Reconstruction of the Esophagus and Voice

Foot

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Background: Esophageal defects are reconstructed using a variety of methods and tissue types. The choice depends on the location of the defect, the condition of the patient, and the flaps that are available for reconstruction. Often, patients with esophageal defects also lack a mechanism for voice production following a total laryngectomy procedure.
Methods: A review of the literature was performed for esophagus reconstruction and voice rehabilitation following laryngectomy. Methods of voice restoration using intestinal transfers are presented based on the authors' experience.
Results: Several methods of esophagus and voice restoration can achieve excellent functional outcomes.
Conclusion: Esophagus reconstruction and voice rehabilitation following esophageal resection and total laryngectomy is possible using a variety of flaps with good functional outcomes. (*Plast. Reconstr. Surg.* 126: 471, 2010.)

The advent of microsurgical techniques and advances in understanding of flap surgery have allowed for the successful reconstruction of complex defects involving the hypopharynx, cervical esophagus, and voice mechanisms in a single-stage operation with minimal complications.[1,2] In the past, multiple staged procedures were performed to reconstruct hypopharyngeal and esophageal defects, which ultimately resulted in some successes[3]; however, many procedures were required, hospitalization times were longer, and immediate and long-term complications and poor functional outcomes were met. In patients in whom conventional methods were exhausted and all attempts had failed, a gastrostomy or jejunostomy was placed for nutrition. Microsurgical advances over the past four decades have allowed for completion of reconstruction of almost all types of esophageal defects.[4] Indications for esophagus reconstruction, with or without voice reconstruction, are congenital disease, tumor excision, radiation damage, a failed reconstructive effort, or corrosive injury. The defect may be partial or complete (circumferential), and may involve a short or long segment. A complete circumferential defect involving the hypopharynx and/or cervical esophagus is typically encountered following tumor excision. Complete circumferential defects can extend from the pharynx to the pylorus.[5]

When total laryngectomy is performed with or without esophageal resection, the patient is left with the catastrophic predicament of the lack of a mechanism for voice production. The ultimate goal in performing reconstruction in these patients is to establish a continuous gastrointestinal tract, using a functional conduit, and create a mechanism for voice production in patients who have undergone total laryngectomies. The hope is that these patients will be able to eat without choking, nourish themselves through oral intake alone, and be able to produce intelligible speech through one of the available mechanisms that are discussed below.

The anatomical defect dictates the type of reconstruction that should be used.[6] Therefore, one must clearly understand the normal anatomy (Fig. 1) and physiology of the upper gastrointestinal tract and the voice production mechanisms. F1

The options available for hypopharyngeal and esophageal reconstruction range from placing a skin graft over a stent, to local and regional flaps that are pedicled (local random pattern skin flaps, deltopectoral flap, or pectoralis major flap), regional pedicled intestinal flaps (stomach, colon,

