Methods of Voice Reconstruction

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ABSTRACT

This article reviews methods of voice reconstruction. Nonsurgical methods of voice reconstruction include electrolarynx, pneumatic artificial larynx, and esophageal speech. Surgical methods of voice reconstruction include neoglottis, tracheoesophageal puncture, and prosthesis. Tracheoesophageal puncture can be performed in patients with pedicled flaps such as colon interposition, jejunum, or gastric pull-up or in free flaps such as perforator flaps, jejunum, and colon flaps. Other flaps for voice reconstruction include the ileocolon flap and jejunum. Laryngeal transplantation is also reviewed.

KEYWORDS: Electrolarynx, esophageal speech, ileocolon flap for voice reconstruction, laryngeal transplantation, pneumatic artificial larynx, tracheoesophageal puncture, voice reconstruction

Oropharyngeal carcinoma has conventionally been treated with surgery and combined radiation for advanced disease. Although there is ongoing controversy surrounding laryngeal organ preservation by treating with radiation alone, the traditional treatment for advanced oropharyngeal disease involving the larynx results in laryngectomy.¹

The incidence of laryngeal carcinoma is 1 in 100,000, with more than 10,000 patients in the United States diagnosed each year; 70% of these patients are completely cured of their disease.² Most of the patients presenting with squamous cell cancer in the advanced stages, as well as those with recurrent disease, will undergo a laryngectomy. This procedure leaves patients without a mechanism for voice production, and alternate options for producing sound must be sought.

Voice reconstruction in patients with total laryngectomy is a complex and exciting topic. Options range from nonsurgical methods such as esophageal speech or

use of an external device to surgical methods creating a tracheoesophageal fistula by placement of a prosthesis or by using local and/or free skin or intestinal flaps for creation of a voice tube (a tube that acts as a shunt from the trachea to the esophagus or neoesophagus).^{3,4}

NORMAL SOUND PRODUCTION

The production of sound involves the lungs, the vocal cords within the larynx, and the oral cavity. The lungs develop airflow and pressure to vibrate the vocal cords or folds, which then originate sound in the larynx as a fundamental tone. The tone is then modified by various resonating chambers above and below the larynx. The sound is converted to speech by actions of the tongue, lips, palate, pharynx, teeth, and related structures. The molecules in the airflow from the lungs pass out at the adducting vocal folds, which open and close in rapid cycles, allowing the air to exit the supraglottic vocal tract

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Advances in Head and Neck Reconstruction, Part I; Guest Editors, Samir Mardini, M.D., Christopher J. Salgado, M.D., and Hung-Chi Chen, M.D., F.A.C.S.

Semin Plast Surg 2010;24:227-232. Copyright © 2010 by Thieme Medical Publishers, Inc., 333 Seventh Avenue, New York, NY 10001, USA. Tel: +1(212) 584-4662.

DOI: <http://dx.doi.org/10.1055/s-0030-1255340>.

ISSN 1535-2188.

as periodic sound waves. These sound waves can resonate in the vocal tract and be heard as voice. The vibrating vocal folds are the major source of periodic sound for phonation.

The movement of the vocal folds is explained by the aerodynamic-myoelastic theory.⁵ At the beginning of phonation, the vocal folds are closed in the midline position. As the subglottic pressure increases and overcomes the resistance from the closed vocal folds, the folds are forcibly separated, creating an increase in air-flow through the glottis. A momentary pressure drop occurs as the airflow decreases, causing the vocal folds to move back together. The elastic tissue of the vocal folds pulls them back to midline, completing a full cycle of vibration.

METHODS OF VOICE REHABILITATION

Speech impairment occurs in 34 to 70% of head and neck oncologic patients.⁶⁻⁸ There are nonsurgical methods of voice rehabilitation, which include the electrolarynx, pneumatic artificial larynx, and esophageal speech.

Nonsurgical Methods of Voice Rehabilitation

THE ELECTROLARYNX

There are two types of battery-operated electrolarynx. One type requires placement of the device against the external throat, a button is pushed, and the electrolarynx transmits a vibratory noise to the pharynx (Fig. 1). This vibratory noise is then formed into words and sounds with the lips, teeth, and tongue. The second type of battery-operated electrolarynx transmits the sound directly into the mouth via a small tube, and words and sounds are made in a similar manner. The sound produced by using these devices is understandable but machine-like and monotonous. The device is expensive, and its appearance and sound are associated with a strong social stigma. It requires batteries, and it is difficult for patients who speak languages requiring intonation of words to be understood.

PNEUMATIC ARTIFICIAL LARYNX

The external pneumatic device or pneumatic artificial larynx is the simplest and least costly method of voice restoration. It is one of the mechanisms used by post-laryngectomy patients and is the most commonly used method in Taiwan.

