Acoustic and Perceptual Analysis of Alaryngeal Speech (Gastric and TGP with B.S. Prosthesis Modes)

REGISTER NO. M 9911

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***A* Dissertation submitted in part fulfillment of the second year M.Sc (Speech and Hearing), University of Mysore, Mysore**

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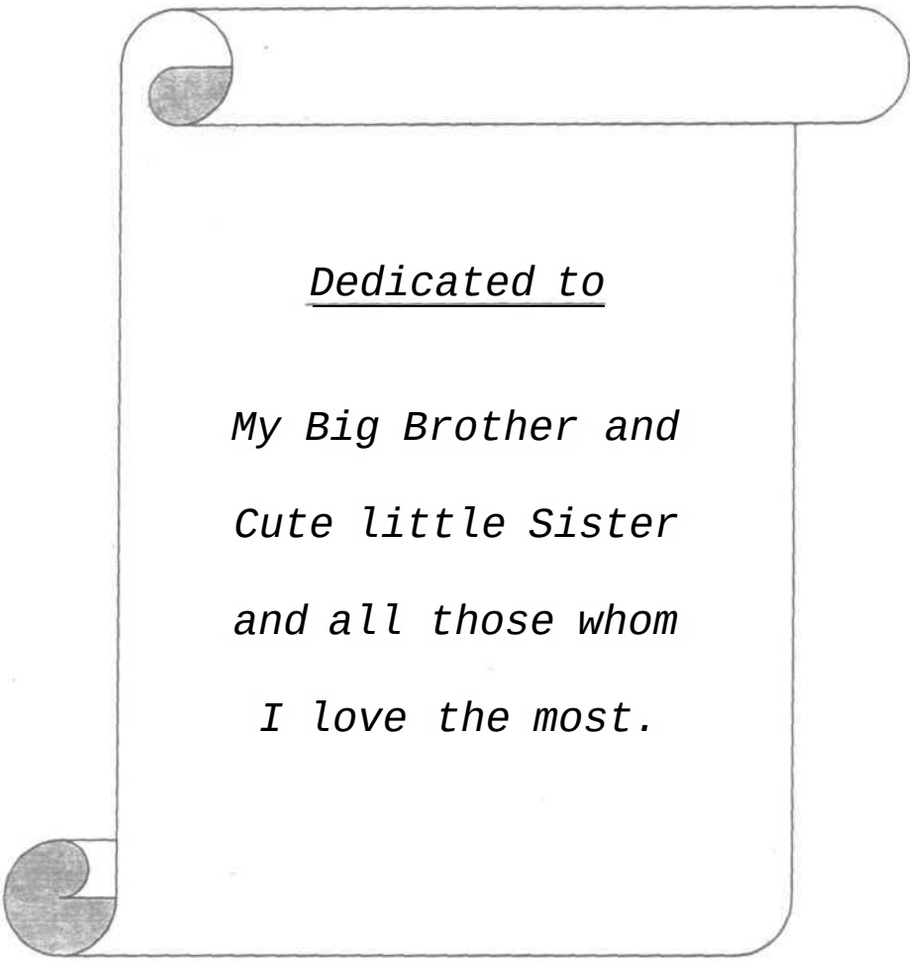

Dedicated to

My Big Brother and

Cute little Sister

and all those whom

I love the most.

Certificate

This is to certify that the Dissertation entitled *"Acoustic and Perceptual Analysis of Alaryngeal Speech (Gastric and TGP with B.S. Prosthesis Modes)"* is the bonafide work done in part fulfillment of the degree of Master of Science (Speech and Hearing) of the student (Register No. M 9911).

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This is to certify that the Dissertation entitled *"Acoustic and Perceptual Analysis of Alaryngeal Speech (Gastric and TGP with B.S. Prosthesis Modes)"* has been prepared under my supervision and guidance. It is also certified that this has not been submitted earlier in any other University for the award of any Diploma or Degree.

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This dissertation entitled *"Acoustic and Perceptual Analysis of Alaryngeal Speech (Gastric and TGP with B.S. Prosthesis Modes)"* is the result of my own study under the guidance of Ms. M. Pushpavathi, Lecturer in Speech Pathology, All India Institute of Speech and Hearing, Mysore, and has not been submitted earlier at any other University for the award of any Diploma or Degree.

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CONTENTS

CHAPTER I

INTRODUCTION

Speech is one of the form of communication which people use most effectively in establishing interpersonal relationships. With speech, they give form to their inner most thoughts - their dreams, ambitions, sorrows and joys. Speech is the key to human existence. Underlying basis of speech is voice. The voice transmits a wealth of information concerning the speaker through changes of vocal tone registered in the diverse attitudes evoked by different social contexts.

Voice being the vital entity for communication is affected by various vocal pathological conditions viz., cancer of larynx. Laryngeal carcinoma is a life threatening disease. Depending on the glottic staging, site and extent of lesion treatment of laryngeal carcinoma may range from minimal anatomical laryngeal alteration to total removal of larynx and surrounding muscles.

There are mainly two types of laryngeal carcinoma - primary and secondary. Primary tumors can occur at any site in the larynx, they may be glottic, supraglottic or subglottic. Primary cancer may spread by direct penetration into the surrounding tissue but a more serious risk of secondary growth arises with involvement of lymphatic glands since cancer may now occur widely throughout the body by lymphatic metastasis. As there are

practically no lymphatic vessels in the vocal folds, lymphatic metastasis will only occur when considerable invasion of larynx has taken place. Treatment procedures involve radiotherapy, chemotherapy and surgical procedures. The primary concern for both patient and surgeon is the removal of this feared disease and if laryngectomy is the price that has to be paid, so be it. This operation, unlike others, leaves the patient in an altogether altered state, with a permanent tracheostoma and no means of normal voice production.

Carcinomas arising in the pyriform fossa, post cricoid region and cervical esophagus have a much worse prognosis than similar carcinomas arising within the larynx. When carcinoma arises in post cricoid or upper esophagus surgical excision can be achieved only by resection of a whole segment of the laryngo-pharynx and cervical esophagus and same applies to carcinomas arising from pyriform fossa. The resection of laryngo-pharynx and variable amount of cervical esophagus in addition to larynx necessitates a much more extensive operation in order to restore the continuity of upper alimentary tract. The esophagus has a segmental blood supply and it is not possible to rely on mobilization of the esophagus and elevation of it to provide an end to end anastomosis with the pharynx.

The reconstructive problems of deglutition and voice preservation are evidenced by the large number of operative solutions mat have been offered

over the years. The four most popular techniques for reconstruction of the upper digestive tract are as follows:

1) free jejunal transfer
2) colon interposition
3) pectorals myocutaneous or deltoputoral flap reconstruction and
4) gastric pull up.

Ranger (1964) and Le Quesne (1966) carried out immediate repair after pharyngolaryngectomy and esophagectomy by creating a pharyngogastric anastomosis. Stomach and duodenum are mobilized and transplanted into the neck to form a continuous tract between pharynx and stomach. The advantages of using stomach include its good vascular supply, its ease of suture to the remaining pharynx and wide anastomosis that can be made.

Rehabilitation of swallowing is rapid and stenosis is rare but speech tends to be weak and reduced in volume and quality. It has been reported that excellent cosmetic result of pharyngogastric anastomosis coupled with relatively trouble free eating is however associated with a poor gastric voice.

Production of voice in gastric transposition cases utilizes the stomach as accessory lung and pharyngogastric anastomosis as a vibratory source. These patients are called "Gastric speakers" Fig. 1 (a&b). According to Diedrich & Youngstrom (1966), in these individuals, the neoglottis lies at the

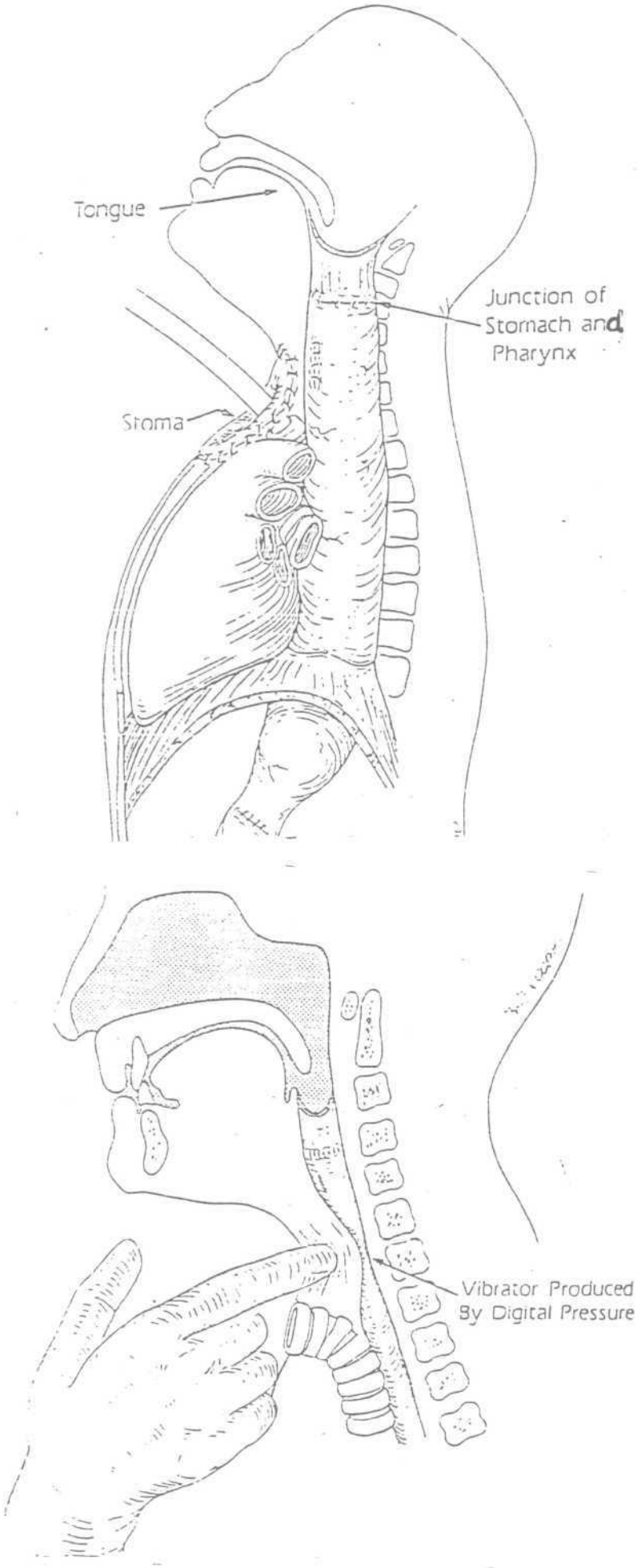

Figure 1 (a&b) shows reconstruction after total laryngectomy, oesophagectoy and gastric pull-up.

pharyngogastric anastomosis while the air reservoir is the gastric bubble in the stomach. Since gastric pull-up patients have no lower esophageal sphincter, only a large flaccid stomach that tends to distend progressively. It is the factor along with lack of effective vibrating segment that causes difficulty in speech production.

The rehabilitation of these patients aims to restore voice mainly by three methods.

