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REVIEW ARTICLE

Prosthetic voice rehabilitation after total laryngectomy

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Abstract
Loss of voice is a major concern after total laryngectomy. Tracheo-esophageal prosthesis was described in 1980 by Blom and Singer as a method of post-laryngectomy voice rehabilitation. Since then it has seen many phases of developments. Now it has evolved into highly effective method with success rates more than 90% and better quality of voice than other modalities. It also gives good quality of life and voice related quality of life. Though it is associated with some complications, they are easy to manage. All these have made tracheo-esophageal prosthesis the 'Gold Standard' of post-laryngectomy voice rehabilitation.

Keywords TEP · Tracheo-esophageal · laryngectomy · voice · rehabilitation

Introduction

Excellent voice and articulate speech helped the ancient man to evolve into the modern human being. Even after millions of years of evolution speech forms very essential part of human functioning. Loss of speech/voice has severe physical as well as psychological effects. Loss of voice has been a major concern after total laryngectomy. These concerns were raised even after the first laryngectomy in 1873 (ref. 1) and also were main force to develop organ preservation strategies for larynx. In spite of effective organ preservation protocols, many patients still require total laryngectomy. Excellent quality of voice and high success rate has made tracheoesophageal speech the 'Gold Standard' of post-laryngectomy voice rehabilitation.

Historical review

The history of prosthetic voice rehabilitation is as old as total laryngectomy itself. The first total laryngectomy for laryngeal cancer was performed by Billroth in 1873.[1,2] It was reported by his fellow Gussenbauer in 1874. Gussenbauer was also the first one to describe the first 'Artificial Larynx' in 1874. This was a complex metallic device with series of valves. In those early days, pharynx was not closed after laryngectomy. As a result, the patient would have two stomas – a pharyngostoma on top and tracheostoma in lower part of the neck. One metallic tube of this 'artificial larynx' used to fit into the tracheostoma and the other one into the pharyngostoma. The series of valves, exactly like current age prosthesis, used to allow air to pass from trachea to esophagus preventing aspiration of esophageal contents into the trachea. It is said that patients would speak loudly and clearly with this 'Artificial larynx'. In 1894 Gluck and Sorensen succeeded in primary closure of pharyngeal defect. Now there was no pharyngostoma therefore 'artificial larynx' could no longer be used. Slowly it became obsolete and completely forgotten.

In 1932 Guttman reported a case of laryngectomised patient who in frustration performed an operation on himself.[3] He used a hot ice-pick to create a fistula between

the trachea and the esophagus. After that he was able to phonate by closing his tracheostoma by finger. He would prevent aspiration by using a quill to block this fistula while drinking. Though effectiveness of tracheo-esophageal fistula, as a method of voice rehabilitation, was recognized way back in 1932; it took almost 50 more years to develop effective one-way mechanism to prevent aspiration. Meanwhile many surgeons reported complex surgical procedures to create this valve mechanism. These include Conlay (1958), Calcaterra (1971), Arslan (1972), Asai (1972), Amatsu (1980), Griffith (1980) and Staffieri (1981). These procedures, though effective, were difficult to perform and replicate. In 1980 Blom and Singer were the first to report the use of valved prosthesis.[1,2]

Mechanism of voice production[1]

Contrary to the common belief, voice is not produced by the prosthesis. It is a lung powered speech produced by the vibration of pharyngo – esophageal (PE) segment or the neoglottis. Tracheo-esophageal (TE) prosthesis is a one-way valve which is fitted into an artificially created fistula between the trachea and the esophagus. TE prosthesis prevents the fistula from closure. When patient breaths out and closes his tracheostoma, air passes from the trachea through the prosthesis to the esophagus. The pharyngo-esophageal (PE) segment vibrates producing voice. Optimum tone of PE segment musculature is essential for voice production. Good quality voice is produced by normotonic or slight hypertonic PE segment. Severe hypertonia or hypotonia is a main cause of failure of voice production.[4] TE prosthesis being a one way valve prevents aspiration of liquids into the trachea.

Development[2]

The current day voice prostheses are quite different from those earlier ones developed by Blom and Singer.[2] The first prosthesis was made by making a slit at one end of a red rubber catheter and was retained by a string around the neck. Developments have taken place in various aspects of prosthesis like:

Design: The frequent outward displacements led to development of esophageal flange for retention. Though this solved the problem of outward displacement, inward displacement into the esophagus was common occurrence. This was prevented by development of tracheal flange.