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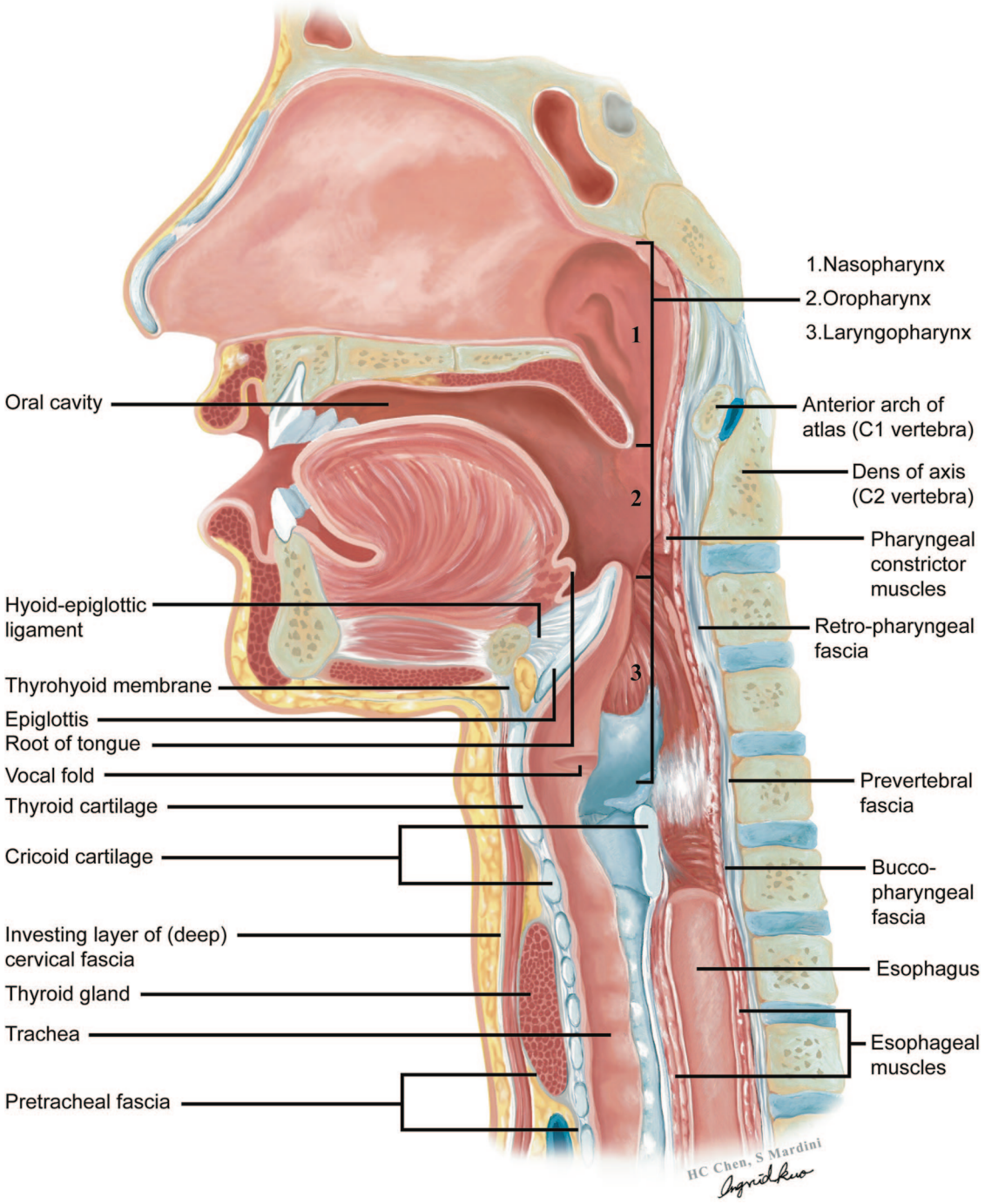

Fig. 1. Schematic of normal human structural anatomy (sagittal view).

or jejunum), or free tissue transfer with skin (radial forearm or anterolateral thigh) or free intestinal flaps (jejunum or colon).[7–10] Surgical resection of cancer of the head and neck region commonly involves laryngectomy, which results in significant anatomical and functional alterations, such as a permanent tracheostoma and loss of laryngeal speech.[11] The end result is impairment of respiration, swallowing, and speech function.

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 (the standard therapy at this time) or use of 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).[2,6]

SURGICAL INDICATIONS

Esophageal Reconstruction

Patients requiring esophageal reconstruction present with either a tumor that requires resection, a stricture caused by irradiation, a previous resection and inadequate reconstruction, or a stricture caused by corrosive injury. Computed tomographic scans, esophagograms, and other medical studies to determine the medical condition of the patient are commonly performed, as is endoscopy for tumor biopsy and evaluation of surrounding anatomy. In patients found to have poor pulmonary function, pedicled intestinal flaps that go through the thorax or mediastinum should be avoided. The skin of the chest and the pectoralis major muscle are also evaluated to see whether there is scarring or disruption of tissues that may be needed in the reconstruction. If free tissue transfer is contemplated, recipient vessels must be present, and assessment of those vessels can be performed preoperatively using a form of angiography. Usually, assessment of vessels is performed intraoperatively unless there are particular circumstances that warrant preoperative assessment. Previous irradiation and/or surgery may have a negative impact on the recipient vessels.[12–14]

Functional Anatomy

The hypopharynx and the cervical esophagus connect the oral cavity to the thoracic esophagus. They are tubular structures that act in a coordinated fashion to allow the food bolus to move from the oral cavity to the thoracic esophagus. Because of the coordinated motions and the secretions from the salivary glands and the mucosal lining, the food passes smoothly from proximal to distal. The hypopharynx provides the function of deglutition and, because of constrictive and propulsive forces, is able to provide a "functional" conduit for transit of the food bolus.[15] Because the tongue is the most significant contributor to the propagation of the food bolus, and not the pharyngeal muscles, efforts to restore a passive conduit can often yield reasonable results.[16]

Voice Reconstruction

The incidence of laryngeal carcinoma is one in 100,000, with more than 10,000 patients in the United States discovered each year; 70 percent of these patients are completely cured of their disease.[17] Most of the patients presenting with squamous cell cancer in the advanced stages, and those with recurrent disease, will undergo laryngectomy. This procedure leaves the patients without a mechanism for voice production, and alternate options for producing sound must be sought. Reconstructive goals for patients who have undergone laryngectomy are both a mechanism for voice production and maintenance or restoration of swallowing function (in patients who have undergone partial or complete excision of a segment of the cervical esophagus).

