speakers. Pindzola and Cain (1989) attributed the reduced rate of speech in oesophageal speakers to the increased pause time needed to insufflate the pseduoglottis. Rajashekhar (1991) also attributed the reduced rate of speech in oesophageal speakers to the frequency of pausing for air insufflation into the oesophagus.

The present study thus supports the findings of reduced rate of speech in oesophageal speakers by Robbins (1984), Pindzola and Cain (1989) and Rajashekahar (1991).

SPECTRAL MEASURES

11) Formant frequencies:

The mean S.D and range of the formant frequencies F_1, F_2, F_3 are shown in tables 14a, 14b and 14c and graphs 12, 13, 14 respectively for the vowels /e/, /ə/, /a/, /o/ and /u/ for oesophageal and normal groups.

Parameter F1	Oesophageal group			Normal group			W*
	Mean.	S.D.	Range	Mean	S.D.	Range	
/e/	446.98	11.38	439.2-464.3	401.56	39.58	355.1-464.3	S
/ə/	593.64	51.47	527.1-671.4	578.52	56.45	520.8-656.3	NS
/a/	790.30	79.70	665.1-909.0	758.13	67.05	589.8-903.0	NS
/o/	431.25	37.67	439.2-533.3	460.13	31.355	407.8-495.7	NS
/u/	412.24	37.43	301.2-470.6	361.34	43.496	276.1-436.04	S

Table 14a: The mean, SD, range and significance of Fl for oesophageal and normal groups.

Parameter F2	Oesophageal group			Normal group			w*
	Mean	S.D.	Range	Mean	S.D.	Range	
/e/	2073.34	57.40	1928.6-2509.8	1954.12	98.72	1788.2-2045.5	NS
/ə/	1529.54	84.18	1436.9-1637.7	1400.48	68.67	1336.5-1490.8	S
/a/	1330.18	96.73	1180.9-1603.8	1301.40	98.30	1109.4-1531.0	NS
/o/	911.06	103.70	765.5-1154.5	895.00	58.11	690.2-1098.0	NS
/u/	846.42	110.99	602.4-1217.3	817.10	54.65	690.2-963.8	S

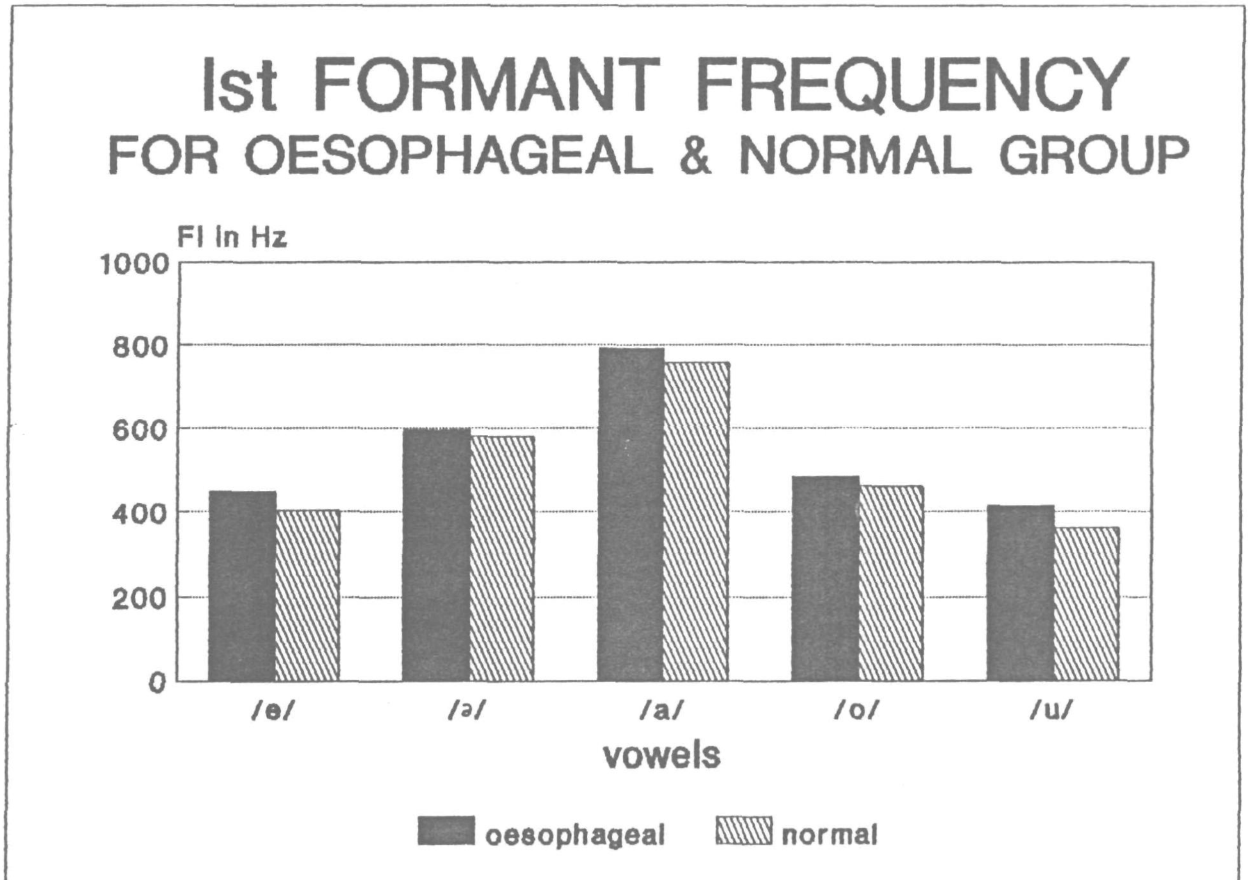
Table 14b: The mean, SD, range and significance of F2 for oesophageal and normal groups.