1) The esophageal/gastric voice
2) Electronic devices (artificial larynx)
3) Tracheoesophageal/tracheogastric puncture and voice prosthesis

The success in the rehabilitation of alaryngeal speakers depends mostly on the efficacy with which the individual is able to use his voice and convey messages intelligibly. It is essential to evaluate the factors affecting intelligibility of laryngectomees for their successful rehabilitation.

Intelligibility of speech depends highly on factors like acoustic, temporal and spectral characteristics of the speech, which is altered in case of laryngectomees as a result of changes in the speech production mechanism. These altered characteristics which highlight some of the differences between normal and alaryngeal speech, serve to identify measures of speech important for clinical evaluation and management.

Based on the results of Christensen & Weinberg (1976), Weinberg (1982) commented that total laryngectomee produced changes in articulatory behaviour are evidenced by altered duration characteristics of vowels.

Rollin (1962) and Kytta (1964) suggested that the removal of larynx resulted in altered vocal cavity transmission characteristics. However, evaluating the factors affecting the intelligibility of alaryngeal speech is important for the rehabilitation of laryngectomees. Hence, the knowledge of acoustic and temporal properties of gastric speech represents an important body of information and a significant area of theoretical and applied study. This can be interpreted in such a manner as to enlarge understanding of speech production following laryngopharyngoesophagectomy. Therefore the present study has been proposed to analyze the acoustic temporal and perceptual parameters of gastric and tracheogastric puncture speakers.

CHAPTER II

REVIEW OF LITERATURE

It is after all, a man who has cancer of the larynx. He may be an essential surgical or historic statistic to others but he is much more to himself and his family. For thousands of years, man died as a result of cancer of larynx and because of other laryngeal disorders and injuries. The first surgical break through came almost one hundred years ago with the work of Billroth in 1873. Throughout the years, interest in surgery and related problems has grown. It is stressed that the larynx is to be considered as comprised of a number of parts, many of which can be preserved and reformed into new pseudolarynx. The concept that it is single organ requiring removal in to simply because one section of it is the site of cancer is an out model concept. The surgical research is constantly striving to perfect operations, which permit more nearly normal speech than is possible with total laryngectomy.

Cancer arising in post cricoid region and/or upper esophageal areas of hypopharynx needs surgical excision of the whole segments of laryngopharynx and esophagus. Esophagus in these cases has been reconstructed with stomach or colon or free jejunal flap. Production of voice in gastric transposition cases utilizes the stomach as an accessory lung and pharyngogastric anestomosis as a vibratory source. The patients are called "gastric speakers".

INCIDENCE

Incidence of laryngeal and hypopharyngeal malignancy varies in different parts of India with a range of 17-44% of total body malignancies (Gangadharan, 1979). Distribution of hypopharyngeal and laryngeal malignancy is depicted in Table 1.

Table 1. Distribution of hypopharyngeal and laryngeal malignancy (Gangadharan, 1979)

Place	Percentage of total Body Malignancy
Bombay	34
Goa	44
Manipal	29
Madras	20
Orissa	28
Calcutta	43
Assam	38
New Delhi	35
Vizag	17
Hyderabad	31

AGE

Hypopharyngeal cancer is predominantly a cancer of middle age. However, no age is exempted from occurrence of this disease. Lederman (1967) reported that it is more common in 5^{th} and 6^{th} decade. Annual report of National Cancer Registry 1983, India (1986) also shows the same incidence. Bahadur and Chattopadhay (1988) reported mean age of 44 years with a range of 22 years to 67 years in their study.

SEX

Its greater occurrence in men is an invariable characteristic of hypopharyngeal cancer in various studies as evidenced from Table II.

Table II. Sex distribution of hypopharyngeal cancer

	Male/Female Ratio
Gandagule and Agarwal (1969)	2 : 1
Harrison (1979)	2 : 1

National Cancer Registry for the year 1983, India also shows the male predominance.

Table III. Sex Distribution
(Cancer Registry 1983, India 1986)

	Male/Female Ratio
Bangalore	4.9: 1
Bombay	4.2: 1
Madras	6.1 : 1

However, various other authors reported female predominance (Table IV).

Table IV. Sex distribution

	Male/Female Ratio
Jones et al. (1986)	1 :4
Silver (1981)	3:4

Bahadur and Chattopadhay (1988) reported male to female ratio of 1:1

CLINICAL FEATURES:

The cardinal presenting symptoms are dysphagia, odynophagia, hoarseness, sore throat but patients also present with either a swelling in the neck or a foreign body sensation in the throat as reported by Marks (1985). He also attributed difficulty in swallowing saliva to the irritable lesion resulting in excessive salivation, dysphagia for solid and semi-solid food.

Pain in the throat is present in varying degrees and is more when the superior laryngeal nerve is involved (Million and Cassissi, 1981). Hoarseness of the voice could result due to recurrent laryngeal nerve involvement either by direct pressure or oedema and breathlessness may be due to extensive laryngeal involvement.

As far as surgical and radio-therapeutic treatments are concerned, the oesophagus cannot safely be divorced from lower pharynx. Jacobson (1951)

noted that 2/3 of cancer affecting the lower pharynx extend to oesophagus because of submucosal extension of malignancy. The same is expressed by Harrison (1979).

Like any other epithelial malignancy the most common spread ts by lymphatic route which occur either by penetration or embolization. Seventy percent of the patients with carcinoma of the pyriform fossa have palpable lymphnode at presentation (Lederman, 1962) and only 25% of patients with a neck mass (Marks, 1985).

Bilateral adenopathy was reported in 10.5% by Harwik (1975) and if the lesion involving the midline i.e., post pharyngeal wall or post cricoid area, the percentage may go up to 60% (Mc Gravran et al. 1963).

Incidence of cervical metastasis was noted to be 47% by Spiro et al. (1983), 70% by Harrison (1970) and 30% by Bahadur and Chattopadhay (1988).

The upper cervical and retropharyngeal node involvement occur when the pyriform sinus growth extend to posterior and lateral pharyngeal wall (Ballantyne, 1967).

SITE

Carcinoma of lower part of hypopharynx and cervical oesophagus is fortunately uncommon. But, most patients present with extensive primary lesion often accompanied by metastatic lesion because of minimum symptoms in early stage of disease. In most studies pyriform sinus accounted for approximately 65% or more of the hypopharyngeal tumor, as evident from Table V.

Table V. Distribution of hypopharyngeal tumors

	Total Patients	Pyriform Fossa	Post Pharyngeal Wall	Post Cricoid
Kirchner(I977)	177	152	17	8
Sessions (1976)	195	189	6	0
Harrison (1970)	67	23	4	40
Bahadur Chattopadhay (1988)	28	4	1	23

Pyriform sinus accounted 75% of all the hypopharyngeal malignancies in series (Mc Combs, 1960) whereas Paymaster (1967) reported 70% and Spiro et al. (1983) reported 50% of tumor located in hypopharyngeal area to be from pyriform sinus.

HISTORICAL TYPING AND STAGING:

The malignant growth of hypopharynx is usually primary but spread into it may occur from primary growth in oropharynx, larynx, nasopharynx and rarely the thyroid glands (Harrison, 1970). Metastasis from primary in the breast, the bronchus and the gastrointestinal tract have been reported. Multicentric origin of cancer, especially in the hypopharynx is well known (Dalley, 1968).

Harwick (1975) reported a second primary lesion developing in eight out of ninety one patients in his study in related areas like the soft palate, the tongue, the lung and the oesophagus preceding or following hypopharyngeal lesion.

Hypopharyngeal tumor tend to be large and rather advanced when first diagnosed. Kirchner (1977) reported only 11 of 120 patients with pyriform sinus carcinoma as T_1 and T_2 whereas 109 patients were staged T_3 and T_4.

The commonest malignant tumor of hypopharynx is squamous cell carcinoma followed by adenocarcinoma, malignant lymphoma, mesodermal tumor and metastatic development (Lipkin et al. 1985, Million and Cassissi, 1981). Silver et al. (1981) reported nineteen out of twenty one malignant tumors as squamous cell carcinoma and rest as thyroid neoplasms.

Spiro et ai. (1983) reported 93.3% of patients having squamous cell carcinoma and 3.3% each of adenocarcinoma and mucoepidermoid carcinoma. Lederman (1967) reported 85% of patients having squamous cell carcinoma. Goldberg (1989) reported 100% of patients having squamous cell carcinoma in their series.

De Vries, et al. (1989) in their series noted distribution of stage for hypopharyngeal tumors as Stage III - 21.4%, and Stage IV - 78.6%. Bahadur and Chattopadhay (1988) reported two patients (7.17%) in Stage II, ten patients (35.71%) in Stage III and sixteen patients (57.14%) in Stage IV in the series of 28 patients.

TREATMENT OF HYPOPHARYNGEAL CANCER

Patient with hypopharyngeal cancer usually presents quite late and often with cervical lymph node metastasis. Treatment in such cases is palliative (Harrison, 1969). Surgery either alone or in combination with pre or post operative radiation is superior to radiotherapy alone for treatment of hypopharyngeal cancer (Eisbach and Krause, 1977; Harrison, 1977; and Kirchner, 1975).

Table VI. Survival rate in different treatment modalities for hypopharyngeal cancer.

	Year Post Op.	Radiotherapy Alone	Surgery Alone	Combined treatment
Kirchner(1975)	3	2/55 (4%)	9/28 (29%)	12/36 (36%)
Eisbach&Krause(1979)	5	2/23 (13%)	11/16(69%)	9/16 (56%)
Harrison (1977)	3	0/9 (0%)	2/14(14%)	-
Harwick(1975)	*5*	-	15/59(25.4.%)	-
El Badawi & Goepfert (1982)	*5*	-	10%	24%

Table VI shows the results of various treatment modalities reported by various authors in literature and their survival rate. These studies clearly indicate that the surgery appears to be clearly superior to radiotherapy alone. But it is unclear whether combined therapy improves the results achieved by surgery alone.

Eisbach and Krause (1977) attributed the lower cure rate obtained by pre operative radiotherapy compared with surgery alone as being due to impairment of surgeon's ability to determine the margin of tumors following the radiotherapy.

While combined radiation and surgery are widely accepted as treatment of choice for patients with T_3 and T_4 lesions, there is debate as to whether the radiation should be pre operative or post operative.

El Badawi and Goepfert (1982) reported a series of patients with radiotherapy, surgery and surgery combined with post operative radiotherapy. In radiotherapy group, 45% were alive with evidence of disease at two years whereas in surgery group the incidence of recurrence above clavicle was 47% and in combined group, it was 19%. Five year survival rate was 10% for surgery and 24% for surgery and post operative radiotherapy.

SURGERY

Resection of the entire larynx, pharynx and various portions of oesophagus is required in various instances (Silver, 1981).

1. Annular post cricoid carcinoma.
2. Extensive lesions of pyriform sinuses with the involvement of more than $2/3^{rd}$ of circumference of hypopharynx.
3. Extensive posterior pharyngeal wall lesion with involvement of the larynx.
4. Carcinoma of cervical oesophagus.