There are both surgical and nonsurgical voice rehabilitation methods. The purpose of this article is to discuss surgical methods of voice reconstruction. The standard treatment and most common method for restoration of a mechanism for voice production involves creation of a tracheoesophageal fistula and placement of a one-way voice prosthesis; however, other surgical methods, with less long-term follow-up, such as reconstruction of voice with intestinal transfers, can provide good voice quality, with fewer long-term complications and maintenance requirements.

PHARYNGOLARYNGECTOMY

Hypopharyngeal tumors often present with hoarseness, dysphagia, sore throat, and ipsilateral otalgia or odynophagia. The patient undergoes endoscopy (usually performed as part of a triple endoscopy procedure) and biopsy to establish the diagnosis. Depending on the stage of the tumor, appropriate therapy is instituted. T1 and T2 tumors have comparable outcomes when radiation therapy or surgery is performed. Surgery, in combination with radiotherapy and sometimes chemotherapy, yields the best results for more advanced tumors. For these advanced tumors, such as T3 and T4 lesions, laryngopharyngectomy with neck dissection is often required. The defect created results in the lack of a voice mechanism and a discontinuity in the gastrointestinal tract. The reconstruction can then be performed for the esophagus defect only, or it can be combined with one of the options for voice rehabilitation.

ESOPHAGEAL RECONSTRUCTION METHODS

The most common methods for esophageal reconstruction are gastric pull-up, pectoralis major flap, colon interposition, fasciocutaneous flaps (radial forearm free flap or anterolateral thigh flap), and free jejunum and free colon flaps. A thorough comparison of the different types of reconstruction is presented in Tables 1 through 4.[1,18–34] Data interpretation in the presented tables is limited because of wide ranges in variability and data recording. Data are recorded as best interpretation of each series.

T1, AQ:2

Gastric Pull-Up

Replacement of the esophagus by transposition of the entire stomach through the posterior mediastinum is applicable when total esophagectomy is required for complete cancer resection. It is less applicable for high cervical esophageal or hypopharyngeal lesions that extend superiorly toward the base of the tongue. Gastric transposition is a one-stage procedure. Only one anastomosis is placed superiorly to the remnant pharynx, and a pyloroplasty is performed. The stomach is mobilized solely on the right gastric and gastroepiploic vessels. Successful swallowing can be achieved in 83 to 98 percent of patients, with stricture rates between 0 and 29 percent, fistula rates between 3 and 48 percent, and overall low mortality (Table 1).[1,18–23]

Pectoralis Major

Local, regional musculocutaneus flap transfer is usually used for partial defects of the hypopharynx or cervical esophagus. After completion of a laryngopharyngectomy or partial pharyngeal resection, a skin paddle of appropriate size is outlined on the anterior chest wall. The major blood supply is the pectoral branch of the thoracoacromial artery. The skin paddle can serve as a patch for partial pharyngeal wall defects or tubed for circumferential defects after tunneling under the undermined neck skin.[35] In general, these flaps have a lower pulmonary and cardiac morbidity (0 to 15 percent) than other reconstructive options and exhibit functional swallowing (60 to 100 percent) and good voice outcomes (Table 2).[1,21,24,25]

Pedicled Colon (Colon Interposition)

The use of the colon to reconstruct the esophagus is reserved for cases in which previous surgery makes gastric pull-up impossible (such as previous gastrectomy). Its main purpose is to bypass the entire thoracic esophagus, but it can also be used to replace the cervical esophagus only. The segment of transposed colon, typically the left because of less anatomical variability, may be routed retrosternal or through the posterior mediastinum, depending on the esophageal remnant. Complications are related to the three anastomotic requirements and the fact that the middle colic blood supply to the segment is less abundant than that of the transposed stomach or free jejunum.[36]

Stricture rates are similar to gastric pull-up and vary from 6 to 21 percent. Reported fistula rates vary from 9 to 40 percent, with successful swallowing rates from 58 to 98 percent (Table 3).[1,19,20,22,26–29]