Parameter (F3)	Oesophageal group			Normal group			w*
	Mean	S.D.	Range	Mean	S.D.	Range	
/e/	2835.06	334.97	2302.7-3232.4	2596.66	55.72	2522.4-2671.7	NS
/ə/	2590.02	155.62	2415.7-2823.0	2283.56	83.61	2160.9-2378.0	S
/a/	2591.30	310.30	2027.9-3240.1	2458.80	215.30	2076.9-2913.9	NS
/o/	2224.90	463.9	1568.6-2811.0	2458.40	124.11	1932.6-2722.0	NS
/u/	2296.86	438.6	1631.4-3011.8	2360.46	205.96	1725.5-2686.8	NS

Table 14c: The mean, SD, range and significance of F3 for oesophageal and normal groups.

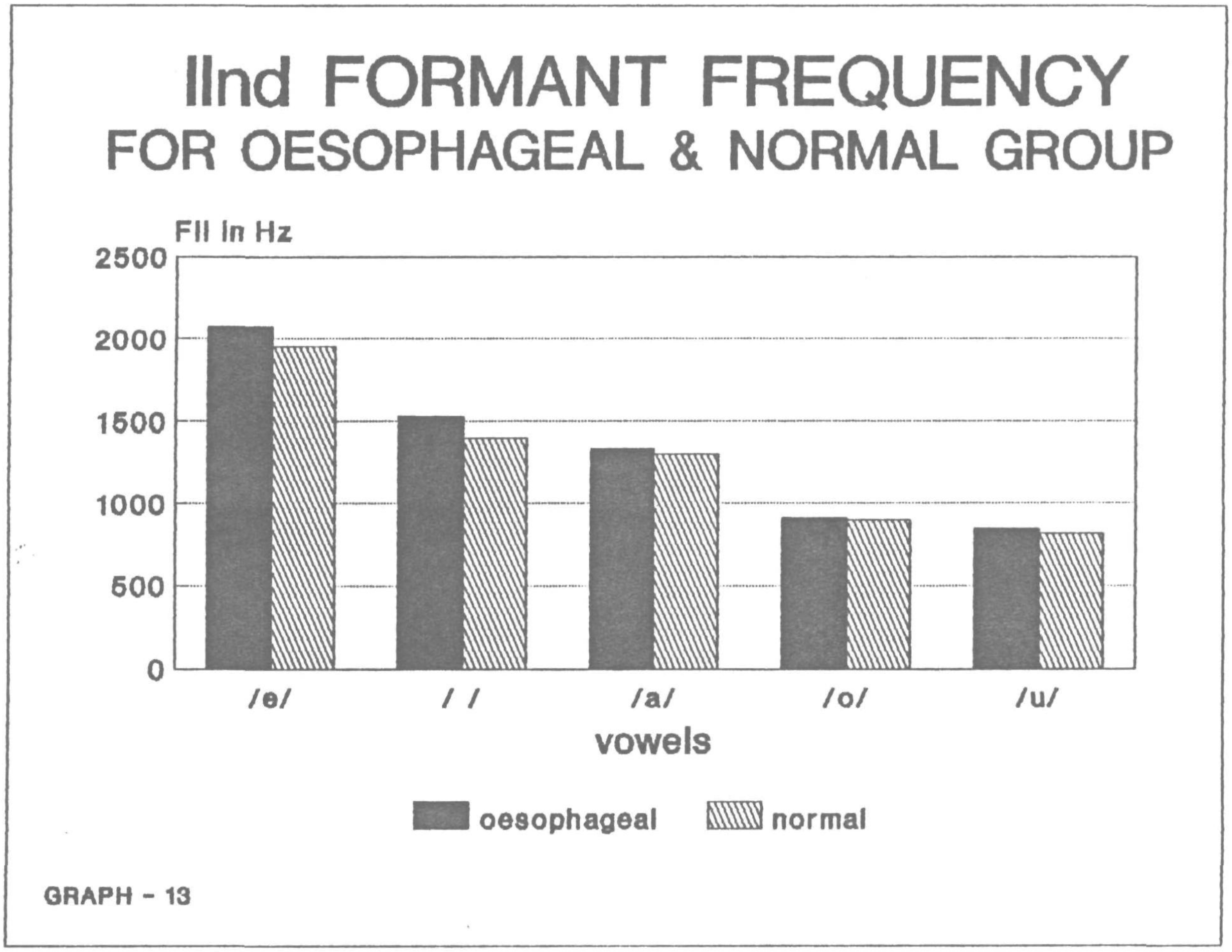
* - Results on Wilcoxon test of significance.

