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Voice Rehabilitation Following Total Laryngectomy

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ABSTRACT

Despite continuing advances in surgical management of laryngeal malignancy, total laryngectomy is still the treatment of choice in advanced laryngeal malignancies. Considering the longevity of the patient following total laryngectomy, various measures have been adopted in order to provide voice function to the patient. Significant advancements have taken place in voice rehabilitation of post laryngectomy patients. Advancements in oncological surgical techniques and irradiation techniques have literally cured laryngeal malignancies. Among the various voice rehabilitation techniques available TEP (Tracheo oesophageal puncture) is considered to be the gold standard. This article attempts to explore the various voice rehabilitation technique available with primary focus on TEP.

Introduction:
The current 5 year survival rate of patients following laryngectomy ranges between 75-80% 1. Larynx is the second commonest site for cancer in the whole of aero digestive tract. Commonest malignancy affecting larynx is squamous cell carcinoma. Surgery carries a good prognosis. Conservative laryngeal surgeries are getting common by the day.

After total laryngectomy there is a profound alteration in the life style of a patient. The patient is unable to swallow normally, associated with profound changes in the pattern of respiration. Olfaction is also affected 2. The importance of speech is not appreciated unless it is lost.

Physiology of phonation:
Voice is produced by the respiratory system with active lungs forming the bellows pumping air into the laryngeal cavity. Vibrating air in the larynx generates voice. Clear and understandable speech is created by articulators (lips, tongue, teeth etc.). The larynx acts as a transducer during phonation converting the aerodynamic forces generated by the lungs, diaphragm, chest and abdominal muscles into acoustic energy. This energy transduction precisely at the space between the two vocal folds. However subglottic and supra glottic pressures also play a role in this transformation of aerodynamic energy into sound energy.

The requirements of normal phonation are as follows:
1. Active respiratory support
2. Adequate glottic closure
3. Normal mucosal covering of the vocal cord
4. Adequate control of vocal fold length and tension.

The vibrations of the vocal folds are complex in nature and are known as the glottic cycle. This cycle involves glottic opening and closing at set frequencies determined by the subglottic air pressure. Normal vocal folds produce three typical vibratory patterns:

1. Falsetto
2. Modal voice
3. Glottal fry

In falsetto or (light voice) the glottic closure is not complete, and only the upper edge of the vocal fold vibrates.

In Modal voice complete glottic closure occurs. This occurs in a majority of mid frequency range voice. During this modal voice production the vocal fold mucosa vibrates independently from the underlying vocalis muscle. This is the basic frequency at which a person phonates. The modal frequency in adult males is 120 Hz while in adult females it is 200 Hz.

Glottal fry is also known as low frequency phonation is characterized by closed phase. This closed phase is long when compared to the open phase. The vocal cord mucosa and vocalis muscle vibrate in unison.
During phonation two vibratory phases occur i.e. open and closed phases. The open phase denotes the phase during which the glottis is at least partially open, while the closed phase denotes the phase when the vocal folds completely occlude the glottic chink.
The open phase can be further divided into opening and closing phases. The opening phase is defined as the phase during which the vocal folds move away from one another, while during the closing phase the vocal folds move together in unison.

One important physiologic parameter which must be noted during phonation is the mucosal wave. The mucosal wave is an undulation which occur over the vocal fold mucosa. This wave travels in an infero superior direction. The speed of mucosal wave ranges from 0.5 - 1 m/sec. The symmetry of these mucosal waves must also be taken into consideration while studying the physiology of voice production. Any mild asymmetry between the two vocal folds must be considered as pathological.
The function of vocal folds is to produce sound varying in intensity and pitch. This sound is then modified by various resonating chambers present above and below the larynx and are converted into words by the articulating action of the pharynx, tongue, palate, teeth and lips.

The consonants of speech can be associated with particular anatomical sites responsible for their generation i.e. ‘p’ and ‘b’ are labials,’t’ and’d’ are dentals and ‘m’ and ‘n’ are nasals.

Methods of alaryngeal speech:
There are 3 methods of alaryngeal speech. They include:
1. Oesophageal speech
2. Electrolarynx
3. Tracheo oesophageal puncture

Oesophageal speech: Patients after total laryngectomy acquire a certain degree of oesophageal speech. In fact all the other alaryngeal speech modalities are compared with that of oesophageal speech. It is the gold standard for post laryngectomy speech rehabilitation methods during 1970’s.