Surgical treatment should not only include adequate removal of the tumor but must provide restoration of alimentary continuity by reconstructing the pharyngo-oesophageal segment. The result of surgical treatment of carcinoma of hypopharynx and cervical oesophagus is so poor that patient should be considered only for a palliative treatment. Occasionally, the patients die of metastasis before the final reconstruction can be completed (Ong and Lee, 1960).

For effective palliation the following condition must be fulfilled (Ong and Lee, 1960):

1. Should be a one staged procedure and swallowing must be possible soon after the operation.
2. Operation should not carry with it high mortality rate.
3. Patient must not be worse off than before operation.

It will be unnecessary as well as unlikely for a single surgeon to acquire experience with each of the reconstructive procedures that have been reported. Number of techniques that have been tried indicate that no ideal method exists and that each procedure presents its own merits and demerits (Silver, 1981).

Transportation of the stomach through the posterior mediastinal into the neck was first reported by Ong & Lee (1960). This technique was successfully modified by Le Quesne and Ranger (1966). It may be best described as a "synchronous" combined maneuver, with the head and neck surgeon carrying out a pahryngolaryngectomy with mobilization of the cervical and superior mediasrmal esophagus from above. Meanwhile, the abdominal surgeon mobilizes the stomach, duodenum and esophagus up to the region of the cervical.

A variety of surgical procedures have been used in the treatment of hypopharyngeal cancer since 1954 which include skin graft, deltopectoral flap,

multistage skin flap, laryngeal autograft, tracheal autograft revascularized intestinal autograft colon reposition, gastric reposition, multistage repair with skin flaps and when stomach is unavailable, repositioned colon are now the only alternative to the more favored stomach "pull-up" (Harrison, 1979).

Good results in terms of operation and subsequent function can be obtained using stomach or colon, although at high price in terms of the operative hazards of such intrathoracic procedures.

An extensive study by Huguier, et al. (1970) described the results of 112 patients about evenly divided between colon and stomach transplants. Serious complications and operative mortality were about the same in both; whereas the functional results were superior when using colon. Anostomatic leakage was reported twice as often when using stomach. However, in United Kingdom, there is a tendency to favor the use of stomach (Le Quesne and Ranger, 1966, and Harrison, 1969), on the grounds of simplicity and convenience. Although in the United States (Huguier, et al. 1970; Staley and Scanlon, 1967), and in other countries, the more versatile use of colonic replacement appears to retain favor.

Harrison (1972) provided the surgical results of 63 patients with post cricoid or cervical oesophageal cancer. Thirty five (55%) had primary

pharyngogastric anastomosis. He suggested that in experienced hands and with reasonably fit patients operative mortality should be less than 10%. However, many patients are undernourished and elderly, some having being subjected to a long course of radiotherapy and without adequate dietary control. Myocardial degeneration accounted for the death of three such patients in his own series. Series emphasized that at least 50% of patients treated by this limited procedure developed local recurrences prior to the closure of pharyngooesophageal gap.

Voice and speech characteristics of laryngopharyngoesophageetomees.

Griffiths and Shaw (1973) reported about the details of operation in a series of 26 patients who underwent radical resection for cancer of laryngopharynx and upper oesophagus with repair by isoperistaltic colon transplant through a retrosternal passage. He reported nine alive and well cases after seven years, 6 died of postoperative complications. Nine died of disease and two died of other causes. One of the longest survivors obtained an excellent colonic voice, comparable with good esophageal speech. The patients who died of disease died within 2-year period after surgery.

Saito et al. (1984) reported a tracheogastric shunt method using the gastric mucosal tube for voice restoration with gastric pull up reconstruction following pharyngolaryngoesophagectomy. Thus shunt requires a stent and the

shunt's downward direction is its disadvantage in introducing expiratory air into the oral cavity. Ethrenberger et al. (1985) proposed a sphinctor like tracheohypopharyngeal shunt using free jejunum.

A review of 162 patients including gastric pull up procedures was reported by Harnson (1981). Out of 68 patients who underwent laryngopharyngoesophagectomy, he reported 12% operative mortality, 8.8% operative morbidity, 3% positive margins and 3% local recurrence.

Gastric pull-up reconstructions of hypopharynx and cervical oesophagus is reported to be superior to other methods. A new technique uses this procedure, allowing immediate vocal rehabilitation (Krespi et al. 1984). Five patients underwent pharyngolaryngoesophagectomy for malignant lesions of post cricoid area on cervical oesophagus. There were no instances of stenosis of the mueosa lined semi rigid voice shunt. One patient died ten months after surgery from hypocalcaemia, due to calcium and vitamin D intoxication. Four patients were reported alive and free of disease. The longest survivor was reported alive 18 months after surgery.

Lam et al. (1987) reported 91 patients in a 6 year period (1980 to 1985). The morbidity and mortality rates gradually decreased to 30 - 5% respectively. This was attributed to changes in indication for the operation.

The above studies reported about the different types of surgery. But the studies on the voice rehabilitation and acoustical analysts of the postoperative voice are not given much importance.

Pharyngogastrie anastomosis has become the preferred technique for reconstructing circumferential defects of the hypopharynx and cervical esophagus in many centers. A major reason for the popularity of this technique is early rehabilitation for swallowing, however, speech rehabilitation has not received similar emphasis.

Wei et aL (1984) reviewed the records of 136 patients who had undergone pharyngogastric anastomosis and found that only nine (6.6%) were able to produce audible whisper, another six were able to use the elecrolarynx (4.4%). The remaining 122 patients (89%) had failed voice restoration. Oral intake of food was satisfactory in majority of cases.

Harrison and Thompson (1986) found that an adequate voice was possible in only a small number of 101 patients who were reconstructed by pharyngogastric anastomosis and only by manual compression of cervical stomach or when an undersigned pharyngogastrie fistula happened to be present..

Sehechter et al. (1987) stated that speech restoration after pharyngogastric esophageal reconstruction was not satistactory because only single -words were produced or an electrolaryrrx was required.

(Singer & Blom, first reported their endoseopic techniques for restoration of voice after laryngeetomy in 1980. Success rates for the use of their tracheoesophageal puncture (TEP) technique by others in laryngectomy patients have ranged from 50-85% (Donegan et al. 1981; Wetmore et al. 1985). It has been suggested that good quality speech following this procedure is dependent on the vibration of cricopharyngeous muscle which produces acoustic energy. However, Singer & Blom have found that spasm in this muscle may actually prevent fluent speeeh. Patients who undergo total pharyngolaryn goesophagectomy lose their ericopharyngeous muscle, yet Harrison and Thompson (1986) suggested that tracheogastric shunt might be beneficial for restoring speeeh in patients who underwent pharyngogastric anastomosis.

Medina et al. (1990) confirmed the value of Harrison's suggestion when he reported successful speech rehabilitation by traeheogastric puncture (TGP) in patients who had undergone pharyngogastric anastomosis. In comparing their TGP patients to others who were similarly rehabilitated but reconstructed

by other methods, they found that the TGP patients had a lower fundamental frequency but maintained similar intensity measures.]

Schechter, et al. (1987) presented their 12 year experience with 115 patients who had pharyngoesophageal resections for cancer treatment. Each patient received a reconstruction by 1 of 4 major techniques - Deltopectoral flaps (H243), peetoralis myoeutaneous flaps (H236), gastric pull ups (H219), and free jejunal autografts (H217). Each patient was evaluated in 3 categories i.e., swallowing, weight and speech development. Patients who had preserved larynx were not considered in speech evaluations. Deltopectoral and peetoralis myoeutaneous flap groups had no difference in functional scores. The jejunal autograft group achieved significantly higher seores in swallowing and weight than did either of skin flap groups but scored lower in speech. The gastric pull up group achieved higher seores than did the other reconstruction groups in all three functional categories. The highest seores in speech can be attributed to the effects of negative mtrathoracic pressure on mediastmal portion of gastric pouch. Their speech improves with time as the cervical portion of gastrie pouch apparently diminishes in size secondary to fibrosis.

According to Izdebski et al. (1988), restoration of voice and speeeh in patients with gastric pull up presents a formidable challenge and many of these patients left at best with a poor puncture functional electrolaryngeal speech.

To improve this condition, traeheogastrie puneture stented with a biflanged self retaining Groningon voice button was accomplished resulting in gastric mucosa vibrations during exhalatory phase.

Maniglia et-al. (1989) described their experience with -five patients who underwent a delayed tracheogastric puncture (TGP) after pharyngogastric anastomosis. When compared to patients who had undergone tracheoesophageal puneture (TEP) after laryngeetomy, speeeh intelligibility and fluency were adequate for conversational speech, but voice quality was characterized by lower pitch, reduced intensity, slower rate and wet quality. The mean fundamental frequency of three speakers was 95.5 Hz, mean intensity was found to be 33.3 dB and mean duration as 6.24 sec.

Rinishi, et al. (1991) report of a primary tracheojejunal shunt operation for voice restoration following paryngolaryn goesophagectomy with free jejunum reconstruction for advanced hypopharyngeal cancer. Occluding the tracheostoma with a finger to divert the exhaled air through the TJ shunt into the jejunum, where the sound is produced, could produee voice. AH the patients acquired voice capability with the TJ shunt and consistently use TJ shunt speech. Initial phonation was obtained on 33rd post-operative day, on an average. The duration of sustained vowels ranged from 8 seconds to 12 seconds. The voice intensity ranged from 68 dB sound pressure level (SPL) to

85 dB -SPL, and the air flow rate during phonation ranged from 20 ml/sec to 100 ml/sec. The fundamental frequency could not be detected by the phonatory function analyzer because of noisy component of the voice. Pitch formation was seen in the voice waveform with TJ shunt patients having two different values of mean fundamental frequency that is 100 Hz and above, 300 Hz against the single value obtained in tracheoesophageal patients. The swallowing was better than the patients reconstructed with other grafts such as pectoralis major myocutaneous flap and radical forearm free flap. No spasm, regurgitation, or asphyxiation was seen at all. The natural peristalsis of jejunum may influence production of the high fundamental frequency during phonation.

Bleach et-al (1991) reported the use of Blom-Singer prosthesis in four patients (Table VII), who had undergone pharyngogastric repair following laryngopharyngo-esophagectomy and who had failed to achieve a satisfactory voice. All patients initially developed good speech using prosthesis. Two patients subsequently had their prosthesis removed, one because of recurrent malignant disease and one beeause the procedure had not significantly altered the quality of voice. The remaining two patients had continued to use the device for two and five years after insertion with good voice production.

Table VH depicts the speech characteristics before and after insertion of Blom-Singer procedure in patients with pharyngogastrie repair following laryngopharyngoesophagectomy.

	Pre Tracheogastric puncture				**Post Tracheogastric puncture**			
	Pt.l	**Pt.2**	**Pt.3**	**Pt.4**	**Pt.l**	**Pt.2**	**Pt.3**	**Pt.4**
Mean vowel & duration /a/ (sec)	.5	.5	<.*25*	<.25	5	8	6	9
Syllables/Breath	2		1	1 2	15	12	9	10
	All the subjects had poor speech intelligibility with breathy "gurgly" voice quality				All subjects improved in intelligibility and loudness (subjective reports)			

Premalatha et al. 1997 described their experience with eleven patients of gastric transposition who attended intensive speech therapy and developed gastric speech using different method of speech producing and attaining various levels of proficiency. It was noted that three of the five patients (60%) who applied digital pressure developed "excellent" speech over an average of 9.5 sessions with greater ease than the patients using inhalation method (average If sessions) to come to the word level. In addition, there is an appreciable increase in the frequency, intensity and duration of voiee between gastric speech obtained by the two different techniques. Intelligibility of gastric speech deemed "excellent" and when produced by digital pressure and

is more acceptable than when using inhalation method. Two out of four patients were graded as "just intelligible" speakers who used digital pressure to enhance their communication. Thus application of digital pressure is one of the niost effective technique for production of satisfactory and intelligible voice in gastric transposition cases who fail to develop speech by inhalation method.

