Current Status of Voice Restoration Following Total Laryngectomy

ABSTRACT: Total laryngectomy is the surgical procedure traditionally used to treat patients with advanced-stage cancer of the larynx. The impairments resulting from removal of such a small organ are, indeed, profound. They include loss of voice and speech; altered respiration, necessitating a permanent breathing opening in the neck; and diminished sense of smell and taste. When one considers these factors, successful treatment of laryngeal cancer cannot be measured by survival rate alone. Rapid, effective restoration of voice and speech is one of the primary focuses of rehabilitation and is pivotal to the prevention of the potential psychosocial and economic consequences of total laryngectomy. This article focuses on the methods of voice restoration currently being employed to reestablish the ability to speak. [ONCOLOGY 14(6):915-922, 2000]

Introduction

Speech is a uniquely human ability that allows us to communicate with others. It is used primarily to send and receive messages and to express emotions. As part of this process, the larynx generates voice, which renders speech audible and gives each person a recognizable “voiceprint” that is nearly as individual as a fingerprint. Speech is such an integral part of our daily life that most of us rarely appreciate its significance until the ability to speak is interrupted.

The global incidence of cancer of the larynx is estimated to be 136,000 new cases annually, with a 7:1 male predominance. Geographically, there is a higher incidence in western Asia (6% of all cancers diagnosed in males are of the larynx), South America, and eastern, southern, and western Europe. In 1999, 10,600 Americans developed cancer of the larynx, with a male to female ratio of 4:1.[1]

Epidemiologic evidence suggests that cigarette smoking is the major risk factor for the development of squamous cell carcinoma in the glottic and supraglottic areas of the larynx, and that this risk increases when combined with the carcinogenic effect of heavy alcohol consumption.[2,3]

Accordingly, the development of cancer in this important human organ is largely preventable. Treatment of laryngeal cancer, determined primarily by precise staging of the disease, includes radiation, surgery, or a combination of the two modalities. There is also emerging interest in chemoradiation protocols aimed at organ preservation.[4]

Total laryngectomy, ie, removal of the entire larynx, is the surgical procedure traditionally employed in patients with advanced-stage disease. A significant proportion of the 10,600 people in the United States diagnosed with laryngeal cancer this year will lose their larynx and their voice after undergoing this ablative procedure.

It is important to appreciate that, unfortunately, the impact of total laryngectomy goes far beyond the elimination of voice and speech. Removal of the larynx results in complete separation of the airway from the digestive tract and, consequently, the person breathes and coughs through a permanent opening or tracheostoma in the midline of the neck. This anatomic diversion eliminates the upper airway humidification and filtration normally provided primarily by the nose and also diminishes olfaction and gustation.

It is clear from the foregoing comments that surgical removal of the larynx has a myriad of devastating physical and psychosocial consequences. In fact, despite the smaller chance of survival with radiation therapy compared to total laryngectomy, some patients choose radiation because of the fear of voicelessness and concomitant postsurgical impairments.[5] Clearly then, the rapid reestablishment of acceptable voice and fluent, intelligible speech is the principal focus of
rehabilitation following total laryngectomy. This report provides a brief overview of the methods of voice restoration currently being employed. Highly technical details have been purposely omitted.

**Artificial Larynx**

**FIGURE 1**

Neck-type electrolarynx

A handheld artificial larynx is probably the most widely used method of postlaryngectomy voice restoration throughout the world today (Figure 1). This may be attributable primarily to the fact that the basic skills necessary for functional use of an artificial larynx often can be rapidly learned. Two basic types of artificial larynx devices are commercially available—pneumatic and electronic—and the designations differentiate the two types with regard to their tone-producing mechanism and power source.

**Pneumatic Devices**

The earliest artificial larynx devices were pneumatic. These devices produced a sustained tone when the user exhaled across a reed housed within the instrument. The cup-shaped end of the device is coupled by hand over the permanent tracheostoma in the neck, and a tube on the other end is inserted approximately 1½ inches into the corner of the mouth. The tone that is introduced is articulated by the tongue, lips, and teeth into fluent, intelligible speech.