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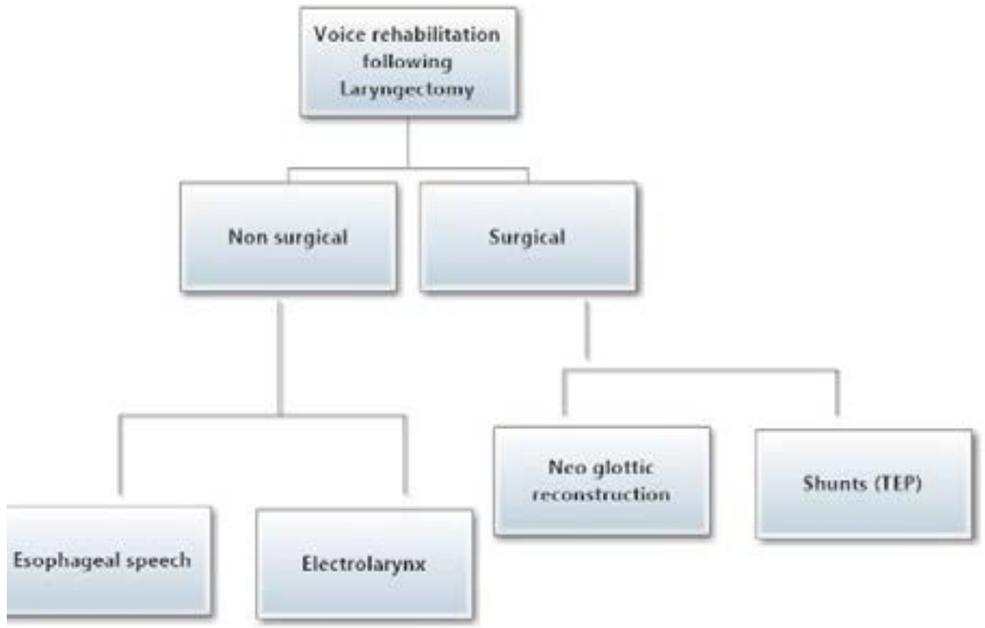
In this method air is swallowed into the cervical esophagus. This swallowed air is immediately expelled out causing vibrations of pharyngeal mucosa. These mucosal vibrations along with tongue in the oral cavity cause articulations. The exact vibrating portion in these patients is the pharyngo esophageal segment. This segment is made up of musculature and mucosa of lower cervical area (C5 – C7 segments). This method is very difficult to learn and only 20 % of patients succeed in this endeavor. Patients with oesophageal speech speak in short bursts, as the bellow effect of the lungs are not utilized in speech generation. The vibrations of muscles and mucosa of cervical esophagus and hypopharynx are responsible for speech production. Oral cavity plays an important role in generation of oesophageal speech. Air from the oral cavity is swallowed into the cervical oesophagus before speech is generated.

There are two methods by which air can be pumped into the cervical oesophagus. They are:
Injection method: In this method the person builds up enough positive pressure in the oral cavity forcing air into the cervical oesophagus. This is achieved by elevating the tongue against the palate. Air can also be injected into the cervical oesophagus by voluntary swallowing. Lip closure along with elevation of tongue against the palate generates enough positive pressure within the oral cavity to force air into the cervical oesophagus. This method is also known as tongue pumping, glossopharyngeal press and glossopharyngeal closure. This method is effective before speaking Obstruent phonemes like plosives, fricatives and affricatives.

Inhalational method: This method uses the negative pressure used in normal breathing to allow air to enter the cervical oesophagus. The air pressure in the cervical oesophagus below the cricopharyngeal sphincter has the same negative pressure as air in the thoracic cavity. Hence during inspiration, this pressure falls below atmospheric pressure. Laryngectomees often learn to relax the cricopharyngeal sphincter during inspiration thereby allowing air to get into the cervical oesophagus as it enters the lung. This trapped cervical column of air is responsible for speech generation. Patients are encouraged to consume carbonated drinks during the initial phases of rehabilitation. Gases released can be expelled into the cervical oesophagus causing speech generation.

The major advantage of oesophageal speech is that the patient’s hands are free. The patient does not have to incur cost of a surgical procedure or a speaking device. Nearly 40% of patients fail to acquire oesophageal speech even after prolonged training. This could be due to cricopharyngeal spasm / reflux oesophagitis. Reflux must be aggressively treated. Cricopharyngeal myotomy must be performed in patients with cricopharyngeal spasm. Botulinum toxin injection into the cricopharyngeus muscle can also be attempted 3, 4. 30 Units of Botulinum toxin is injected via anterior portion of the neck (via the tracheostome over the posterior pharyngeal wall bulge.