A similar finding after gastric repair was noted by Wolfe et al. (1971) who found evidence of poor lower oesopharyngeal sphincter function (Gastrichernia or gastroesophageal reflux) in seven patients with poor esophageal speech. They postulated that the esophagus depended on a competeat distal sphincter in order to act as an effective air reservoir for speech production.

Similarly Baugh et al. (1987) found the insufflation test ineffective if the nasal catheter extended more than 27 cm from the nares, because gastric insufflations resulted gastric pull up patients have no lower oesophageal sphincter, only a large flaccid stomach that tends to distend progressively. It is this factor along with the lack of an effective vibrating segment that causes such difficulty in speech.

The Blom-Singer prosthesis is proven to be beneficial in the rehabilitation of voice after laryngectomy. It is relatively simple technique and has been used both as a primary procedure at the time of laryngectomy (Juarbe et al. 1986; Milford et al. 1988) and as a secondary procedure in patients who have failed to develop esophageal speech. The use of B.S. prosthesis in patients who required gastric pull up repair appears to be similarly effective as reported by Bleach et al. (1991). This application was not previously described. They concluded that the use of Blom-Singer voice prosthesis is an effective method of surgical rehabilitation of speech following laryngopharyngoesophagectomy and pharyngogastric anastomosis.

Rajashekar and Anupriya (2000) conducted a study on a patient who was rehabilitated with the B.S. prosthesis. He underwent total laryngopharyngoesophagectomy with a gastric pull-up for voice restoration. Their acoustical analysis showed the mean fundamental frequency (phonation) as 75 Hz and mean fundamental frequency (speech) as 85 Hz. Extent and speed of fluctuations in fundamental frequency were reported as 76.9 Hz and 9 respectively. Extent and speed of fluctuations in intensity were reported to be 2.9 dB and 4.5. Word duration /ondu/ was 1146 ms whereas intelligibility and acceptability were reported to be 88% and 2.5 (on 5-point rating scale).

The review of literature, thus, shows that the voice rehabilitation in laryngopharyngoesophagectomees is not given much importance. There is a need for studying acoustic, temporal and perceptual parameters in conventional gastric and tracheogastric speakers. As pointed by Robbins, 1984, such findings 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. This particularly gain importance as there are few studies using Indian population especially on tracheogastric speakers.

Therefore, the present study is aimed at acoustic and temporal analysis of these two modes of speech and to explore their relative contribution to the acceptability and intelligibility of speech.

CHAPTER III

METHODOLOGY

The purpose of this study is to:

1) conduct acoustic and temporal analysis of Blom-Singer (B.S) prosthesis aided Tracheogastric (T.G) speech and conventional gastric speech,
2) determine the acceptability and intelligibility of TGP and gastric modes of alaryngeal speech, and
3) identify the importance of various parameters contributing to intelligibility and acceptability of T.G. and gastric speech.

The parameters considered as useful and feasible have been measured in the present study. These parameters are grouped as follows:

Acoustic measures:

I a) Frequency

1) Fundamental frequency (Fo) in phonation (/a/, /i/, /u/)
2) Fundamental frequency in speech
3) Extent and speed of fluctuations in fundamental frequency in phonation (/a/, /i/ & /u/)

b) Intensity

4) Intensity range in phonation.
5) Intensity range in speech.
6) Extent and speed of fluctuations in intensity in phonation (/a/, /i/ & /u/).

II Temporal Measures

7) Maximum phonation duration (MPD) (/a/, /i/, & /u/).
8) Syllables per breath/air charge (SPB)

III Perceptual/Psycho-acoustic measures

9) Acceptability
10) Intelligibility

Subjects:

Comprised of four speakers who underwent laryngopharyngo-esophagectomy with gastric pull-up using gastric speech mode or tracheogastric mode (B.S. prosthesis). All of them were screened for hearing impairment and neurological condition. Their pure tone thresholds in speech frequencies were within normal limits. They had no other speech problems.

All the subjects received speech therapy to produce gastric speech or TGP speech. Details of these subjects are provided in case reports.

Procedure:

The speech samples of all the subjects were recorded individually in a sound treated chamber. Recordings were made using metal cassette using professional stereo cassette deck and having unidirectional microphone which was kept at a distance of 12 cm. from mouth.

All the subjects were required to perform the following tasks:

1) **Phonation of vowels:** Verbal instructions were given to the subjects. The tracheogastric puncture (T.G.P.) speakers were instructed to "take a deep breath, close the puncture with the finger and say /a/ as long as possible, without removing the finger." The gastric speakers were instructed to "insufflate the stomach and say /a/ as long as possible in one breath." This was followed by demonstration by investigator. Three trials of /a/ /i/, and /u/ were recorded for all the subjects.

The recorded samples of vowels (/a/, /i/ & /u/) were used for measuring the following parameters.

a) Mean fundamental frequency
b) Extent and speed of fluctuations in fundamental frequency in phonation.
c) Extent and speed of fluctuations in intensity in phonation
d) Intensity range.
e) Maximum phonation duration (MPD)

2) **Syllables per breatli:** To measure this parameter, subjects were asked to say /ba/ as many times as possible in single exhalation. T.G. speakers were asked to "take a deep breath closing the puncture with finger and say /ba/ as many times as possible without removing the finger. The gastric speakers were asked to insufflate the stomach and say /ba/ as

many times as possible in one breath." The gastric speakers and TGP speakers were given 2-3 trials before the final recording to make sure that they understood the instructions. Three trials were recorded. Thus the number of syllables/breath was measured for each subject.

3) **Speech sample:** Subjects were asked to read three meaningful non-emotional Kannada sentences (I) /idu topi/, 2) /idu kannu/, and (3) /idu pennu/. Each subject was required to repeat these sentences thrice and recordings were done.

These recordings were used to obtain the following parameters:

a) Fundamental frequency in speech
b) Intensity range in speech

4) **Reading a list of words:** Subjects were required to read a set of 50 most familiar words in Kannada chosen from the test material used at Department of Speech Pathology, AIISH, Mysore for routine diagnostic purposes (Appendix A). A time gap of 5 seconds was provided between the words. The recorded speech samples were used to measure the intelligibility of subjects from all three groups.

5) **Reading a passage:** The subjects were asked to read a standardized passage developed and routinely used in the Department of Speech

Pathology, AIISH, Mysore, for speech and voice evaluation (Appendix B). The subjects were instructed to read at comfortable rate and loudness. Familiarization to the passage was done before recording. The task was used for the acceptability measurements.

Analysis

I Acoustic analysis:

Analysis was made using the following equipment:

1) Tape Deck to play the recorded speech samples.
2) Antialiasing filter **(LPF** having cut-off frequency at 7.5 kHz)
3) A-D/D-A converter (sampling frequency of 16 kHz - 12 bit)
4) PC (AT Intel 80386) Micro Processor with 80837 numerical data processor.
5) Software (developed by Voice and Speech Systems, Bangalore) for acoustic and temporal analysis
6) Amplifier and speaker.

Procedure:

The recorded speech samples of each subject were digitized at the rate of 16 kHz using 12 bit VSS data input and output cord by feeding the signal from tape deck to the speech interface unit through the line feeding. To analyze the fundamental frequency and intensity related parameters, the upper limit of the lower level was specified. The upper limit was given as 200 Hz and

the lower level was 50 Hz. The digitized samples were stored in hard discs/floppies for further analysis.

All the parameters were obtained from the analysis of digitized sample of speech.

All the three trials of utterances of each word were recorded and best sample of the three samples was selected for analysis. The values of each parameter for each subject were tabulated.

The following parameters were analysed using the above procedure.

1) Fundamental frequency in phonation
2) Fundamental frequency in speech
3) Extent and speed of fluctuations in fundamental frequency in phonation (/a/, /i/ and /i/)
4) Intensity range in phonation
5) Intensity range in speech
6) Extent and speed of fluctuations in intensity in phonation (/a/, /i/and /u/)

II **Temporal Analysis:**

1) Maximum phonation duration (MPD)

The MPD was measured by using stop watch. MPD was determined for three trials of /a/. The longest of three trials was considered the MPD of

/a/ for that subject. Similarly, the MPD of /i/ and /u/ for each subject was determined. Thus, the MPD was obtained for all the four subjects.

2. Syllables per breath (SPB)

The numbers of syllables (/ba/) uttered in one breath or air charge for each subject were measured using the computer. Display of the utterances was obtained on the screen of the computer and the number of peaks representing each syllable was counted. Thus, the number of syllables/air charge for each subject was obtained.

III **Perceptual Analysis**

1) Intelligibility of speech

The recorded word list materials by all the subjects were played at a comfortable loudness levels to the listeners from a tape recorder in noise free environment. The judges were requested to write down the words as they heard them from the tape recorder and not as what they thought the word could be. For totally unintelligible words, they were asked to draw blanks. The interjudge reliability for both the judges for the four subjects was determined by correlation. The intelligibility scores was computed as percentage [(number of words correctly identified/total number of words) x 100]. Intelligibility scores provided by both the

judges were averaged and that was considered as the intelligibility of that subject.

2) Acceptability

The recorded speech material (passage reading task) 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 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 (cannot understand anything at all).

The interjudge reliability for both the judges for the four subjects was determined by correlation. The average of the ratings by both the judges was taken as the acceptability score for that subject.

All the acoustic parameters and one temporal parameter (maximum phonation duration) were compared with the age and sex matched controls, the

normative data of the laryngeal speakers were obtained from the study done by Suresh, (1991). Another temporal parameter (syllables per breath) was obtained from the study done by Rajashekar (1991).

Definitions of all parameters are given in Appendix C.

CASE REPORTS

Case 1: A 35 year old man presented with throat pain and headache. Stroboscopy findings confirmed a growth in retroarytenoid area extending to cricoid area. Right vocal cord was mobile whereas left vocal cord movement was restricted. Indirect laryngoscopy showed overlapping epiglottis. Endoscopic findings revealed growth in cricopharyngeal region i.e., post-cricoid growth involving sphincter. Biopsy gave a histological diagnosis of squamous cell carcinoma. A laryngopharyngoesophagectomy and pharyngogastric anastomosis (gastric pull-up) was performed. The postoperative course was uncomplicated (diet mixed, sound sleep, bowel and bladder control) and the patient underwent regular outpatient review.

After around 10 months, patient was referred for speech therapy. He attended 19 sessions of therapy. He was able to produce the speech sounds with good intelligibility by providing the digital pressure. Re-evaluation was

done after a year and there was no sign of reoccurrence of cancer and he was able to communicate using intelligible speech.