One end of the device is placed over the tracheostomy. Air is directed from the tracheostomy through the device, where it travels through a membrane that produces air vibrations that end up in the mouth, where articulation by oral structures produces intelligible speech. This method requires very little training. Additionally, it allows patients to intonate words, which is

Figure 1 Electrolarynx. The device is placed externally on the pharynx, a button is pushed, and the electrolarynx transmits a vibratory noise.

necessary for communication in languages such as Mandarin, Taiwanese, and Cantonese. The pneumatic artificial larynx, although effective, has several disadvantages: The device is external, requires maintenance, and cannot be concealed; and its use carries a negative social stigma for the patient. Often, these patients draw a significant amount of attention to themselves during social interactions and are ridiculed by children. Occasionally, some patients may abandon the pneumatic artificial larynx simply because of the awkwardness of its use (Fig. 2).

Figure 2 Pneumatic artificial larynx. One end of the device is placed over the tracheostoma, and air is directed through the device, which has a membrane that produces air vibrations that are transferred to the mouth for articulation.

ESOPHAGEAL SPEECH

Esophageal speech works by training the patient first to collect air in the stomach and lower esophagus. The air is then propelled into the upper part of the esophagus and pharynx, where it creates vibrations of the walls, and sound is produced. The sound is articulated in the mouth to produce intelligible speech. This technique of voice production requires long periods of training for patients to master and is considered one of the most challenging methods to learn. Only 50 to 60% of patients who train to use this method can effectively and comfortably do so. Additionally, the maximum phonation time is relatively short and is significantly interrupted by attempts to gather more air to use for the upcoming sound. Nevertheless, this method does not require the use of hands or battery-powered devices, and after adequate training patients can produce short bursts of intelligible speech.

Surgical Methods of Voice Reconstruction

NEOGLOTTIS

The neoglottis involves suturing the pharyngeal mucosa over the superior end of the transected trachea above the primary tracheostoma and making a permanent stoma in the mucosa. The goal of the neoglottis is a tracheo-hyoidpexy technique that aims at restoring laryngeal function. After the creation of a fistula between the trachea and the esophagus, local flaps are raised and sutured to keep the fistula open.

This method of reconstruction has a high rate of regurgitation of food and liquid into the trachea as well as a high incidence of fistula closure. In addition, no one-way valve is created, which exists in other methods of reconstruction. Because of these inherent problems, use of the neoglottis has been abandoned by our team and by most other surgeons.

TRACHEOESOPHAGEAL PUNCTURE AND PROSTHESIS

In this procedure a fistula is created between the posterior wall of the trachea and the anterior wall of the esophagus, and a prosthetic one-way valve mechanism is inserted. The patient occludes the trachea stoma with a finger and the air is diverted into the esophagus where the air movements vibrate the walls of the esophagus and pharynx, thereby creating sound. This sound is transferred to the mouth where, with the help of the tongue, teeth, and lips, articulation produces intelligible speech (Fig. 3).

Because of the presence of a one-way valve, air passes from the trachea into the esophagus. Food can remain in the esophagus and does not regurgitate into the trachea. Various prostheses are used, including the Blom-Singer (InHealth Technologies, CA), Provox (Atos Medical, Horby, Sweden) and Nijdam.⁹⁻¹³ There are also "hands-free" valves, which allow speech without the patient having to occlude the stoma.

Figure 3 Tracheoesophageal puncture and prosthesis. A fistula is created between the posterior wall of the trachea and the anterior wall of the esophagus. The patient occludes the tracheostoma with a finger, and the air is diverted into the esophagus and pharynx to create sound.

In general, tracheoesophageal puncture (TEP) is usually performed secondarily months after the primary reconstruction. However, there are patients who are candidates for placement of the TEP primarily at the same setting as the reconstruction. Primary speech restoration carries a questionable increase in the incidence of stricture, fistula, and postoperative wound breakdown.¹⁴⁻¹⁷

Advantages of this method of reconstruction include simplicity of the procedure, minimal training requirement, low aspiration risk, and no external device. Published success rates vary from 65 to 85% in laryngectomy patients with the use of TEP.^{18,19}

Potential complications of the device include obstruction, tissue maceration, growth of fungus and bacteria on the voice prosthesis, aspiration of a dislodged prosthesis into the trachea or esophagus, tracheal stenosis, esophageal perforation, and valve failure.²⁰

TEP and Prosthesis in Patients with Colon Interposition or Gastric Pull-Up Voice reconstruction can be performed in patients who have undergone a pharyngolaryngectomy and reconstruction of the esophagus with a pedicled colon, stomach, or jejunum. In a simple surgical procedure, a fistula is created between the posterior wall of the trachea and the anterior wall of the neoesophagus (pedicled colon or pedicled stomach).

The fistula is allowed to develop for a few weeks, then a prosthesis is inserted into the fistula. We consider that the quality of speech is better with gastric pull-up compared with colon interposition due to the thickness of the stomach wall and the presence of rugae.

TEP and Prosthesis in Patients with a Neoesophagus Created Using Free Tissue Transfer Patients who have undergone a pharyngolaryngectomy followed by esophageal reconstruction with a free fasciocutaneous or cutaneous flap, a free jejunum flap, or a free colon flap can regain voice function by using creation of a tracheoesophageal fistula and insertion of a voice prosthesis. In a similar procedure to that discussed above, a fistula is created between the trachea and the neoesophagus by puncturing the posterior wall of the trachea and the anterior wall of the neoesophagus.