Flow chart showing various voice restoration options following laryngectomy

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Common cause of failure to develop oesophageal voice:
1. Presence of cricopharyngeal spasm
2. Disorders involving pharyngo oesophageal segment
3. Poor motivation on the part of the patient
Cricopharyngeal spasm can be managed by performing cricopharyngeal myotomy on a routine basis in all patients undergoing total laryngectomy. If this fails Botulinum toxin injection can be resorted to.
Advantages of oesophageal speech:
1. Hands free speech
2. No additional equipment is necessary
3. No additional surgery is necessary

Disadvantages of oesophageal speech:
1. Significant training is necessary
2. Controlling pitch and loudness can be really difficult in these patients
3. The fundamental frequency of oesophageal speech is about 65 Hz which is about half of the normal adult male speaker. Its intensity is also pretty low making it difficult for the speaker to he understood in noisy environments.

Electrolarynx: These are vibrating devices. A vibrating electrical larynx is held in the submandibular region. Muscular contraction and facial tension can be modified to generate rudiments of speech. The initial training phase to use this machine must begin even before the surgical removal of larynx. This helps the patient in easy acclimatization after surgery.

There are three types of electro larynges available 5. They are:
1. Pneumatic - Dutch speech aid, Tokyo artificial speech aid etc.
2. Neck
3. Intra oral type
Among these three types neck type is commonly used. It should be optimally placed over the neck for speech generation. Hypoesthesia of neck during early phases of post op period may cause some difficulties in proper placement of this type of artificial larynx. If this device cannot be used intra oral devices can be made use of.

While using intra oral type cup must form a tight seal over the stoma so that air does not escape during exhalation 6. The oral tip of the tube is positioned in the oral cavity.
The pneumatic artificial larynx uses the patient's exhaled air to create the fundamental sound. A rubber, plastic, or steel cup is placed over the stoma, creating a seal. A tube is then directed from the cup into the mouth. The exhaled air vibrates a reed or rubber diaphragm within the cup, creating a sound. Speech quality can be varied through a number of mechanisms. Changes in breath pressure can affect pitch and loudness.

The major disadvantage of these electro laryngees is their mechanical quality of speech. There is also a certain degree of stomal noise. With practice a patient can reduce stomal noise by placing fingers over the stoma during phonation. These equipment are expensive and need to be maintained.