Case 2: A 61 year old man underwent total laryngopharyngoesophagectomy with gastric pull-up for carcinoma of post cricoid that extended to the larynx, esophagus and posterior pharyngeal wall. Histological examination of the specimen confirmed differentiated squamous cell carcinoma. Two months later, patient was better with no postoperative complication. Speech therapy was initiated after two months to achieve gastric speech. "Inhalation along with digital pressure" method was adopted. The case was able to get belch sounds frequently. His speech was intelligible and also had adequate loudness.

Case 3: A 47 year old man underwent total laryngopharyngoesophagectomy with gastric pull-up for post cricoid carcinoma extended to the larynx, esophagus and posterior pharyngeal wall. Histological examination revealed squamous cell carcinoma. Stroboscopy indicated restricted movement of vocal folds. Case attended speech therapy for 20 days but could not develop reasonable speech. Case wanted to try Blom-Singer prosthesis. Tracheogastric puncture was performed and after one month, he was fitted with prosthesis. Within 10 sessions, he started using it well with index finger to occlude the stoma and produce speech.

Case 4: A 43 year old women was referred for assessment, having undergone radiotherapy followed by laryngopharyngoesophagectomy for post cricoid carcinoma. The case reported of voice change, cough, sputum expulsion and stridor. No dysphagia or odynophagia was present. Endoscopic findings revealed oedema of larynx, stomach erosion and bleeding. Stroboscopic examination showed restricted vocal cord movement during adduction. Squamous cell carcinoma was revealed on biopsy. The case underwent speech therapy for around one month. However, never developed reasonable speech and had, as a consequence suffered many social problems.

The main complaint was regurgitation of stomach contents on attempting loud speech. The videoflouroscopy assessment confirmed hypotonicity. The air insufflation test, however, produced no voice and digital pressure made no improvement. This problem was thought to be due to inability to inflate the stomach with sufficient air. But she could attain gastric voice and with external digital pressure (external pressure band) client could improve her voice quality. Despite of this, she wanted to try Blom Singer prosthesis. Tracheogastric puncture was performed and within four weeks, she was fitted with the prosthesis and was using it well with index finger to occlude the stoma and produce speech.

CHAPTER IV

RESULTS AND DISCUSSION

The present study was undertaken to analyse the speech produced by conventional gastric speakers and Blom-Singer prosthesis aided tracheogastnc speakers in terms of acoustic, temporal and perceptual parameters. The parameters were compared with the normal subjects to explore the possibilities of suggesting therapeutic implications.

Each case was compared to age and sex matched normal group (Suresh, 1991, Rajashekar, 1991) for acoustic and temporal parameters. The normal groups were named as group 1,2 3 and 4 corresponding to the cases 1, 2, 3 and 4.

Perceptual analysis was done by two judges (experienced speech and language pathologists). The interjudge reliability for intelligibility was 0.94 and 0.88 for acceptability.

The parameters analysed for all subjects (gastric mode speakers - cases 1 and 2, tracheogastric speakers - cases 3 and 4) are discussed, in the following section.

GASTRIC SPEAKERS (Cases 1 & 2)

I Acoustic measures:

a) Fundamental frequency

Both the gastric speakers (case 1 & 2) obtained lower fundamental frequency in phonation as compared to normals. However, case 1 showed higher fundamental frequency for /u/ compared to normal subjects as depicted in Table IX.

Table IX. Mean and S.D. of fundamental frequency (Hz) (phonation) in normals and fundamental frequency (Hz) (phonation) in gastric speakers.

	Normals (Group 1)		Case 1
	Mean	S.D.	
/a/	122.28	12.55	94.23
lii	121.66	11.39	100.28
/n/	119.23	7.53	127.91
	Normals (Group 2)		Case 2
	Mean	S.D.	
/a/	150.63	23.80	91.75
lil	145.06	22.97	100.25 .
/u/	144.43	32.59	104.05

The lower fundamental frequency in phonation can be attributed to the failure of flaccid stomach to provide efficient pharyngogastric vibratory

segment. The voice thus tends to be gurgling in quality due to liquid gastric content that is particularly noticeable after meals. This result supports the findings of Premalatha et al. (1997) and Rajashekar and Anupriya (2000). Figure 2 displays the sample frequency vs. time and intensity vs. time wave forms in phonation in one of the gastric speakers.

Wolfe et al. (1971) and Baugh et al. (1987) suggested that the gastric pull up patients have no lower esophageal sphincter and has only a large flaccid stomach that tend to distend progressively, together with lack of an effective vibrating segment that causes difficulty in speech production. The higher fundamental frequency for /u/ in case 2 can be attributed to the intra-subject variability (Weinberg, 1982) which is one of the important defining property of alaryngeal voices.

In normals, speech production of high vowels has a higher fundamental frequency than low vowels. Various explanations have been offered to account for these intrinsic variations in fundamental frequency between vowels. The source tract coupling hypothesis (Atkinson, 1973) and the tongue-pull hypothesis (Ladefoged, 1968; Lehiste, 1961) dominate the plethora of explanations.

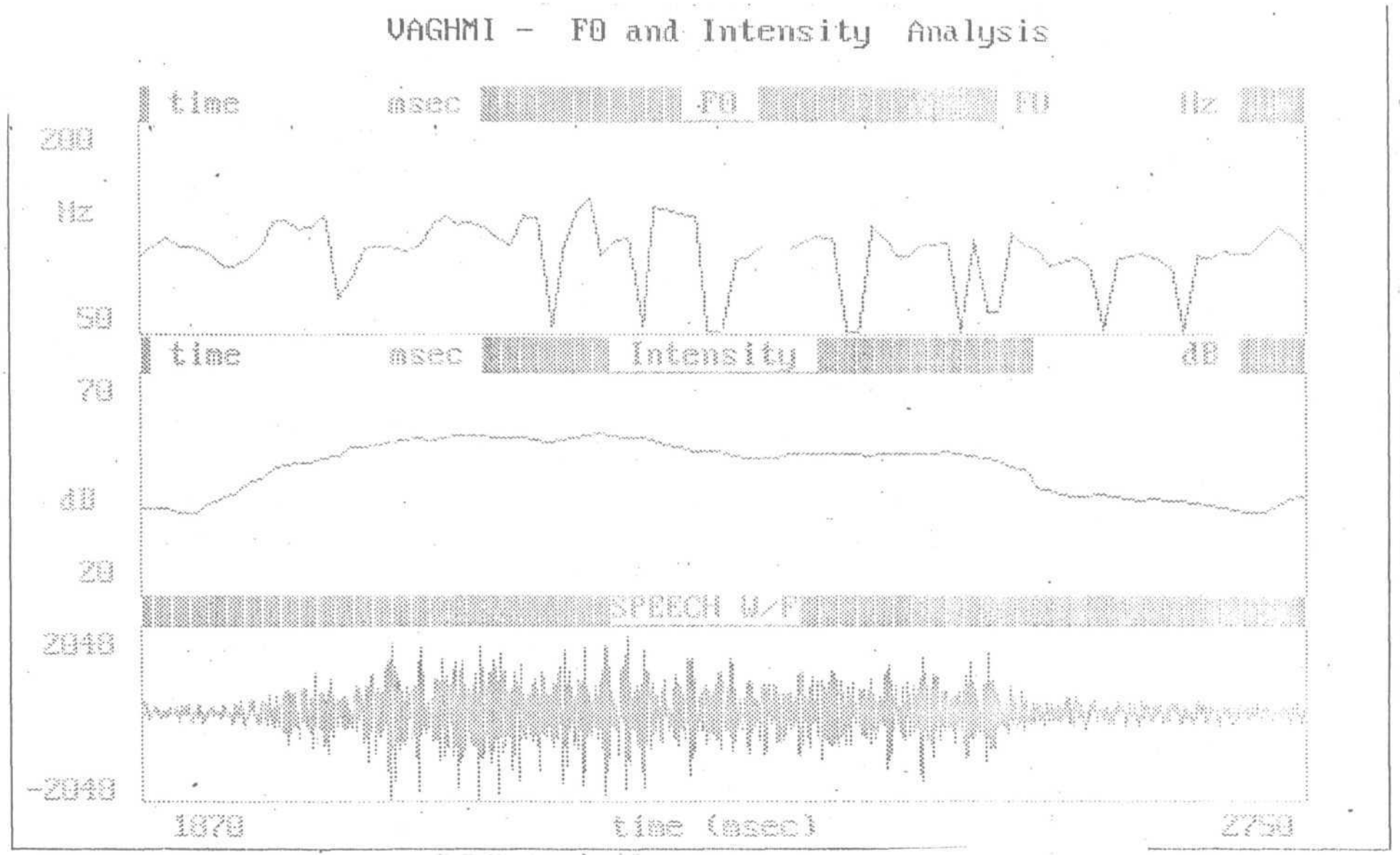

Figure 2 shows sample waveform of frequency vs. time and intensity vs. time for phonation in gastric speakers

The source tract coupling hypothesis states that coupling between vocal tract and source occurs when the first formant frequency of the vowel is near the fundamental frequency of the source. This results in increase in fundamental frequency for high vowels. In low vowels, coupling does not occur due to the first formant being farther away from fundamental frequency.

The tongue-pull hypothesis states that as the tongue is stretched or elevated to produce high vowels, a pull is exerted on the larynx altering the sensation of the vocal folds and consequently, an increase in fundamental frequency.

Weinberg's contention was that in laryngectomees, there is no question of hyoid influence, mediating tongue pull on the tongue. If tongue pull hypothesis is correct, systematic differences in fundamental frequency between high vs low vowels in laryngectomees, would not be expected.

The observed higher mean fundamental frequency for high vowels *I'll & lul* in both gastric speakers in this study does not offer support to the source tract coupling hypothesis as well as tongue pull hypothesis.

b) Fundamental frequency in speech:

The fundamental frequency in speech for both case 1 and 2 was lower than normal subjects as presented in Table X.

Table X. The Mean & S.D. of fundamental frequency (Hz) (speech) in normals (group 1 & 2) and fundamental frequency (hz) (speech) in gastric speakers

Normals (Group 1)		Casel
Mean	S.D.	
223.5	9.11	116.09
Normals (Group 2)		Case 2
Mean	S.D.	
211.10	34.15	151.34

The results are supported by the study done by Rajashekar and Anupriya (2000). The lower fundamental frequency for speech in both the cases can be attributed to the same reasons as given for lower fundamental frequency in phonation.

c) Extent and speed of fluctuations in frequency in phonation:

Extent and speed of fluctuations were found to be greater in both the cases when compared to the normal subjects as presented in table XI & XII. Similar findings were reported by Rajashekar and Anupriya (2000).

Table XL Mean and S.D of extent of fluctuations (Hz) in fundamental frequency in normals (Group 1 & 2) and extent of fluctuations (Hz) in fundamental frequencies in gastric speakers

	Normals (Group 1)		Case l
	Mean	S.D.	
/a/	3.44	0.5	62.75
/i/	3.46	0.7	47.62
/u/	3.39	0.4	34.65
	Normals (Group 2)		Case 2
	Mean	S.D.	
/a/	3.28	0.78	30.58
/i/	3.46	1.00	31.87
/u/	3.05	1.25	37.33

The higher extent of fluctuations in sustained phonation reflects less stability in control of fundamental frequency.