Although some pneumatic artificial larynx devices produce an exceptionally high-quality artificial voice, they are not popular because they are cumbersome to use, and coupling of the neck and mouth is hygienically unacceptable.[6] Examples of commercially available pneumatic artificial larynx devices are the Van Humen DSPB, (Velp, The Netherlands) and the Tokyo (Omaha, Nebraska). The price of these devices ranges from approximately $75 to $150.

**Electronic Devices**

Most artificial larynx devices in use today are electronic. They are designated as either neck-type or intraoral, reflecting the manner in which the sound is introduced into the user’s vocal tract. All are battery powered and handheld, with the exception of one device that is incorporated into a dental plate.

The tone-generating mechanism is either an electromagnetic diaphragm or a small piston that is driven at high velocity against a rigid plastic membrane. The sound that is produced has been described, at best, as electronic or mechanical, and, in less favorable terms, as robotlike. Unfortunately, development of an advanced technology electrolarynx that can produce a more human-sounding artificial voice, while simultaneously maintaining small device size, low complexity, and acceptable cost, has undoubtedly been discouraged by corporate awareness of market size and return on investment.

**Neck-Type Electrolarynx**—The neck-type electrolarynx seems to be used more widely than the intraoral type. To speak, the user couples the head of the neck-type device against the surface of the neck at a location determined to have the most favorable tissue density so as to facilitate introduction of the tone through and into the vocal tract (Figure 1). As the sound reaches the mouth, it is articulated into speech.

The basic skills that a person must learn in order to use the neck-type electrolarynx include constant, accurate placement of the device against the neck. Press-button activation of the electronic voice tone must be correctly timed so that the tone starts precisely at the beginning of a sentence and ends at its completion. As with all methods of postlaryngectomy voice restoration, a comprehensive
rehabilitation program with a speech-language pathologist is recommended to achieve maximum speech outcome. Commercially available neck-type electrolarynx devices vary considerably in quality, and prices range from $150 to $800. Examples include the Servox (Seimens Hearing Instruments, Picatawny, New Jersey) and the Nu Vois (Lauder Enterprises Inc, San Antonio, Texas).

**Intraoral Electrolarynx**—An intraoral type electrolarynx is selected for use in individuals whose neck tissue is either insufficiently healed to permit contact with a neck-type electrolarynx or too dense to transmit the electronic tone. With the intraoral device, a small piece of plastic tubing connected to a handheld, battery-powered tone generator is inserted approximately 1½ inches into the side of the mouth. The tone is introduced directly into the mouth and articulated into speech. In addition to learning the same skills as those required for use of a neck-type electrolarynx, the user of the intraoral larynx must master speaking with a tube present in the mouth. An interdental variant of an intraoral artificial larynx, with a tone generator built into a dental plate, avoids a mouth tube and the need to be handheld. The tone is activated by a remote switch. The concept of the intraoral electrolarynx was introduced first in 1957 and again in 1992, but acceptance has been limited by reliability and substantial cost.[7] Commercial examples of an intraoral electronic larynx are the Cooper-Rand (Luminaud Inc, Mentor, Ohio), which costs approximately $375, and the interdental Ultra Voice (Health Concepts, Inc, Malvern, Pennsylvania), with an estimated cost of $2,000.

**Esophageal Speech**

The first report of what is known today as esophageal voice was presented by Reprand at the Academy of Science in Paris in 1828 in his account of a patient with atresia of the larynx. Despite a completely nonfunctioning larynx, the patient was able to speak by ingesting air into the esophagus and releasing it to produce a pseudovoice “sufficiently, clearly and in a manner to be audible at a certain distance.”[8] This report preceded by many years Billroth’s pioneering total laryngectomy in 1874.[9] Other reports of alaryngeal patients able to produce voice with their esophagus gradually appeared as more laryngectomies were performed, but this method of substitute voice remained unnamed until 1919, when the laryngologist Seeman coined the term “esophageal speech.”[10] FIGURE 2

![Esophageal Speech Diagram](image)

**Esophageal speech**

The basic mechanism for esophageal voice production is in some ways similar to producing a belch but is purposeful and controlled rather than unexpected and abrupt. To produce esophageal voice, the laryngectomized individual learns to either inject or inhale into the upper esophagus that small amount of air always present in the mouth (Figure 2).