Graph - 12 Showing mean first formant frequency values for vowels /e/, /ə/, /a/, /o/, /u/.

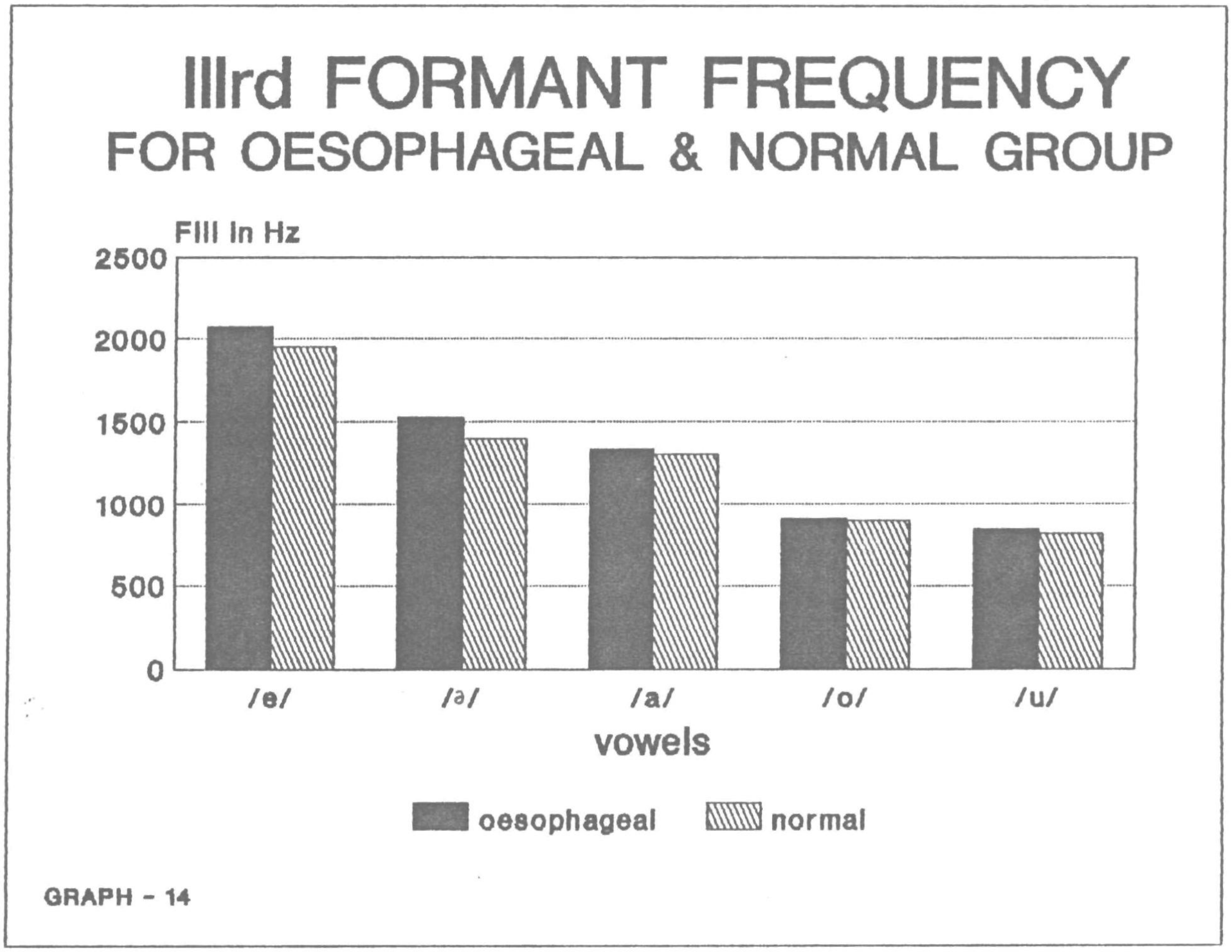


GRAPH - 12

Graph - 13 Showing mean second formant frequency values for vowels /e/, /ə/, /a/, /o/, /u/. for oesophageal and normal groups.



Graph - 14 Showing mean third formant frequency values for vowels /e/, /ə/, /a/, /o/, /u/ for oesophageal and normal groups.



Formant frequencies were higher for all the vowels in the oesophageal speakers than in the normal speakers. These findings correspond with the reports by Rollin 1962, Kytta 1964, Sisty and Weinberg 1972 and Rajashekhar 1991.

In the normal group, the vowel /a/ had the highest first footman and vowel /a/ the lowest first formant vowel /e/ had the highest second formant and vowel /u/ the lowest second formant. The changes in the formant frequency characteristics for different vowels were systematic and essentially the same for normal and oesophageal groups.

The Wilcoxon test revealed significant differences between the oesophageal and normal speakers on F for the vowels /e/ and /u/, on F_2, for the vowels /ə/ and /u/ and on F_3 for vowels /ə/ and /o/.

Hence the hypotheses that there is no difference between the oesophageal and normal speakers on F_1 for vowels /e/ and /u/, on F_2, for vowels /ə/ and /u/ and on F_3 for vowels /ə/, and /o/ are rejected and on F_1 vowels /ə/, /a/ and /o/ and on F_2 for vowels /e/, /a/ and /o/ and on F_3 for vowels /e/, /a/ and /u/ are accepted.