Table XII. Mean and S.D of speed of fluctuations in fundamental frequency in phonations of normals (Group 1 & 2) and speed of fluctuations in fundamental frequencies in gastric speakers

	Normals (Group 1)		Case l
	Mean	S.D.	
/a/	2.54	1.00	17.77
/i/	2.86	0.93	33.14
/v/	2.26	0.78	31.52
	Normals (Group 2)		Case 2
	Mean	S.D.	
/a/	2.74	2.52	25.01
/i/	2.89	2.29	20.94
/v/	2.24	1.75	24.54

The greater values of extent and speed of fluctuations suggests irregularity in the vibrations of vibratory segment.

d) Intensity range in phonation:

Intensity range in phonation of /a/, /i/ and /u/ was found to be greater than normal subjects (Table XIII).

Table XIII. Mean and S.D of intensity range (dB) in phonation in normals (Group 1 and 2) and intensity range (dB) in gastric speakers.

	Normals (Group 1)		Case 1
	Mean	S.D.	
/a/	5.36	1.34	17.72
/i/	5.13	2.36	26.72
/u/	4.36	0.90	28.9
	Normals (Group 2)		Case 2
	Mean	S.D.	
/a/	4.22	1.65	19.56
/i/	3.76	2.22	16.99
/u/	4.33	6.33	17.89

The PE segment varies in individuals in terms of location, tonicity and in morphology which contributes in individual differences. The greater intensity range indicates the gastric mode speakers inability to maintain the intensity at steadv level.

e) Intensity Range in speech:

The intensity range in speech in both the cases did not differ from values obtained for normal subjects (Table XIV).

Table XIV. Mean and S.D. of intensity range (dB) in speech in normals (Group 1 & 2) and intensity range (dB) in speech in gastric speakers.

Normals (Group 1)		Case 1
Mean	S.D.	
24.10	3.92	22.12
Normals (Group 2)		Case 2
Mean	S.D.	
23.50	6.34	20.43

These findings indicate that though the speakers differed from the normal groups in intensity range in phonation, they did not differ much in terms of intensity range in speech. This implies the ability of speakers to maintain at par with the normal laryngeal speakers during speech.

f) Extent and speed of fluctuations in intensity in phonation:

The extent and speed of fluctuations in intensity for all the vowels /a/, /i/ and /v/ in sustained phonation were more than the normal groups (Table XV).

Table XV. Mean and S.D of extent of fluctuations (dB) (intensity) in sustained phonation in normals and extent of fluctuations (dB) (intensity) in phonation in gastric speakers.

	Normals (Group 1)		Case 1
	Mean	S.D.	
/a/	2.39	1.11	9.8
/i/	1.60	1.38	14.29
/v/	1.34	0.70	11.8
	Normals (Group 2)		Case 2
	Mean	S.D.	
/a/	1.31	0.98	5.76
/i/	1.42	1.33	7.69
/u/	0.71	0.41	5.94

Similarly higher speed of fluctuations in intensity in phonation were also observed compared to normal groups (Table XVI).

Table XVI. Mean and S.D. of speed of fluctuations (intensity) in phonation for normal groups and speed of fluctuations (intensity) in phonation in gastric speakers.

	Normals (Group 1)		Case 1
	Mean	S.D.	
/a/	1.43	0.74	5.76
/i/	0.74	0.70	7.69
/v/	1.42	1.40	8.52
	Normals (Group 2)		Case 2
	Mean	S.D.	
/a/	0.54	0.79	4.01
/i/	0.43	0.91	3.61
/u/	0.51	1.36	4.40

The higher values for extent and speed of fluctuation in intensity are also reported by Rajashekar and Anupriya (2000).

The higher extent and speed of fluctuation in intensity reflected inability of the gastric speakers to maintain intensity of voice. The increased extent of fluctuations in intensity was reported by Robbins et al. (1984) attributing to the rapid depletion of air. He reported greater mean shimmer in alaryngeal speakers than in normals. This can also be attributed to the gastric speakers.

Temporal Parameters

a) **MPD**

The cases 1 and 2 showed reduced MPD for all three vowels compared to the normal subjects. Highest MPD was obtained for /a/ followed by /i/ and /u/ respectively (Table XVII).

Table XVII. Mean and S.D. of MPD (sec) in normals and MPD (sec) in gastric speakers

	Normals (Group 1)		Case I
	Mean	S.D.	
/a/	18.10	2.33	1.2
/i/	19.15	3.00	1.1
/u/	19.50	2.87	0.9
	Normals (Group 2)		Case 2
	Mean	S.D.	
/a/	14.72	2.36	1.6
/i/	14.71	2.94	1.5
/u/	14.53	2.76	1.2

The differences between MPDs across vowels do not differ appreciably. The reduced MPD for cases 1 and 2 can be due to low volume of air in stomach of conventional gastric speakers. Both the gastric speakers demonstrated higher MPD values compared to the MPDs demonstrated by five patients studied by Bleach et al. (1991).

b) Syllable per breath

Table XVIII presents the mean and S.D. of SPB for normals and SPB of case 1 and 2

Normal		Case 1	Case 2
Mean	S.D.		
68	21.9	1	6

Similar values to case 1 were demonstrated by Bleach et al. (1991) for SPB in 2/4 of his patients. Other two demonstrated 2 SPB each. However, in this study, case 2 could compensate better for the low air volume in the stomach.

The lesser SPB value in gastric speakers can be attributed to amount of air insufflated in stomach in very much reduced volume compared to the pulmonary air supply. The low volume of air in stomach of conventional gastric speakers probably limits the syllables per breath.

Perceptual parameters:

Acceptability and Intelligibility

The cases 1 and 2 showed the acceptability rating of 2.5 and 5 respectively. Case 2 with maximum rating score performed exceptionally well on reading task. Shipp (1967) and Hoops and Noll (1969) have opined 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 and not the mode of alaryngeal speech had a significant effect on judgements of acceptability. The judges who rated the acceptability of the subjects in this study attributed pitch, clarity of words, extraneous noise, pause duration, rate of speech and voice quality as factors influencing their judgement of acceptability. Due to the vanation of all these parameters, the acceptability rate varied among these subjects.

The mean intelligibility scores (%) computed from the scores of two judges for the subjects (case 1 and 2) were 35% and 100% respectively. Weinberg (1982) opined that total laryngectomy results in major changes in articulatory aerodynamics and produced alteration in vocal tract morphology. Further, the intention of gestures essential for air filling exerts disruptions in dynamic articulatory behaviour in such speakers. However, case 2 performed at par with the normals showing that the speech was more natural, speaker could manage to compensate for the altered articulatory aerodynamics and vocal tract morphology. However, the rate of speech was found slower than normals.

TRACHEOGASTRIC SPEAKERS (Cases 3 and 4)

a) Fundamental frequency in phonation:

The fundamental frequency in phonation presented by cases 3 and 4 as compared to the normal age and sex matched groups is depicted in Table XIX).

Table XIX. Mean and S.D. of fundamental frequency (Hz) in phonation in normals (Group 3 and 4) and fundamental frequency (Hz) in tracheogastric speakers

	Normals (Group 3)		Case 3
	Mean	S.D.	
/a/	123.10	13.78	93.02
/i/	128.60	11.39	119.39
/u/	119.23	7.53	116.33
	Normals (Group 4)		Case 4
	Mean	S.D.	
/a/	190.80	16.22	100.39
/i/	200.53	17.10	110.01
/v/	202.10	19.33	118.09

4

Case 3 presented the similar values of fundamental frequency for vowels /i/ and /u/ whereas fundamental frequency for /a/ was lower than the normal group. The lower fundamental frequency in phonation in TGP cases was also reported by Maniglia et al. (1989).

The similar values obtained in case 3 and normals can be attributed to the use of pulmonary air flow in TG speakers which is accomplished with a closed tracheal air way.

However, case 4 depicted lower fundamental values for all vowels compared to the age matched normal female subjects. The probable reason can be intersubject variability in terms of anatomy (tonicity of vibrating segment), air leakage through stoma, inadequate digital pressure etc. Figure 3 displays the sample frequency vs. time and intensity vs. time I phonation in one of the TGP speakers.

Similar to cases 1 and 2, in cases 3 and 4 also, the higher mean fundamental frequency for high vowels *IV* and *Id* does not support the source tract coupling hypothesis and tongue-pull hypothesis.

b) Fundamental frequency in speech

Both male and female TGP cases showed lower fundamental frequency for speech as compared to normal subjects (Table XX).

Table XX. Mean and S.D. of fundamental frequency (Hz) in speech in normals and fundamental frequency (Hz) in speech in TGP speakers.

Normals (Group 3)		Case 3
Mean	S.D.	
204.4	35.89	106.52
Normals (Group 4)		Case 4
Mean	S.D.	
137.8	8.43	110.7

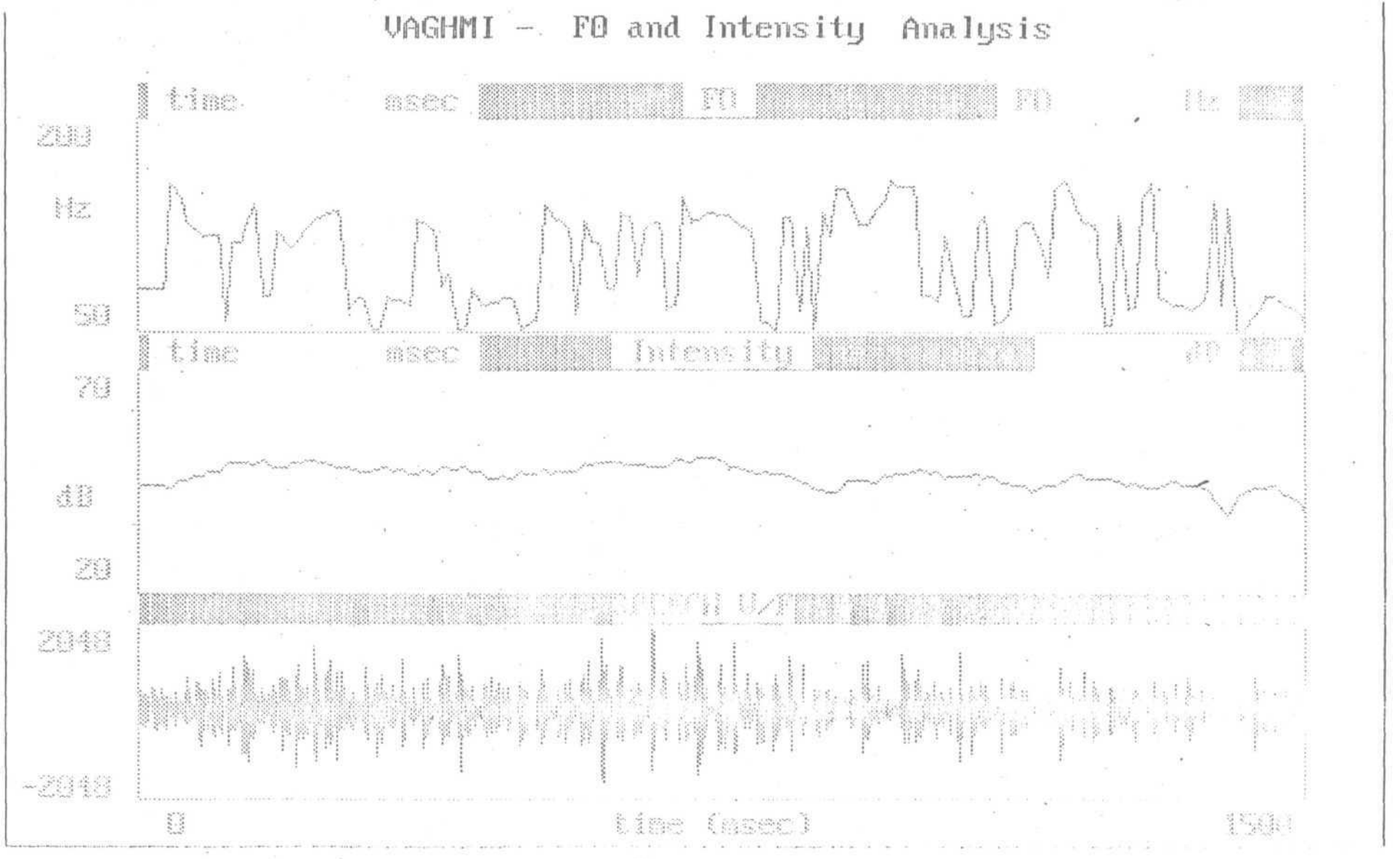

Figure 3 shows sample waveform of frequency vs. time and intensity vs. time for phonation in TGP speakers.