In the injection method, the broad surface of the tongue pushes upward and backward against the palate. This compresses a small volume of air into the upper one-third of the esophagus. The air is then immediately expelled by the user primarily by contracting the intrathoracic-abdominal muscles so as to apply a controlled sustained pressure against the lower esophagus. Upward movement of the air column through the constricted uppermost fibers of the esophagus and other adjacent opposed mucosal surfaces induces a vibration, which is perceived as a sustained sound. The esophageal voice is articulated into speech by the tongue, lips, and teeth. The sound quality of esophageal voice varies but is often described as husky, rough, and low pitched. This is directly attributable to the physical properties of the bulky mucosal surfaces that vibrate and the altered resonance tract in which the voice is processed. By comparison, normal healthy vocal cords provide an intricately adjustable mechanism specifically designed to produce human voice as we know it. In addition, esophageal speech is characterized by shortened duration and discontinuous phrasing.
due to the small reservoir of air in the esophagus available to power sustained voice production. The vital lung capacity of a normal, healthy adult is 2,200 to 4,690 cm³, and most of that air is available for continuous conversational speech prior to requiring replenishment. By comparison, the volume of the esophagus is only 40 to 80 cm³, providing only enough air to speak six to seven syllables before requiring replenishment.[11]

The mechanism of rapidly exchanging air in and out of the esophagus to produce esophageal voice can be a difficult-to-learn, easily tiring, unnatural process. The literature suggests that only about 60% of those who attempt to learn esophageal speech are successful.[12] Failure is attributable to a variety of physical and psychological factors. On the other hand, those who do master this method often acquire an effective method of voice and speech that requires no artificial appliances or surgery.

Advantages and Disadvantages of the Artificial Larynx and Esophageal Voice

Artificial larynx devices and esophageal voice provide two good alternatives to postlaryngectomy rehabilitation for countless thousands of people. Both methods have advantages and disadvantages that often influence which one a person will ultimately use. A prominent advantage of the artificial larynx is that its use is often easily and rapidly learned, while major disadvantages include unnatural voice quality and the need to use a hand to speak.

Advantages of esophageal voice include a more natural-sounding voice and no reliance on a mechanical device, but disadvantages are the length of time it takes to learn this method and the disappointing small percentage of those who are able to do so.

Moreover, there are individuals who for some reason cannot or do not successfully learn to use either an artificial larynx or traditional esophageal voice. Another postlaryngectomy voice restoration option was needed for these individuals, and, eventually, such an option emerged with the introduction of tracheoesophageal voice by Singer and Blom in 1979.[13]

Tracheoesophageal Voice

Interestingly, one of the earliest attempts to “surgically” restore voice following total laryngectomy was performed in 1931 by a patient, who used a red hot ice pick to self-inflict a tiny “puncture” tract through the posterior wall of the permanent tracheostoma in his neck into the hypopharynx.[14] He inserted a goose quill to prevent this tract from closing and from leaking substances from the digestive tract back into his airway when he swallowed. Voice was produced when he removed the quill and occluded his tracheostomal neck opening with his thumb to direct exhaled air through the puncture and up through his mouth. Airflow across the mucosal surfaces produced a response that was similar to esophageal voice but was more continuous and loud because it was powered by air from the lungs.

Guttman’s attempts to replicate this method in 1935 were complicated by infection, aspiration of fluids into the airway, and eventual spontaneous closure of the puncture tract.[15] As a result, this seemingly simple method was relegated to the archives of medicine for many years.