Thus the present study revealed higher than normal formant frequencies in oesophageal speakers.

The present study thus supports the views of Sisty and Weinberg (1972) according to which, laryngectomees pose a reduced vocal tract length and hence lead to an alteration in the vocal cavity transmission characteristics in oesophageal speakers. Table 15 Summarizes the significant differences between the groups, in terms of different parameters studied.

Parameters	Oesophageal Vs Normal
Acceptability	S
Intelligibility	S
Fundamental frequency in speech	NS
Frequency range in speech	NS
Vowel duration	NS
Burst duration	S
Voice onset time for voiceless plosives	S[1]
Mean pause duration	NS
Rate of speech	S
Formant frequencies (Fl, F2, F3) for the vowels /e/ /ə/ /a/ /o/ /u/	S*

Table 15 Summary of significance of difference between Oesophageal and normal groups for all the parameters

S = significant NS = Non significant

1 = significant for /ph/ and /kʰ/

* = significant in terms of F_1 for /e/ and /u/ in terms of F_2, for /ə/ and /u/ and in terms of F_3 for /ə/ and /o/

The null hypotheses (1,2,6,7,9,10) stating that there is no significant difference between the oesophageal speech and normal speech is rejected with reference to

a) Acceptability

b) Intelligibility

c) Burst duration for stops /p/, /p^h/, /t/, /t^h /, /d/, /d^h /, /k/, /k^h, /g/ and /g^h/.