Image showing electrolarynx

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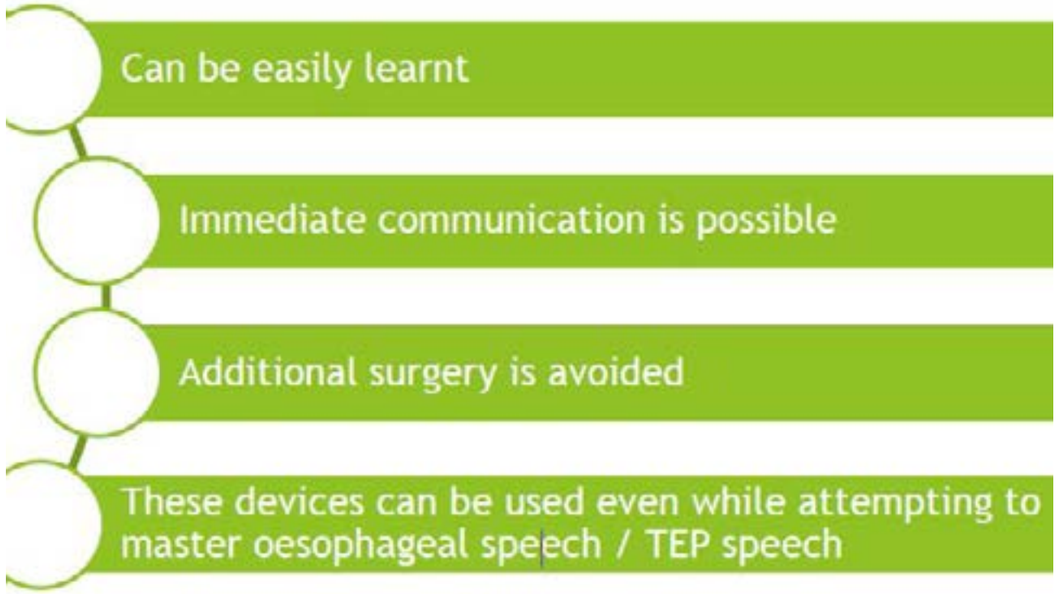
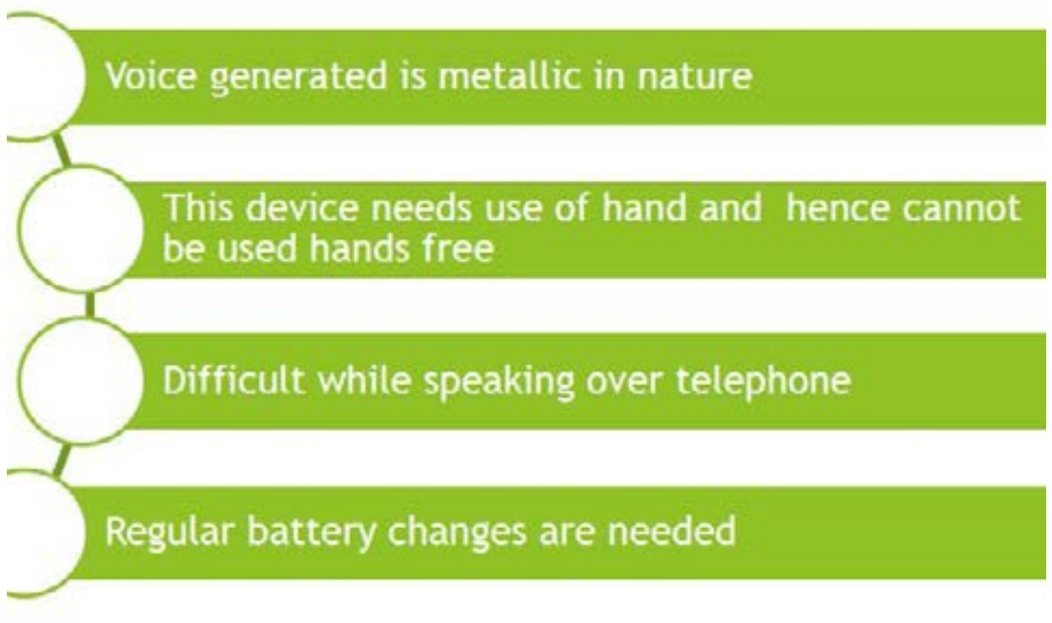


Advantages of Electrolarynx



Disadvantages of electrolarynx

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Voice restoration surgeries in patients who have undergone Laryngectomy:
1. Neoglottic reconstruction
2. Shunt techniques
Neoglottic reconstruction:
Numerous surgeons all over the world attempted to develop a reliable tracheohyoidpexy procedure which could restore voice function in patients who has undergone Total Laryngectomy. Most of these techniques were abandoned due to complications 8.
Shunt technique:
This technique involves creation of shunt between trachea and oesophagus. This technique was first developed by Guttmann in 1930 9. Lots of modifications have occurred, but the basic concept remains the same. Basic aim of this procedure is to divert air from the trachea into oesophagus. The place where sound is generated depends on where the fistula enters pharynx / oesophagus.

Types of shunts:

1. High tracheo oesophageal shunt (Barton)

2. Low tracheo oesophageal shunt (Staferri)

3. TEP shunts (Guttmann)

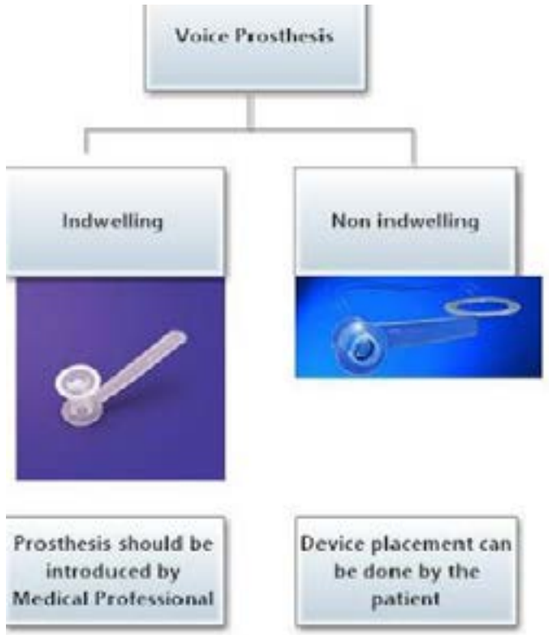
Creation of shunt between trachea and oesophagus usually failed because:

1. Aspiration through the fistula
2. Closure of fistula
This lead to the development of one way voice prosthesis designed by Blom and Singer which was introduced via the puncture wound.