Some 20 years passed before interest in surgical voice restoration following total laryngectomy was renewed. Beginning in 1952, a series of reports described various methods for constructing either an internal or external shunt connecting the residual amputated trachea with the upper digestive tract.[16-24] The underlying goal of these procedures was to direct exhaled air through the shunt to induce vibration of some source within the pathway so as to produce audible voice for speech; some of the sources for this vibration included an artificial reed, reconstructed tissue, and the mucosal surfaces of a natural anatomic narrowing.

The unmet challenge for nearly all of these techniques was the construction of a shunt or tract that was durable, nonstenosing, and minimally resistive to airflow for voicing, while simultaneously preventing aspiration of food from the upper digestive tract into the airway during swallowing. None of the proposed surgical voice restoration methods achieved a level of success that translated into widespread clinical applicability. Each failed to satisfy one or more of the following important criteria: (1) normal swallowing without aspiration, (2) reliable voice, (3) no oncologic compromise, (4) surgical simplicity, (5) universally consistent reproducibility, (6) inclusion of an uncomplicated, cost-effective prosthetic valve to prevent stenosis and aspiration, and (7) viability in irradiated tissues.[25]
Tracheoesophageal voice production

In 1979, Singer and Blom, mindful of the aforementioned criteria, introduced the tracheoesophageal “puncture” method, which incorporated a simple, disposable, valved silicone prosthesis.[13] Initially, this prosthesis was placed months or years after laryngectomy but later was inserted as part of the laryngectomy.[26] Over a 20-year period, both the surgery and prosthesis have evolved and been refined to the point that they are now recognized as a major advance in the field of postlaryngectomy voice restoration.

The tracheoesophageal puncture method is similar in principle to the “ice pick” surgery described above but replaces the goose quill with a valved silicone prosthesis. The tracheoesophageal puncture is surgically established, either at the time of laryngectomy or as a delayed procedure, and a soft, silicone, stenting catheter is advanced through and down the esophagus.[27] After approximately a 1-week interval of healing, the catheter is removed and the tracheoesophageal tract is measured for length and fitted with a valved “voice” prosthesis (Figure 3).

Blom-Singer voice prosthesis

The tracheoesophageal voice prosthesis is a hollow, 16- or 20-French, silicone tube that has a one-way flap valve positioned within its proximal tip (Figure 4).[28,29] The valve serves two functions. First, its presence prevents the natural tendency of the puncture tract to spontaneously and slowly heal closed. This is critical to the success of this method, because the stenosing action results in the formation of a tissue “seal” around the tubular shaft of the prosthesis and prevents tracheal aspiration of the esophageal contents. The unidirectional, hinged flap valve opens with the flow of exhaled pulmonary air directed through the prosthesis during voice production and remains in the fully closed position during swallowing to prevent leakage back into the airway. Semiflexible, disc-shaped retention flanges on either end of the prosthesis prevent its dislodgment from the tracheoesophageal puncture. FIGURE 5

Insertion of Blom-Singer voice prosthesis

During the insertion process, one-half of a dissolvable gelatin capsule transiently maintains the forward folded position of the proximal (esophageal) retention flange to permit atraumatic entry of
the prosthesis through the tracheoesophageal puncture tract (Figures 5 and 6).[29] Saliva in the esophagus dissolves the gel cap and deploys the retention flange, such that it seats itself against the anterior esophageal wall. A moderately gentle outward tug on the prosthesis with a hemostat flexes the esophageal retention flange in the opposite direction to permit removal for cleaning or replacement.

Some prosthesis models are cleaned in situ by the user and only removed and replaced twice yearly on average by a professional during a 5-minute office visit. An alternate-style prosthesis allows independent removal and replacement by the user. FIGURE 6

Blom-Singer voice prosthesis in situ

Fluent tracheoesophageal voice is produced when the user inhales, occludes the tracheostomal neck opening with the thumb, and exhales. Airflow against the occluded tracheostoma diverts through the voice prosthesis and up the esophagus to the mouth. Vibration of opposed mucosal surfaces along the pharyngoesophagus produces a variably husky or hoarse quality voice that is articulated by the tongue, lips, and teeth into intelligible speech.