The lower fundamental frequency in speech can be due to differences in anatomical and physiological mechanisms used by the alaryngeal speakers during voice production.

c) **Extent and speed of fluctuations in frequency in phonation**

Table XXI and XXII show the results with reference to extent and speed of fluctuations in fundamental frequency in phonation of /a/, /i/ and /u/ for the cases 3 and 4.

Table XXI. Mean and S.D. of extent of fluctuations (Hz) in frequency in normals (Group 3 and 4) and extent of fluctuations (Hz) in TGP speakers.

	Normals (Group 3)		Case 3
	Mean	S.D.	
/a/	3.57	0.54	68.8
/i/	3.69	0.72	59.62
/u/	3.50	0.49	51.30
	Normals (Group 4)		Case 4
	Mean	S.D.	
/a/	4.32	1.56	66.89
/i/	3.73	0.42	58.28
/u/	3.90	1.03	59.5

Table XXII depicts that both male (case 3) and female TGP (case 4) speakers had higher speed of fluctuations than normal groups.

Table XXII. Mean and S.D. of speed of fluctuations in frequency in normals (Group 3 and 4) and extent of fluctuations in TG speakers

	Normals (Group 3)		Case 3
	Mean	S.D.	
/a/	2.44	1.49	33.69
/i/	2.54	1.58	15.81
/u/	2.64	1.51	18.49
	Normals (Group 4)		Case 4
	Mean	S.D.	
/a/	4.49	1.93	31.92
/i/	3.69	1.30	28.62
/u/	3.96	1.80	23.91

The higher extent and speed of fluctuations in cases 3 and 4 may be attributed to the irregularity in vibrations of the vibrating segment (stomach wall / pharyngogastric segment).

d) Intensity range in phonation

Case 3 demonstrated intensity range for /i/ and /u/ close to the normal groups however, intensity range for /a/ was higher than normal subjects. However, case 4 presented higher range of intensity for all the vowels (Table XXIII).

Table XXIII. Mean and S.D. of intensity range (dB) in phonation in normals (Group 3 and 4) and intensity range (dB) in phonation in TG speakers.

	Normals (Group 3)		Case 3
	Mean	S.D.	
/a/	6.22	1.96	11.74
/i/	5.70	1.55	5.92
/u/	5.33	1.93	5.16
	Normals (Group 4)		Case 4
	Mean	S.D.	
/a/	3.80	0.83	12.73
/i/	5.06	0.91	20.99
/v/	3.83	0.63	7.74

The higher intensity range in case 4 for all the vowels indicates inability of the case to maintain the intensity at steady level. This may be due to inadequate air supply or inefficiency of the vibrating segment.

e) Intensity range in speech

Case 3 demonstrated higher intensity range in speech compared to age and sex matched normal group, however, the female speaker (case 4) demonstrated intensity range similar to normal group (Table XXIV).

Table XXIV. Mean and S.D. of intensity range (dB) in speech in normals (Group 3 and 4) and intensity range (dB) in speech in TG speakers.

Normals (Group 3)		Case 3
Mean	S.D.	
22.10	5.14	34.41
Normals (Group 4)		Case 4
Mean	S.D.	
28.20	7.74	27.76

Both the cases showed contrary results compared to phonation i.e., case 1 could maintain the intensity range steady in phonation but showed higher range than normal subjects in speech. However, case 4 showed inability to maintain the intensity in sustained phonation but showed intensity range in speech similar to normal subjects.

The higher intensity ranges in speech or phonation indicates inability to control the vibratory behaviour of the vibrating segment.

f) Extent and speed of fluctuations in intensity in phonation

Extent of fluctuations demonstrated by case 3 were close to the values obtained by normal subjects except for /i/ which showed slightly higher extent of fluctuations than normals, whereas case 4 demonstrated higher extent of fluctuations than corresponding normal group (Table XXVI).

Table XXVI. Mean and S.D. of extent of fluctuations in intensity (dB) (phonation) in normals (Group 3 and 4) and extent of fluctuations (dB) in TG speakers.

	Normals (Group 3)		Case 3
	Mean	S.D.	
/a/	1.65	1.03	1.28
/i/	1.81	1.05	4.85
/u/	1.95	0.96	0.2
	Normals (Group 4)		Case 4
	Mean	S.D.	
/a/	1.32	1.18	7.28
/i/	3.57	0.79	6.62
/u/	1.08	0.91	1.65

Similarly, in terms of speed of fluctuations both the speakers (cases 3 and 4) demonstrated slightly higher values compared to their corresponding normal subjects (Table XXVII).

Table XXVII. Mean and S.D. of speed of fluctuations in intensity (phonation) in normals (Group 3 and 4) and speed of fluctuations in TG speakers.

	Normal (Group 3)		Case 3
	Mean	S.D.	
/a/	1.00	0.85	3.55
/i/	0.82	1.09	3.89
/u/	0.87	0.72	0.2
	Normal (Group 4)		Case 4
	Mean	S.D.	
/a/	0.45	0.78	3.93
/i/	0.35	0.44	4.26
/u/	0.09	0.09	3.06

Both the speakers demonstrated lesser extent and speed of fluctuations in intensity compared to the fundamental frequency in phonation.

The decreased values could be due to the available pulmonary support facilitating maintenance of intensity or intensity stability.

The difference in TGP speech and normal speech can be attributed to the anatomical physiological mechanisms used by alaryngeal groups for voice production. This is supported by Robbins et al. (1984) who opined that the

differences in the anatomical physiological mechanisms used by the alaryngeal groups for production of voice were not only different from those employed by laryngeal speakers but were substantially different from those employed by each other.

Temporal parameters

a) MPD

Lower MPD values were demonstrated by both the TGP speakers compared to the normal subjects as shown in table XXVIII. The MPD for /a/ is lower than the MPD values demonstrated by the patients (n=4) in study by Bleach, etal (1991).

Table XXVIII. Mean and S.D. of MPD (sec.) in normals (Group 3 and 4) and MPD (sec.) in TG speakers.

	Normals (Group 3)		Case 3
	Mean	S.D.	
/a/	13.55	2.26	6.0
/i/	14.8	2.05	5.1
/u/	14.95	1,78	4.2
	Normals (Group 4)		Case 4
	Mean	S.D.	
/a/	17.55	3.32	3.0
/i/	18.55	15.22	3.2
/u/	18.55	15.90	2.5

The difference between MPDs across the vowels did not differ significantly. Low MPD values in the TGP cases as compared to normals may be probably due to the high trans-source flow rates and poor digital

occlusion of stoma resulting in leakage of pulmonary air prior to its diversion into the stoma by prosthesis. The TGP speakers have better access to larger volumes of pulmonary air supply enabling them to sustain phonation longer than the conventional gastric speakers.

b) **Syllable per breath/air charge (SPB)**

The mean syllables per breath in normal groups and SPB in cases 3 and 4 as compared to normal groups are given in Table XXIX.

Table XXIX. Mean and S.D. of SPB in normals and SPB in cases 3 and 4

Normal		Case 3	Case 4
Mean	S.D.		
68	21.9	36	29

In spite of accessibility of larger volume of pulmonary air in tracheogastric speaker, the case showed reduced SPB. This can be attributed to the greater than normal resistance offered by the prosthesis and the tracheostoma valve worn by T.G. speakers. However, the same values can not be expected in the conventional gastric speakers without prosthesis because amount of air that can be insufflated and stored in the stomach is very much reduced when compared to the pulmonary air supply and the low volume of air in stomach of conventional gastric speakers, which limits the syllables per air charge that they can produce. In this study also the value of SPB in gastric speakers are very less. It may further be stated that

the stomal air leak owing to inappropriate occlusion of the stoma and puncture may also reduce the syllables/breath in TGP speakers compared to normals.

Peceptual parameters

Acceptability and Intelligibility

The cases 3 and 4 showed the acceptability ratings of 4 and 3.5 respectively.

The mean intelligibility scores (%) for cases 3 and 4 as computed from the scores of two judges were 90% and 55% respectively. Though the scores were poorer than normals should be fairly good for a TGP speaker compared to gastric speakers.

TGP speakers also use pulmonary air for voice production like normals and are accomplished with a closed tracheal air way. Their pitch did not differ significandy from normals.

Also the intensity range for phonation and intensity range for speech were found to be similar to normal groups in cases 3 and 4 respectively. Lower extent and speed of fluctuations in intensity in both the cases indicated greater intensity stability.

All the above factors may be contributing to the acceptable and intelligible speech in both the speakers.

All the four cases in this series developed satisfactory voice after speech therapy. Though successful acquisition of voice was noted in all the cases following voice therapy, variation was noted in their level of proficiency. All the cases benefited from digital pressure for voice production. Cases 3 and 4 were able to obtain maximum proficiency in lesser number of sessions than gastric speakers (case 1 and 2).

Patients who have undergone laryngopharyngoesophagectomy have had extensive surgical resection. Pharyngogastric anastomosis, although providing a reliable rehabilitation of swallowing does tend to produce a voice of little power and of "gurling" quality. Speech production after gastric repair is difficult because the large flaccid stomach fails to develop a true pharyngogastric vibrating segment. The voice therefore tends to be weak and whispery and has an additional gurgling quality due to liquid gastric content that is particularly noticeable after meals.