This method is successful in patients who have undergone either anterolateral thigh (ALT) flap or radial forearm free flap (RFFF) reconstruction.^{21–23} Azizzadeh reported on 20 RFFF reconstructions for pharyngoesophageal carcinoma: Five patients received voice reconstruction, and all these five patients had good functional outcome.²¹ In a large extensive review of fasciocutaneous flaps, Murray et al reported 87% good functional outcome after RFFF and ALT reconstruction and voice prosthesis.²² Yu et al also reported 89% functional voice reconstructions after ALT flaps.²³

Ileocolon Flap Anatomically, the ileocolon is suited for a variety of reconstructive options. The colon is used to reconstruct the esophageal defect, and the ileum is used to create a voice tube. Also, the ileum can be used in conjunction with the ileocecal valve, with or without a tubed colon.²⁴

After pharyngolaryngectomy, an ileocolon flap can be used by placing the ascending colon segment to the pharynx and cervical esophagus, then a second voice tube is created using a segment of ileum. The colon provides a better size match for the oropharynx, and the ileocecal valve acts as a one-way valve to prevent regurgitation of food into the voice tube and subsequently into the airway. This flap usually requires plication of the valve to reinforce its function.

The flap may be inset either isoperistaltic or antiperistaltic (Fig. 4). The isoperistaltic design allows for slightly better swallowing, but a longer segment of ileum is required. The ileocecal valve is placed closer to the pharynx, which creates a shorter segment of neoesophagus. In contrast, the antiperistaltic design allows for a shorter segment of ileum and a longer length of neoesophagus, which may enhance voice production. Each patient and the individual defect are assessed and a case-by-case decision is made on whether to inset the flap in an isoperistaltic or an antiperistaltic design.

Figure 4 Ileocolon flap. Inset of the ileocolon flap for voice reconstruction. Magnified view shows internal plication of the ileocecal valve.

For speech, the tracheostoma is occluded, and air is shunted from the trachea into the voice tube, where vibratory movements of the voice tube, ileocecal valve, and pharynx produce voice.

There are variations in this flap, such as in patients with a total laryngectomy and only a partial defect of the esophagus (less than one third of the circumference). The ileocecal valve flap is used with a small patch of cecum. This patch of cecum is used to repair the defect of the esophagus; the ileum is used to create a voice tube, and the ileocecal valve provides a mechanism to prevent food regurgitation into the ileum and trachea.

A variation of this flap is the use of the appendix. The appendix is used to create a voice tube that will shunt air from the trachea to the esophagus or neoesophagus.^{25,26}

Free Jejunum Flap In selected patients with a hypopharyngeal defect, esophagectomy with laryngectomy, or laryngectomy, we prefer to use the free jejunum flap for reconstruction.²⁰ In our practice, this provides excellent swallowing function and a relatively quick recovery time.

After microvascular transfer, the jejunum is divided into two parts, based on the same vascular pedicle. The first part is placed in an isoperistaltic direction and is used for reconstruction of the cervical esophagus. The second part is fabricated into a voice tube that provides a conduit for air transfer between the airway and pharyngoesophagus. When the patient is not speaking, air is not shunted through this conduit. When the patient speaks, the air is diverted through this voice tube by occluding the tracheostoma. Air is driven from the lung through the voice tube into the pharynx and then the mouth, where articulation is performed to produce proper speech. Because there is no inherent valve in this mechanism, various designs have been made to prevent food regurgitation into the airway.²⁷ One

method is to inset the voice tube–esophagus junction in such a way as to create a valve-like structure.

LARYNGEAL TRANSPLANTATION

The future of reconstructive surgery lies in advances in composite tissue transplantation. Although there has been a considerable amount of research and interest in laryngeal transplantation, it remains a controversial topic with several obstacles impeding large clinical trials. It is a complex procedure that would involve at least anastomosis of the superior thyroid artery, jugular vein, and four nerves (two recurrent and two superior laryngeal nerves). In addition, tracheostomy, gastrostomy, and stenting are required.²⁸ The first laryngeal transplant was performed in Cleveland, Ohio, in 1988.²⁹ The patient, who underwent laryngectomy for trauma, suffered early acute rejection episodes but then later achieved normal speech and swallowing function.

The ideal candidate for laryngeal transplantation is the trauma patient. Transplantation in cancer patients is morbid and controversial due to their limited life span. Some argue that laryngeal transplantation yields excellent results of voice production with high success rates and quick return of voice function.³⁰ However, the critics of laryngeal transplantation believe that there is poor reinnervation from the recurrent laryngeal nerve to target muscles, leading to dyskinesia of the cords and other muscles.³¹

In general, the future of transplantation lies in research to decrease rejection and encourage immunogenicity. Although immunosuppressive medications have improved significantly, many long-term and some short-term side effects have not been eliminated.³² With proper clinical trials and medical advances, laryngeal transplantation could indeed revolutionize the way we treat laryngectomy patients and voice reconstruction.

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