Valve mechanism: Major developments have taken place in the mechanism of one-way valve. Initial years saw use of 'Slit valve' as seen in 'Duckbill prosthesis'. But high pressures required to open the valve, frequent blockage by food and difficulty in cleaning led to change in design of this valve. 'Hinged valve' requires lower pressure to open, does not get blocked easily and is easy to clean with a brush. 'Hinged valves' have almost completely replaced the old 'Slit valves'. Formation of fungal biofilm on the valve making it incompetent is the main cause of leakage through the prosthesis, especially in the Western hemisphere. Valves coated with anti-fungal medications and valves with magnetic closure mechanisms are now developed and commercially available.

Material: Initial prostheses were made of rubber. Then came plastic prosthesis. These are now replaced by inert Silicone material.

Insertion: Antegrade or retrograde insertion.

Indwelling: Initial prostheses were non-indwelling i.e. they had to be removed twice a week, cleaned and replaced. This decreased the compliance. Current day prostheses are indwelling. Non-indwelling prostheses are not used very frequently now.

Parts of TE prosthesis

TE prosthesis has following parts

1. *Esophageal flange:* It usually also has a bevel to divert liquids away from the valve.
2. *Tracheal flange:* It has an extension which helps in insertion and retention in case of non-indwelling prosthesis.
3. *Shunt or body of prosthesis:* It holds the valve. The diameter of shunt depends upon the diameter of TE fistula. The length of the shunt (usually called as a size of the prosthesis) depends upon the thickness of tracheoesophageal party wall.
4. *Valve:* usually hinged, rarely slit.

Method of insertion of TE prosthesis

TE prosthesis is inserted into TE fistula by various methods. TE fistula is usually created intra-operatively at the time of total laryngectomy. This is called as 'primary TE puncture' prosthesis can be fitted into this puncture intra-operatively or postoperatively after a few days. TE fistula can also be created as a secondary procedure if it not done at the time of laryngectomy. This is called 'secondary TE puncture'. The success rate of primary TE puncture is significantly more than secondary TE puncture.[5] Therefore, whenever feasible, primary TE puncture is preferred over secondary TE puncture. In a preformed fistula, TE prosthesis can be inserted by 'antegrade' or 'retrograde' method. In antegrade method TE prosthesis is inserted through tracheostoma. In retrograde method the

prosthesis is inserted through oral cavity and pulled out through the fistula. Antegrade methods are simple, can be done in out patient clinic hence are preferred. Retrograde method is usually reserved for intra-operative placement and in difficult fistulas. Proper estimation of size and type of prosthesis is essential prior to insertion. Fistula sizing devices help in this estimation.

Success of TE prosthesis as post-laryngectomy voice rehabilitation:

Success of any post-laryngectomy voice rehabilitation can be measured by two parameters – percentage of patients who are able to phonate and quality of voice. The quality of voice can be studied by various subjective and objective methods. Amongst all methods of voice rehabilitations, TE prosthesis, especially with primary puncture has the highest success rate[6,7] (Table 1). All large series including the one at Tata Memorial Hospital showed success rates more than 90%. This is contrast to esophageal speech where success rate ranges from 0 to 60%. Though the success rate of electrolarynx is higher than esophageal speech, the quality of voice is very mechanical and non-human robot like. Objective (acoustic) analysis of quality of TE speech is been compared with esophageal speech and normal speech by Robbins (1984), Debruyne (1994), Bertino (1996), Max (1996) and Qi (1995).[8] All these studies have shown that TE speech is closer to normal speech compared to esophageal speech. Even subjective (perceptual) analyses by Pindzola and Cain (1988), Nieboer (1988) and Baggs (1983) have shown that TE voice is closest to the normal voice.[9] To remove bias studies have been conducted using naïve listeners instead of clinicians or speech therapists. These also have shown similar results.[10] The ultimate success of any rehabilitation lies in improving the quality of life of its users. Various studies have shown good quality of life in TE prosthesis users.[11,12] Our own prospective study of 199 patients has shown that TE prosthesis users have very good quality of life and Voice Related Quality of Life (VRQOL).[13] These scores were much higher than those reported in western literature.[14]

Success of TE prosthesis can also be evaluated on the basis of prosthesis life. TE prosthesis is often criticized for short life span of 90 to 180 days reported in literature.[6,7]. A prospective study of more than 300 patients done at Tata Memorial Hospital showed median TE prosthesis life of 920 days (30 months) (unpublished data presented at EHNS conference Barcelona, Spain).