d) Voice onset time for the voiceless stops /p^h / and /k^h/

e) Rate of speech

f) Formant frequencies F_1 for /e/ and /u/, F_2 for /ə/ and /u/ and F_3 for /ə/ and /o/

and the null hypotheses (3,4,5,8) are accepted with reference to,

a) Fundamental frequency in speech

b) Frequency range on speech

c) Vowel duration for vowels /e/, /ə/, /a/, /o/, /u/ following the initial stops.

d) Mean pause duration.

i.e., the oesophageal speakers differed from the normal speakers in terms of

a) acceptability of speech.

b) Intelligibility of speech.

c) Burst duration for stops.

d) Voice onset time for voiceless stops.

e) Rate of speech.

f) Formant frequencies

and did not differ from the normal laryngeal speakers in terms of

a) fundamental frequency in speech.

b) frequency range in speech.

c) vowel duration.

d) mean pause duration.

The intonation contours produced by the oesophageal speakers do match those of normal laryngeal speakers but the change in fundamental frequency is not continuous in the oesophageal group due to poor control on the PE segment.

Thus the results showed the oesophageal speakers to be deviating from the normal speakers on many parameters.

The general goal of any voice restoration procedure in laryngectomees is to achieve speech that is comparable to normal in acceptability and intelligibility of speech. Hence changing the deviating parameters towards normalcy would have a positive effect on the acceptability and intelligibility of oesophageal speech.

Generally increasing the rate of speech and reducing the stoma noise would improve the oesophageal speech. Therapy programmes for oesophageal speakers should concentrate on elimination of klunks and reduction of stomal noise. In any clinical setting rate of speech can be measured easily and hence can be used as an easy tool to test the efficacy of speech therapy/proficiency of the oesophageal speaker.

Although the mean pause duration in the oesophageal speakers was not significantly different from that in normal speakers, the number of pauses and the total pause duration in case of oesophageal speakers were greater than in normals. This fact accounts for the perceived lack of continuity in the speech of oesophageal speakers. Directing the therapy towards increasing the amount of air intake and the quickness of air intake in the oesophagus can lead to a longer duration per breath group and thus reduce the overall pause duration and number of pauses to some extent.

The increased burst durations found in the oesophageal speakers could be means to compensate for the lack of intensity of their speech. This however needs further investigation. The burst duration then can be brought to near normal values by increasing the intraoral air pressure and by improving upon the sharpness of their articulation.

The removal of larynx causes a reduction in the size of the vocal tract. With PE segment as the vibratory source, this results in higher formant frequencies compared to normals. The present study too, found the same. By using synthesis programmes one can try to find out whether shifting the place of articulation to a more anterior place will result in near normal formant frequencies.

It is seen that the public speakers over articulate and prolong their vowels to make their speech more intelligible and effective. Using synthesis programmes it can be tested whether increasing vowel duration affects intelligibility of the speaker. This information can then be applied in therapy for improving the intelligibility of oesophageal speakers.

Majority of the subjects of the present study have had many years of practice at oesophageal mode of speaking and were proficient oesophageal speakers. This fact attributes for the near normal findings. It will be interesting to replicated the study using fresh oesophageal speakers, so that the effect of practice can be observed.

CHAPTER V

SUMMARY AND CONCLUSION

Speech is a multidimensional signal that elicils a linguistic association (Flanagan 1972). It is believed that human beings are specialized for speech communication, most evidently for speech production.

Surgical removal of larynx - LARYNGECTOMY - leaves the operated individual - LARYNGECTOMEE - handicapped in speech production. The speech clinician helps in the rehabilitation of the laryngectomee by developing some means of functional communication. The 'oesophageal speech' has been traditionally considered as the method of choice.

Once the laryngectomee has acquired oesophageal phonation, the aim will be to bring the oesophageal speech more towards normal, making it more intelligible and acceptable. Hence identifying the parameters of oesophageal speech derriating from normal speech is very important. The present study is one such effort at identifying the deviation psychoacoustic, acoustic, temporal and spectral parameters of oesophageal speech.

The voice and speech samples from 5 Marathi speaking oesophageal speakers and 5 Marathi speaking normal subjects matched for age, sex and education were collected. These were analysed using computer programmes and judges to obtain the following parameters.

Psychoacoustic measures

1) Acceptability of speech
2) Intelligibility of speech

Acoustic measures

3) Fundamental frequency in speech
4) Frequency range in speech
5) Intonation contours for specific types of sentences i.e., declaratives and interrogatives.