Some patients find using a finger to occlude the tracheostomal opening in order to speak both inconvenient and unhygienic. Blom and Singer introduced an optional secondary prosthesis called a tracheostoma valve that eliminates this problem in some patients.[30] This daytime device attaches with adhesive to the skin surrounding the tracheostomal opening and contains a flap valve that is normally in the open position (Figure 7).[29] When the user exhales to speak, the airflow pushes the valve to the closed position, such that air is diverted through the voice prosthesis, eliminating the need to manually occlude the tracheostomal opening with a finger or thumb. With decreasing airflow at the end of the utterance, the valve automatically returns to its fully open position to permit unrestricted respiration.

Two Common Problems

FIGURE 7

Blom-Singer tracheostoma valve

The tracheoesophageal voice restoration method is not without problems, the majority of which cause temporary inconvenience and generally have simple solutions.[31] Some frequently encountered problems include premature voice prosthesis failure caused by fungal colonization of the flap valve and difficulty producing voice because of airflow-elicited reflex contraction of the pharyngeal muscles of the throat.

Fungal colonization causing internal valve leakage necessitates frequent voice prosthesis replacement at a cost ranging from $100 to $200. Twice-daily decontamination of the oral cavity with a 4-minute rinse of a liquid antimicrobial agent effectively reduces the yeast in the saliva that bathes the prosthesis during swallowing.[32] Using this protocol, the life of the prosthesis can be extended to the expected 6-month duration.[33] Some manufacturers are pursuing a more definitive
solution to the problem by altering the prosthetic material in an effort to make it yeast resistant. An estimated 30% to 40% of tracheoesophageal voice prosthesis users experience reflex contraction of the pharyngeal muscles elicited by air distention of the upper esophagus during attempted voice production. As a result, the voice is either very brief and effortful or cannot be produced at all. It is likely that this same phenomenon contributes to the high failure rate among individuals who attempt to learn esophageal voice. Reflex contraction can be prevented by surgically relaxing the pharyngeal muscles unilaterally or by eliminating their motor innervation during the laryngectomy.[34,35] Recently, tracheoesophageal voice failure has also been resolved nonsurgically on an outpatient basis by unilateral chemical denervation of the pharyngeal muscles with botulinum neurotoxin.[36] Injection of this toxin into the muscles affects presynaptic cholinergic nerve terminals. This impairs the release of acetylcholine at the neuromuscular junction, resulting in paralysis of the muscle. Within 72 hours, the muscles relax sufficiently to facilitate fluent tracheoesophageal voice. This effect is unexplainable but appreciatively permanent in some individuals, while others require reinjection at intervals of 3 to 5 months.

Advantages and Disadvantages

The most prominent advantage of tracheoesophageal voice is rapid recovery of fluent high-quality voice and speech. However, as with essentially all voice restoration techniques, tracheoesophageal voice also has some features that some may consider to be disadvantageous. These include routine prosthesis management and cost, the need for additional surgery, and, for some prosthesis users, the inconvenience of having to use the hand to speak.

Summary

Total laryngectomy terminates normal voice production and significantly alters respiration and the sensory functions of smell and taste. The inability to speak is usually considered to be the most profound impairment. Rapid, effective restoration of voice and speech is a critical factor in enabling the patient to return to normal activities of life and in preventing the negative psychological, social, and economic consequences of total laryngectomy. Traditionally, the artificial larynx and esophageal voice have provided effective methods of alaryngeal speech for countless numbers of laryngectomized persons. Unfortunately, a significant number of patients have either been unsuccessful or dissatisfied with these options. The introduction of tracheoesophageal voice in 1979 offers a third alternative for voice restoration. In many countries throughout the world, tracheoesophageal voice has gradually emerged as the method of choice for postlaryngectomy voice restoration.

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