Table 1. Success rates of tracheo-esophageal prosthesis

Author	Country	Year	N	Success rate (%)
Carlos	Brazil	2005	71	94
Hilgers	Holland	2000	318	95
Steven	USA	2003	81	90
Aust	USA	1997	21	84
TMH	India	2002–7	275	90.5

Complications[6]

Like any other procedure TE puncture has its own set of complications. It is beyond the scope of this article to cover all the complications. Only the important ones are being discussed here.

1. *Failure to phonate:* For the patient as well as the clinician this is a very distressing complication. It occurs in about 5–10% patients undergoing primary TE puncture.[4,6,7] It is essential to identify the cause and adequate corrective measures should be taken before labeling the patient as a 'nonspeaker'. Many-a-times simple mechanical problem like a blocked or a displaced TE prosthesis is responsible for this complication. These can be easily rectified. The more difficult problems to treat are stricture of PE segment and abnormal tone of PE segment. Stricture of PE segment usually occurs as a complication of major pharyngeal leak. These strictures are difficult to dilate. Forceful dilatation can lead to re-opening of healed fistula. Even after dilatation, fibrosed PE segment may not vibrate to produce voice. There is no published data available on success of dilatation, but in our experience, success rate was less than 50%. The outcome is much better with abnormal tone of PE segment. Hypertonicity of PE segment is one of the commonest treatable causes of failure to phonate.[4] Diagnosis of hypertonic PE segment is usually done with lateral film videofluoroscopy and confirmed by diagnostic lignocaine block.[15] The treatment of hypertonic PE segment in the past used to be secondary myotomy which is now almost completely replaced by percutaneus EMG-guided Botulinum toxin injection.[16,17] The success rate of this ranges from 79% to 88% with median duration of 20 months.[17] Even in our own series done at Tata Memorial Hospital, the success rate was 81% (13 out of 16 patients). It was interesting to note that many patients had prolonged speech production even after diagnostic lignocaine block.[18] Though the exact mechanism of this is beyond the scope of this article, it indicates that lignocaine block does have a therapeutic value and should be attempted before costly botulinum injection.
2. *Leakage:* Leakage can be through the valve or around the prosthesis.[6] Leakage through the valve is usually due to fungal biofilm formation making valve incompetent. Though the incidence of this problem is not so high in India, it is a major cause of concern in western countries. Routine use of antifungal mouth washes or

flushes recommended by many in the west[6] are rarely practiced in India. Small through the valve leaks can be managed temporarily by TE prosthesis plugs. Leakage around the prosthesis occurs due to problems related to fistula.[6] Contrary to common relief the usually is not the widening of fistula tract. It is due to atrophy of tracheo-esophageal wall leading to 'pistoning effect' causing leakage around the prosthesis. Proper sizing and re-insertion of prosthesis solves the problem. This problem can be temporarily managed by 'silicone ring washer' put around the prosthesis.

3. *Displacement:* Complete displacement of prosthesis is easily diagnosed. But partial displacement with retraction of esophageal flange into esophageal wall can produce symptoms of straining while speaking or failure to phonate. Removal of displaced prosthesis and re-insertion after proper sizing solves this problem.
4. *Granulation:* Local infection can lead to growth of granulation tissue. Antibiotic (usually local sometimes systemic), removal of granulation with cautery or laser and sometimes temporary removal of prosthesis solves this problem.

Accessories

Various accessories are now available for patient safety and comfort.

1. *HMEs (Heat Moisture Exchangers)[19]:* Breathing through tracheostoma leads to higher incidence of cough and lung complications. This is due to lack of humidification, filtration and temperature difference. These problems increase during dry cold seasons. HMEs are devices that are fitted onto tracheostoma and perform the function of filtration, humidification and heating. Previously HME devices were cumbersome to use because they required sticking around the stoma. Now, with the advent of Lary tube fitting devices, they have become quite user friendly. Still recurrent cost of HME cassettes is a major issue in developing country like India.
2. *Hands free devices:* With these devices there no need for finger occlusion of tracheostoma while phonating. Most of these devices have HMEs incorporated in them. High cost of the device and recurrent cost of HME cassettes are unsolved issues.

Research and Future developments[20,21]

Currently research is going on to prolong the life of prosthesis by preventing fungal bio-film formation. Research is also going on to study the characteristics of PE segment by using quantitative video fluoroscopy and high speed digital imaging. Newer products and methods are under investigations for pulmonary and olfactory rehabilitation.

Summary

To summarize, tracheo-esophageal prosthesis due to its high success rate, easy usage and easily manageable complications has become the 'gold standard' of post-laryngectomy voice rehabilitation.