Tracheo esophageal puncture (TEP):
This procedure for restoration of speech in patients who have undergone total laryngectomy was first introduced by Blom and Singer in 1979 7. In addition to the procedure of tracheo oesophageal puncture Blom – Singer developed a silicone one way slit valve which can be inserted into the puncture wound. This valve formed a one way conduit for air into the oesophagus and also prevented leakage of oesophageal contents into the airway.

Voice prosthesis is actually a one way valve made of medical grade silicon. This is a barrel shaped device with two flanges. One flange enters the oesophagus while the other one rests in the trachea. It actually fits snuggly into the tracheo-oesophageal puncture wound. This prosthesis is provided with a unidirectional valve at its oesophageal end. Indwelling prosthesis usually have more larger and rigid flanges when compared to that of non-indwelling ones. Non-indwelling prosthesis has a safety medallion attached to the main structure to prevent accidental aspiration.

TEP can be performed either immediately after laryngectomy or 6 weeks following successful laryngectomy. TEP performed along with laryngectomy is known as Primary TEP and if performed 6 weeks after laryngectomy it is known as Secondary TEP. It should be stressed that radiotherapy poses no threat to TEP. This procedure initially was reserved for patients who have failed to acquire oesophageal speech even after prolonged effort, and are displeased with the voice produced by artificial larynx. Currently Primary TEP is getting popular.



Anatomical structures involved in TEP:
TEP should ideally be performed in the midline, thereby decreasing the risk of bleeding from midline vessels. Structures that need to be penetrated during TEP procedure include:
1. Membranous posterior wall of trachea
2. Oesophagus (Consists of 3 muscles layers coated with oesophageal mucosa)
3. Interconnecting tissue in the tracheo-oesophageal space

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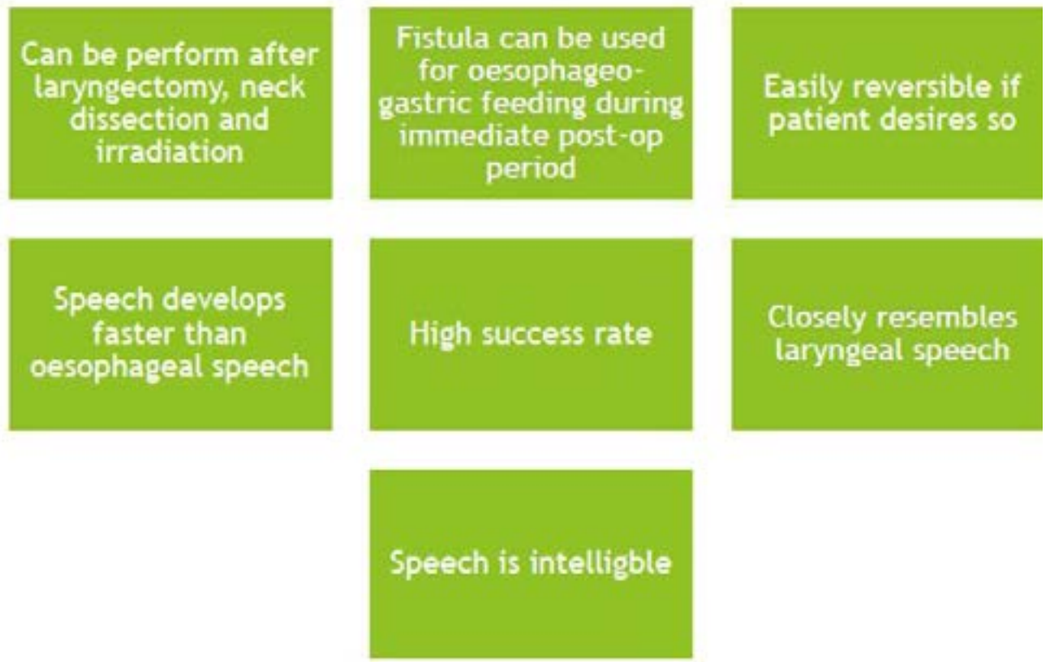
Advantages of TEP:



Disadvantages of TEP:

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Patient selection for introducing TEP:

1. Motivated patient

2. Patient with a stable mind

3. Patient who has understood the anatomy and physiology of the process

4. Patient should not be an alcoholic

5. Patient should have good hand dextirity

6. Patient should have good visual acuity

7. Positive oesophageal air insufflation test

8. Patient should not have pharyngeal stricture / stenosis

9. Patient should have good pulmonary reserve

10. Stoma should be of adequate depth and diameter

11. Patient should have intact tracheo oesophageal wall

Contraindication for TEP insertion:

1. Extensive surgery involving pharynx and larynx with seperation of tracheo oesophageal wall

2. Inadequate psychological preparation

3. Patient's doubtful ability to cope up with the prosthesis

4. Suspected difficulty during post op radiotherapy

5. Impaired hand dextirity

Primary TEP:
Hamaker etal were the first to perform primary TEP in 1985 12. They concluded primary TEP should always be attempted whenever possible. In this type the tracheo-oesophageal prosthesis is inserted immediately during total laryngectomy surgery. Sufficient length of prosthesis should be used.

Advantages:

1. The risk of separation of tracheo-oesophageal wall is minimized
2. The tracheo-oesophageal wall is stabilized by the prosthesis to some extent
3. The flanges of the prosthesis protects trachea from aspiration
4. Stomal irritation is less
5. Important advantage is that patient becomes familiar with the prosthesis immediately following surgery.
6. Post op irradiation is not a contraindication

Because of the excellent exposure provided during total laryngectomy this surgery is rather easy to perform. This procedure is ideally performed before pharyngeal closure. The puncture is performed through the pharyngotomy defect. It is ideal to insert the Ryle's tube through this opening to facilitate early post-op naso gastric feeding. This tube is ideally left in place for at least 3 weeks.
Prosthesis used in TEP:
1. Blom-Singer prosthesis
2. Panje buttons
3. Gronningen buttons
4. Provox prosthesis
The Blom-singer and Panje devices should be taken out by the patients themselves for cleaning and reinsertion whereas Gronningen and Provox are indwelling prosthesis and need not be removed and cleaned.
Panje voice button:
This is a biflanged tube with a one way valve 10. This enables speech in laryngectomy patients by allowing air from trachea to pass into the oesophagus. It can easily be inserted into the tracheo-oesophageal fistula already surgically created for this purpose.

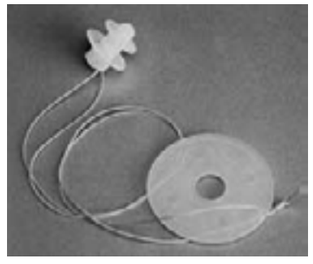

Figure showing Panje speaking valve

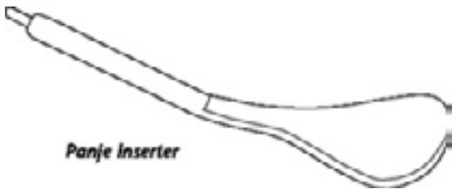

Figure showing Panje introducer

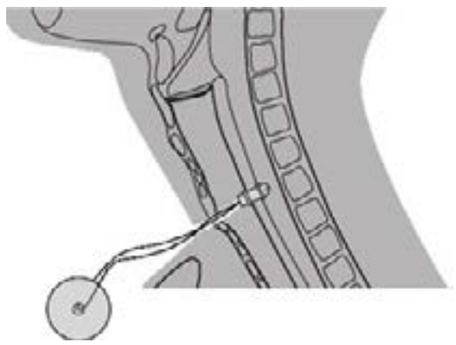

Image showing Panje prosthesis in place

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the need for cleaning.
Usually an introducer is provided along with the prosthesis which makes introduction rather simple. This is a non-indwelling prosthesis and should be removed and cleaned once in 3 days.
Major advantage of Panje voice button is that it can be easily removed, cleaned and reinserted by the patient themselves.

Gronningen Button:
This TEP speaking prosthesis was introduced by Gronningen of Netherlands in 1980 11. Even though it was very useful initially, its high airflow resistance delayed speech development in some patients. With the introduction of low airflow resistance Gronningen button now it is getting popular among surgeons.

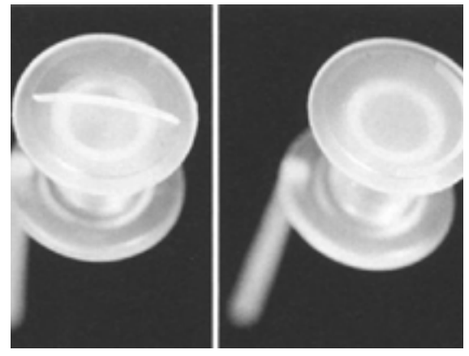

Figure showing Gronningen button prosthesis

Blom – Singer prosthesis:
This device was first designed by Eric Blom, a speech therapist and Mark Singer a surgeon in 1978. They inserted this prosthesis into surgically created tracheo – oesophageal fistula.