This weak gurgling voice may be improved by external digital pressure over the neck, which creates an effective pharyngogastric vibrating segment or pseudoglottis (Logemann, 1983). Similarly, by using an applied device such as

the Dan Kelly pressure band, a simple velcroelastic strap, or even a tight shirt collar or stoma bib tape, anterior resistance over the vibrating segment, voice quality may be improved (Shanks, 1983). All these methods are useful in preventing bellowing of the flaccid gastric segment, hence improving the opposition of the walls of the stomach and defining a pharyngogastric vibrating segment. Of four patients, two failed to develop satisfactory speech following laryngopharyngoesophagectomy and pharyngogastric anastomosis are analogizes to the hypotonic group of failed oesophageal speakers described by Cheesman et al. (1986). Both the cases (3 and 4) showed typically hypotonic appearance with little or no effective vibrating segment. In both the cases, Blom-Singer prosthesis proved its benefit by changing the voice quality of both the patients. Speech was found to be more intelligible and acceptable due to changes in acoustic and temporal parameters. The changes in these parameters can be attributed to the increased pulmonary air availability and preventing the progressive dilatation of the stomach to an extent. However, both the cases required additional external compression to approximate the walls of the stomach and to create an effective vibrating segment. Thus, the use of Blom-Singer prosthesis appears to be similarly effective as in cases of tracheoesophageal speakers.

CHAPTER V

SUMMARY AND CONCLUSIONS

Laryngeal cancer threatens to destroy one of the most essential human attributes - communication through speech. Laryngeal cancer along with post cricoid carcinoma has much worse prognosis. A much more extensive operation is required for resection of laryngopharynx and esophagus along with larynx. The speech pathologist helps in the rehabilitation of such patients by developing various means of functional communication. The voice restoration methods involve - conventional gastric speech, tracheogastric puncture with voice prosthesis and electronic devices (artificial larynx).

Though conventional gastric mode has been traditionally considered as the method of choice, tracheogastric speech is also accepted recently in the rehabilitation of laryngopharyngoesophagectomees.

TGP speech is a method of alaryngeal speech developed by directing the pulmonary air through the prosthesis to vibrate pharyngogastric segment or the stomach wall. Once the gastric phonation is acquired by the laryngectomee, the aim will be to bring gastric speech more towards normal, making it intelligible and acceptable.

The patients who undergo tracheogastric puncture and voice prosthesis placement will benefit from a brief program of speech therapy. Speech therapy usually directed towards capitalizing on the advantages of pulmonary powered alaryngeal speech. The treatment is oriented towards teaching the patients how to take advantage of continuous air flow to enable fluent speech with natural phrasing.

Hence, for rehabilitation of the patients with both the modes requires identifying the parameters of gastric and TGP speech, deviating from normal speech is very important. The present study is one such effort at identifying the deviation of acoustic, temporal and psychoacoustic parameters in conventional gastric and TGP mode speech.

The voice and speech samples from two gastric and two tracheogastric speakers were analyzed in terms of acoustic (frequency and intensity related), temporal (MPD & SPB) and perceptual (acceptability and intelligibility) parameters. These parameters were compared with age and sex matched normal groups. The data for age and sex matched normal groups was obtained from studies by Suresh (1991) and Rajashekar (1991).

Following results were obtained:

1) Fundamental frequency in phonation and speech

All four cases demonstrated lower fundamental frequency values in speech as well as phonation. However, case 3 (TGP speaker) showed similar fundamental frequency in phonation as in normals. Lower fundamental frequency values can be attributed to the inefficient flaccid vibratory segment as well as to the gastric content leading to gurgly voice.

2) Intensity range in phonation and speech

The gastric speakers showed higher intensity range compared to normals in phonation, but did not differ in terms of intensity range in speech. Among TGP cases, case 3 showed intensity range similar to normals in phonation whereas case 4 showed proximity to normals in speech in terms of intensity range. The higher intensity ranges in speech or phonation indicate inability of these cases to control vibratory segment.

3) Extent and speed of fluctuations in phonation (frequency and intensity)

The greater value of extent and speed of fluctuations in frequency and intensity in cases 1 and 2 suggest irregularity in the vibrations of vibratory segment (pharyngogastric segment/stomach wall).

Whereas, cases 3 and 4 showed lesser intensity fluctuations (both extent and speed) as compared to frequency fluctuations. This could be attributed to the available pulmonary support facilitating maintenance of intensity.

4) MPD and SPB

All the cases demonstrated lesser MPD and SPB compared to normals. However, TGP speakers had more MPD and SPB values compared to conventional gastric speakers indicating better access to larger volumes of pulmonary air supply.

5) Acceptability and intelligibility

Case 2 demonstrated the excellent acceptability and intelligibility in spite of being a gastric speaker. However, case 1 showed lower scorings in both the parameters. Case 3 and 4 (TGP speakers) were nearer to normals attributing to the similar acoustic values as in normals in terms of intensity range and also to the lower extent and speed of fluctuations in intensity.

The present study is an early attempt to describe the acoustical features of gastric and tracheogastric puncture speakers. The literature in this area is limited and many studies are descriptive in nature (single case studies). Hence, further studies on the same line are essential to arrive at a diagnostic and therapeutic measures for alaryngeal speakers.

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APPENDIX A

LIST OF WORDS (KANNADA) USED AS TEST MATERIAL FOR INTELLIGIBILITY ASSESSMENT

1) ತಿರುಗಿ	ʈ i ɾ u g i
2) ರುಚಿ	r u ʦ i
3) ಹೊಡೆದ	h o ɖ e ɖ a
4) ಹಗ್ಗ	h a g g a
5) ಬೀಟು	e: ʈ u
6) ಚಿಪ್ಪು	ʧ i p p u
7) ಗುಂಡು	g u n ɖʒ u
8) ಪ್ರದೇಶ	p r a ɖ e: ʃ a
9) ವಿದ್ಯುತ್	v i ɖ j u ʈ
10) ಉತ್ಪಾದನೆ	u ʈ p a: ɖ a n e
11) ಜನರು	ʤ a n a r u
12) ಬೀಳುದು	b e: l u: r u
13) ಅನಕಟ್ಟು	a ɳ a k a ʈ ʈ u
14) ತಿರುಗು	ʈ i r u g u
15) ನೋಣ	n o ɳ a
16) ತಪ್ಪಿಸಿ	ʈ a p p i s i
17) ಸಮಾಜ	s a m a ʤ a
18) ಕರ್ನಾಟಕ	k a r n a: ʈ a k a
19) ನಾರು	n a: r u
20) ಬುದ್ಧಿ	b u ɖ ɖ h i
21) ಹಾಸಿಗೆ	h a: s i g e
22) ಊರು	u: r u
23) ಅಡಿಗೆ	a ɖ i g e
24) ಮನುಷ್ಯ	m a n u ʃ ʤ a
25) ಭೀಮ	bʰ i: m a

26) ನಮ್ಮ n a m m a

27) ನೋಡಲು n o: ɖ a l u

28) ನಂದಿ n a n ɖ i

29) ಕೊಬ್ಬರಿ k o b b a r i

30) ಬೆಂಗಳೂರು b e ŋ g a l u: r u

31) ರಾಗಿ r a: g i

32) ಹಳದಿ h a l a ɖ i

33) ಕೆಲವು k e l a v u

34) ಕೆಲಸ k e l a s a

35) ರಾಜ್ಯ r a: ɖʒ j a

36) ಎಲನೀರು e l a n i: r u

37) ಬೊಂಬಾಯಿ b ɔ m b a: j i

38) ಕೃಷ್ಣಾ ನದಿ k r i ʃ ɳ a ŋ n a ɖ i

39) ಜಮಖಾನ ʤ a m a k h a: n a

40) ಹಾಸಿ h a: n i

41) ಪರ್ವತ p a r v a t a

42) ಜೋಗ ʤ o g a

43) ಸರಿಯಾಗಿ s a r i j a g i

44) ಬರುವರು b a r u v a r u

45) ಹಸಿರು h a s i r u

46) ದೊಡ್ಡ d o ɖ ɖ a

47) ಬೇಸಿಗೆ b e: s i g e

48) ಕಟ್ಟು k a ʧ ʧ u

49) ಗುಂಡು g u n ɖ u

50) ಪ್ರಾಣಿಗಳು p r a: ɳ i g a l u

APPENDIX – B

Passage

ಬೆಂಗಳೂರು ನಮ್ಮ ರಾಜ್ಯದ ಒಂದು ದೊಡ್ಡ ಊರು. ಈ ಊರನ್ನು ನಮ್ಮ ರಾಜ್ಯದ "ಬೊಂಬಾಯಿ" ಎನ್ನುವರು. ಇಂಡಿಯಾದ ದೊಡ್ಡ ನಗರಗಳಲ್ಲಿ ಇದೂ ಒಂದು. ಈ ಊರನ್ನು ನೋಡಲು ಜನರು ಬೇರೆ ಬೇರೆ ರಾಜ್ಯಗಳಿಂದ, ಬೇರೆ ಬೇರೆ ಊರುಗಳಿಂದ ಬರುವರು, ಇದಲ್ಲದೇ ನಮ್ಮ ರಾಜ್ಯದಲ್ಲಿರುವ ಬೇಲೂರು, ಜೋಗ್, ನಂದಿ, ಇವುಗಳನ್ನು ನೋಡಲು ಜನರು ಬರುವರು. ಈ ನಾಡಿನಲ್ಲಿ ರಾಗಿಯನ್ನೂ ಬೆಳೆಯುವರು.

APPENDIX - C

DEFINITIONS OF PARAMETERS

1. Fundamental frequency in phonation (Fo):

   The mean frequency (Hz) of the steady portion of phonation.

2. Fundamental frequency in speech [Fo(Sp)]:

   The mean frequency (Hz) of the speech sitmulus.

3. Extent of fluctuation of fundamental frequency in phonation.

   The extent of fluctuation in frequency (Hz) was defined as the means of fluctuations in fundamental frequency in a phonation of one second.

   Fluctuation in frequency was defined as variations +/- 3 Hz and beyond in fundamental frequency.

4. Speed of fluctuation in fundamental frequency in phonation.

   The speed of fluctuation in frequency was defined as the number of fluctuations in fundamental frequency in a phonation of one second.

5. Extent of fluctuation in intensity in phonation (Ex. F.I)

   The extent of fluctuation in intensity (dB) was defined as the means of fluctuations in intensity in a phonation of one second.

   Fluctuation in intensity was defined as variations +/= 3 dB and beyond in intensity.

6. Speed of fluctuation in intensity in phonation (Sp. F.I.)

   The speed of fluctuation in intensity was defined as the number of fluctuations in intensity in a phonation of one second.

7. Intensity range in phonation (IR).

   The intensity range in phonation (dB) was defined as the difference between the maximum and minimum intensities in phonation.

8. Intensity range in speech (IR)

The intensity range in speech (dB) was defined as the difference between the maximum and minimum intensities in speech.

9. Maximum phonation duration (MPD)

Maximum phonation duration (sec) has been defined as the maximum duration for which an individual can sustain phonation.

10. Syllable per breath/air charge (SPB)

The syllable per breath was defined as the number of syllables uttered in one breath or air charge.

11. Intelligibility (INTL)

Intelligibility (%) was defined as the words intelligible to the listener, i.e.,

$$\text{Intelligibility} = \frac{\text{Number of words identified}}{\text{Total number of words}} \times 100$$

12. Acceptability (ACPTL)

Acceptability was defined as the rating on a 1-5 point scale, where 1 was the least acceptable and 5 was the most acceptable.