References

1. Singer MI. Tracheoesophageal speech: vocal rehabilitation after total laryngectomy. Laryngoscope. 1983;93:1454–65.
2. Singer MI. The development of successful tracheoesophageal voice restoration. Otolaryngol Clin North Am. 2004;37:507–17.
3. Guttman MR. Rehabilitation of the voice in laryngectomized patients. Arch Otolarymgol. 1932;15:478–88.
4. Singer MI, Blom ED. Selective myotomy for voice restoration after total laryngectomy. Arch Otolaryngol. 1981;107:670–3.
5. Chone CT, Gripp FM, Spina AL, Crespo AN. Primary versus secondary tracheoesophageal puncture for speech rehabilitation in total laryngectomy: longterm results with indwelling voice prosthesis. Otolaryngol Head Neck Surg. 2005; 133:89–93.
6. Op de Coul BM, Hilgers FJ, Balm AJ, Tan IB, van den Hoogen FJ, van Tinteren H. A decade of postlaryngectomy vocal rehabilitation in 318 patients: a single Institution's experience with consistent application of provox indwelling voice prostheses. Arch Otolaryngol Head Neck Surg. 2000;126:1320–1328.
7. Blom ED, Hamaker RC. Tracheoesophageal voice restoration following total Laryngectomy. In Cancer of the head and neck (eds Myers EN, Suen JY), Third edn, Philadelphia, Saunders Co; 1996; pp. 839–852.
8. Max L, Steurs W, de Bruny W. Vocal capacities in esophageal and tracheoesophageal speakers. Laryngoscope. 1996;106:93–96.
9. Pindzola RH, Cain BH. Acceptability ratings of tracheoesophageal speech. Laryngoscope. 1988;98: 394–7.
10. van As CJ, Koopmans-van Beinum FJ, Pols LC, Hilgers FJ. Perceptual evaluation of tracheoesophageal speech by naive and experienced judges through the use of semantic differential scales. J Speech Lang Hear Res. 2003;46:947–59.
11. Eadie TL, Doyle PC. Quality of life in male tracheoesophageal (TE) speakers. J Rehabil Res Dev. 2005;42:115–124.
12. Stewart MG, Chen AY, Stach CB. Outcomes analysis of voice and quality of life in patients with laryn-

geal cancer. Arch Otolaryngol Head Neck Surg. 1998;124:143–148.
13. Deshpande MS, Kakade AC, Chaukar DA, Gore VT, Pai PS, Chaturvedi P, D'Cruz AK. Validation and assessment of voice related quality of life (V-RQOL) in Indian patients undergoing total laryngectomy and primary tracheoesophageal puncture (TEP). Head Neck. 2009;31(1):37–44.
14. Kazi R, De Cordova J, Singh A, et al. Voice-related quality of life in laryngectomees: assessment using the VHI and V-RQOL Symptom Scales. J Voice. 2006;21:728–734.
15. Chao SS, Graham SM, Hoffman HT. Management of pharyngoesophageal spasm with Botox. Otolaryngol Clin North Am. 2004;37:559–66.
16. Hamaker RC, Blom ED. Botulinum neurotoxin for pharyngeal constrictor muscle spasm in tracheoesophageal voice restoration. Laryngoscope. 2003;113:1479–82.
17. Lewin JS, Bishop–Leone JK, Forman AD, Diaz EM. Further experience with Botox injection for tracheoesophageal speech failure. Head Neck. 2001;23:456–60.
18. Desphande M, Rao V, Chaukar D, Chaturvedi P, Pai P, D'cruz A. Does diagnostic lignocaine block have a therapeutic value in treatment of hypertonic pharyngoesophageal segment? Laryngoscope. 2008;118:1324–5.
19. Hilgers FJ, Ackerstaff AH, Van As CJ, Balm AJ, Van den Brekel MW, Tan IB. Development and clinical assessment of a heat and moisture exchanger with a multi-magnet automatic tracheostoma valve (Provox FreeHands HME) for vocal and pulmonary rehabilitation after total laryngectomy. Acta Otolaryngol. 2003;123(1):91–9.
20. van As CJ, Op de Coul BM, van den Hoogen FJ, Koopmans-van Beinum FJ, Hilgers FJ. Quantitative videofluoroscopy: a new evaluation tool for tracheoesophageal voice production. Arch Otolaryngol Head Neck Surg. 2001;127(2):161–9.
21. Van As CJ, Op De Coul BM, Eysholdt U, Hilgers FJ. Value of digital high-speed endoscopy in addition to videofluoroscopic imaging of the neoglottis in tracheoesophageal speech. Acta Otolaryngol. 2004;124(1):82–9.