This prosthesis acted as a one way valve allowing air to pass from trachea into the oesophagus, and prevented aspiration into the trachea. This prosthesis is shaped like a duck bill. The duck bill end of the prosthesis should reach the oesophagus, while the opposite end shaped like a holed button rests snugly against the tracheostome.

This is actually an indwelling prosthesis which can be safely left in place for atleast 3-4 months without

Figure showing Blom Singer prosthesis

This prosthesis is available in varying lengths (6mm – 28mm)
Classical Blom-Singer prosthesis is indwelling one. Since it needs higher pressure to open up it can cause problems in some patients. Currently low pressure Blom-singer prosthesis has been introduced. This is also made of medical grade silicone with a one way flapper valve replacing the duck bill. Only difference being the low pressure Blom-singer prosthesis is non-indwelling type and can be easily maintained by the patient.
Blom-singer dual valve prosthesis:
This prosthesis has two valves which ensures there is absolutely no risk of aspiration, while air is allowed to flow from the trachea into the oesophagus. This prosthesis is suitable in whom primary voice prosthesis has failed due to leak from oesophagus into the trachea.

Picture showing dual valve Blom-singer prosthesis

Provox prosthesis:
This is an indwelling low air flow resistance prosthesis.

Figure showing Provox prosthesis

The advantage of this prosthesis is the extended life time. It can last anywhere between 1-2 years if properly used. Insertion and maintenance of this prosthesis is also pretty simple and straight forward.

Major problem with all these silicone prosthesis is candida growth 13. They are constantly exposed to candida from the oesophagus. They grow on the inner surface of the prosthesis preventing the one way valve from functioning.

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Types of tracheo oesophageal prosthesis and their features:

Indewlling	Non indwelling
Can be left in place for 3-6 months	Must be removed and cleaned every 3-4 days
Requires specialist to do the job	Patients can do themselves easily
Less maintenance is required	Periodical maintenance is a must & patient should be trained for the job
Tracheostoma should be 2cms / greater	Tracheostoma should be greater than 2 cms
Patients should pass oesophageal insufflation test before insertion	Patients should pass oesophageal insufflation test before insertion

Secondary TEP:
This procedure is usually performed 6 weeks following laryngectomy. Secondary TEP allows time for the patient to develop oesophageal speech. Traditionally secondary TEP is usually performed with the help of rigid oesophagoscopy for direct visualization of the proposed TEP site. This procedure is performed under GA / LA. If planned under LA then flexible oesophagoscope is used to identify the TEP insertion area.

Current modified procedure followed by the author:
This procedure is performed under local infiltration anaesthesia. Patient is placed on the operation table in a recumbent position. A small roll of drape is placed under the shoulders of the patient to provide mild extension at the level of neck. The end tracheostomy tube is removed. 12 0 clock position of the tracheostome is clearly visualized.

Image showing the end tracheostome after removal of tracheostomy tube

Figure showing TEP incision being widened

Yanker's suction is introduced into the oral cavity of the patient. It is pushed inside till it hitches against the posterior wall of the tracheostome at 12 o clock position.

2% xylocaine with 1 in 100,000 adrenaline is injected via the tracheostome in the exact area where the tip of Yanker's suction hitches against.
Incision is made exactly in the area where the tip of Yanker's suction hitches at the 12 0 clock position of tracheostome.

This incision is widened and deepened till the anterior wall of oesophagus is punctured. Care should be taken not to injure posterior wall of oesophagus. The tip of the suction in fact protects the posterior wall of oesophagus from injury. The puncture site is widened using a curved artery forceps. Minimal stomal diameter should be at least 2 cms.

After ensuring that the TEP is fairly widened, the Blom-singer Prosthesis is introduced and anchored with silk around the neck.

Figure showing TEP in situ being anchored to the neck with silk

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Problems caused due to TEP insertion:

1. Leakage through prosthesis

2. Leakage around prosthesis

3. Immediate aphonia / dysphonia

4. Hypertonicity problems

5. Delayed speech

Caution:
It is always better to perform transnasal oesophageal insufflation test before TEP insertion. This test will assess the response of pharyngeal constrictor muscle to oesophageal distension in these patients.

Trans nasal oesophageal insufflation test: The transnasal oesophageal insufflation test is a subjective test that is used to assess the pharyngeal constrictor muscle response to oesophageal distention in the laryngectomy patient.