Temporal measures

6) Vowel duration
7) Burst duration
8) Voice onset time for voiceless stops
9) Mean pause duration
10) Rate of speech

Spectral measures

11) First three formant frequencies (F1, F2, F3) for the vowels /e/, /ə/, /a/, /o/ /u/.

The results were subjected to statistical analysis using Wilcoxon matched pairs test. The following conclusions were drawn based on the statistical analysis.

1) Oesophageal speech was less acceptable and intelligible than the normal laryngeal speech.

2) The oesophageal speakers did not differ significantly from the normal speakers on the following parameters:

a) Fundamental frequency in speech
b) Frequency range in speech
c) Vowel duration
d) Mean pause duration.

3) Significantly higher burst durations than normals were seen in the oesophageal speakers.

4) Voice onset time for the voiceless aspirated stops /p^h/ and /k^h/ were significantly reduced in oesophageal speakers compared to normals.

5) Higher formant frequencies than in normals were seen in oesophageal speakers.

Comparison of intonation contours used by oesophageal and normal speakers revealed that oesophageal speakers do use the same intonation contours as normal speakers, but the change in frequency in case of oesophageal speakers is discontinuous and produces a scatter.

Thus the results indicate that in oesophageal speakers, the phonatory as well as articulatory behaviour is altered. Analysis of voice/speech of laryngectotmees can help in planning and monitoring the therapy programmes and assessing the gains of therapy.

This is the first study using Marathi speaking laryngectomees.

RECOMMENDATIONS:

1) The parameters can be studied on a larger group.

2) The study can be repeated on patients acquiring oesophageal speech and can be followed up throughout the therapy to assess the gains of therapy at intervals.

3) Contribution of these parameters to intelligibility and acceptability of speech can be studied.

4) Studies using synthesis programmes may be carried out to confirm the contribution of bust duration, vowel duration and formant frequencies and other parameters to intelligibility of speech.

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APPENDIX I

WORD LIST -

1.	/taṭ^{h}/	ताठ
2.	/poṭ/	पोट
3.	/b^{h}ag/	भाग
4.	/t^{h}oḍke/	थोडके
5.	/k^{h}up/	खूप
6.	/kuṭ^{h}e/	कुठे
7.	/p^{h}uge/	फुगे
8.	/baki/	बाकी
9.	/deto/	देतो
10.	/gata/	गाता
11.	/g^{h}at/	घात
12.	/d^{h}əḍa/	धडा

APPENDIX II

Reading passage

dog^{h}e b^{h}au hote. t^{h}orla dIpu anI d^{h}akṭa ṭIpu. dIpu k^{h}adaḍ hota. ṭIpu d^{h}iṭ hota. tjance baba k^{h}up kədək hote. ekda dIpu babãnna mhəṇala, "baba tumhi ṭIpuce p^{h}ukəṭ goḍwe gata anI madz^{h}jawər ṭika kərta. əsə̍ ka?" baba mhəṇale, "beṭa, tIpu kUṭ^{h}e ahe? mi he paise deto. tjace don sark^{h}e b^{h}ag kər. ek tu g^{h}e, baki tIpula de".

dIpu k^{h}uʃ dzala. kaj pən t^{h}at! to tədək baget gela. tjane p^{h}uge g^{h}etle. t^{h}ode t^{h}odke nahi, səgḷe paise udəwle. b^{h}əṭək b^{h}əṭək b^{h}əṭəkla. t^{h}əkla g^{h}ari ala. k^{h}auca ḍəba kaḍ^{h}la aṇI p^{h}ədʃa paḍla.

jaUlət tIpune wIčar kela - "kaj kərawe bəre?" məg tjane k^{h}olitla kəcra kad^{h}la. panjaca g^{h}əḍa b^{h}ərla. ṭak g^{h}etla. t^{h}ode kagaḍ g^{h}etle. ḍoḷe mIṭun pudza keli. tat^{h} bəsla wə d^{h}əda g^{h}oku lagla. tIkde g^{h}at dzala. dIpuca guḍg^{h}a k^{h}ərcəṭla. poṭ wə ḍoke duk^{h}u lagle.

baba ale. tjãni tIpuči paṭ^{h} t^{h}opəṭli. te dIpula mhəṇale," kəḷḷə̍ ka? mi ka ṭIpuce goḍwe gato te?" dIpune man hələwli.

Total number of syllabes = 282

Total number of words = 150

a → a