The test is performed using a disposable kit consisting of a 50-cm long catheter and tracheostoma tape housing with a removable adaptor. The catheter is placed through the nostril until the 25-cm mark is reached, which should place the catheter in the cervical oesophagus adjacent to the proposed TEP.

The catheter and the adaptor are taped into place. The patient is then asked to count from 1 to 15 and to sustain an "ah" for at least 8 seconds without interruption. Multiple trials are performed to allow the patient to produce a reliable sample. The responses obtained are the following: 1. Fluent sustained voice production with minimal effort 2. A breathy hypotonic voice indicating a lack of cricopharyngeal muscle tone 3. Hypertonic voice 4. Spastic voice due to spasm of cricopharyngeus muscle.

Rehabilitation following TEP:
Speech language pathologist should be actively involved in rehabilitation of patients following insertion of TEP prosthesis. The rehabilitation process starts while the patient is still hospitalized and is usually continued during the first week of surgery. During this period the speech and language pathologist should assess the tracheostome and site of TEP. Focus should be directed to identify leaks from inside or around the prosthesis.
During this initial stage patient can be encouraged to communicate using artificial larynx. Intraoral type of artificial larynx is preferred.

Intermediate phase:
During this phase the patient is discharged from the hospital and is requested to attend Speech therapy sessions at least thrice a week. During this phase the patient should be informed of the type and size of the prosthesis. Breathing exercises are taught during this phase. Patient should learn how to push in air from the trachea into the oesophagus via the TEP.
Final phase / Phase of normalcy:
During this phase patient is able to communicate with near normal voice. Patient learns how to remove, clean and reinsert the prosthesis.

Common problems of TEP speakers are caused by:
1. Improper location of Tracheo-oesophageal puncture site
2. In appropriate size of the puncture
3. Presence of cricopharyngeal spasm
4. Leakage through and around the prosthesis

Location of TEP:
The puncture site is ideally located at 12 0 clock position in relation to the tracheostome. It is placed about 1 – 1.5 cms from the tracheocutaneous junction 14. If located superior to the stomal rim patient will find it difficult to occlude the stoma in order to produce speech. Similarly if the stoma is located deep inside the trachea then insertion of the prosthesis becomes rather difficult.

Size of the puncture:
This aspect is important for fluent speech. The size of the stoma should at least be 2 cms for production of fluent speech. If the size of the stoma is smaller than 2 cms it is prudent to enlarge it appropriately to benefit the patient.

Size of the prosthesis:
Appropriate size prosthesis should be chosen to avoid leak. Presence of leak from the prosthesis / around the prosthesis creates lots of problems. If leak occurs around the prosthesis then larger sized prosthesis should be chosen to avoid this problem.

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Presence of cricopharyngeal spasm:
This again impedes production of fluent speech in these patients. This can be identified by performing Transnasal oesophageal insufflation test. If this test is positive then cricopharyngeal myotomy can be performed. Alternatively Botulinum toxin injection has reduced spasm of this crucial area. On an average 30 units of Botulinum toxin 15 when injected in to this area serves the purpose.
Leakage from / through the prosthesis:
Seen when inappropriate size of prosthesis is used (too small than the size of the stoma). Delayed leakage is caused due to colonization of the prosthesis by candida.
Management of leak:
Prosthesis can be removed and cleaned with brush and flushed with saline. Consumption of carbonated beverages helps in generating good quality voice. If leak is persistent then the shaft of the prosthesis can be plugged using q tip while swallowing food.

Management of leaks through the prosthesis:

Cause	Solution
Valve in contact with posterior wall of oesophagus	Replace prosthesis with different length and size
Prosthesis length too short for the puncture "Pinching valve"	Remeasure TEP and refit with appropriate sized prosthesis
Valve deterioration	Replace the valve
Fungal colonization of prosthesis with yeast (most common)	Treat with nystatin paint or used fungal resistant dual valve prosthesis
Back pressure	High resistant prosthesis
Mucous / food lodgement	Clean the prosthesis

Management of leaks around the prosthesis:

Cause	Solution
TEP location	Remove prosthesis allow TEP to close and repuncture
Unnecessary dilatation during routine placement	Defer dilatation and do it only when it is absolutely necessary
Thin tracheo-oesophageal wall 6mm / less	Select customized prosthesis
Prosthesis of incorrect length and size	Choose the correct sized prosthesis
Poor tissue integrity due to irradiation / chemotherapy	Choose custom prosthesis

Conclusion:

If performed accurately and fitted with proper prosthesis TEP is the best method for voice restoration in laryngectomy patients.

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