Table 1. Gastric Pull-Up

Reference	Defect	No. of Patients	Successful Swallowing (liquid or solid) (%)	Stricture (%)	Fistula/Leak (%)	Flap Failure Rate (%)	Medical Complications (e.g., pulmonary, cardiac) (%)	Mortality (immediate) (%)
Schusterman et al., 1990[18]	Cervical esophagus	15	87	13	20	13	27	7
Carlson et al., 1992[1]	Cervical esophagus, hypopharynx	23	83	13	26	0	43	9
Triboulet et al., 2001[19]	Hypopharynx, cervical esophagus	127	98*	6.7	16	—	22	4.8*
Hagen et al., 2001[20]	Esophagectomies	28	—	—	4	0	60	7
Clark et al., 2006[21]	Hypopharynx	21	90	29	48	—	15	—
Pesko et al., 2006[22]	Pharyngoesophagus	29	—	—	17	—	27	10
Ferahkose et al., 2008[23]	Cervical esophagus, hypopharynx	38	—	0	3	5	15	5
Range			83–98	0–29	3–48	5–13	15–60	5–10

*Data represent gastric pull-up, jejunum, and colon.

Table 2. Pectoralis Major and Other Musculocutaneous Flaps

Type of Reconstruction	Reference	Defect	No. of Patients	Successful Swallowing (liquid or solid)	Stricture (%)	Fistula/ Leak (%)	Flap Failure (%)	Medical Complications (e.g., pulmonary, cardiac) (%)	Immediate Mortality (%)	Patients Who Received Voice Prosthesis (%)	Functional Voice Outcome (%)
PM	Clark et al., 2006[21]	Hypopharynx	68	81	12	35	—	15	3	44*	—
PM plus trapezius plus sternocleidomastoid	Carlson et al., 1992[1]	Cervical esophagus, hypopharynx	45	60	27	78	2	0	0	—	—
PM	Spriano et al., 2002[24]	Hypopharyngeal	37	100	0	13	0	10	3	24	100
PM	Saussez et al., 2006[25]	Hypopharyngeal	12	100	17	33	0	0	0	50	(5/6) 83
Range				60–100	12–27	13–78	0–2	0–15	0–3	24–50	83–100

PM, pectoralis major.
*Includes gastric pull-up, other free flaps, and PM.

Table 3. Colon Interposition

Reference	Defect	No. of Patients	Successful Swallowing (liquid or solid) (%)	Stricture (%)	Fistula/ Leak (%)	Flap Failure Rate (%)	Medical Complications (e.g., pulmonary, cardiac) (%)	Immediate Mortality (%)
Carlson et al., 1992[1]	Cervical esophagus/ hypopharynx	19	58	21	11	—	—	—
Hagen et al., 2001[20]	Esophagectomy	72	—	—	13	—	75	6
Triboulet et al., 2001[19]	Hypopharynx, cervical esophagus	5	981	—	40	—	0	—
Popovici, 2003[26]	Esophagectomy	347	83	7	7	1	10	5
Pesko et al., 2006[22]	Pharyngoesophagus	11	—	—	9	1	45	18
Motoyama et al., 2007[27]	Thoracic esophagus	34	78 (7/9)	6	9	—	20	0
Mine et al., 2009[28]	Esophagectomy	95	60	6	13	—	37	5
Knezevic et al., 2007[29]	Esophagectomy	336	95	4	9	3	14	4
Range			58–98	6–21	7–40	1–3	0–75	0–18

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Radial Forearm or Anterolateral Thigh Flap

These fasciocutaneous flaps have both been commonly used for hypopharyngeal and cervical esophagus reconstructions. Both provide pliable and potentially thin tissue with large-diameter pedicles.[12,37,38] These flaps are used primarily in patients who are not candidates for more extensive procedures using abdominal viscera. Murray et al. published an extensive meta-analysis comparing radial forearm free flaps to anterolateral thigh flaps showing that stricture rates are slightly higher in radial forearm free flaps (18 percent) compared with thigh flaps (11 percent).[33] In general, microsurgical flaps have lower cardiac and pulmonary morbidity (0 to 15 percent), with stricture rates between 2 and 20 percent, fistula rates between 1 and 27 percent, and low flap failure T4, AQ:3 rates (Table 4).[21,30–34]

Jejunum Free Flap

This method has become the standard technique for reconstructing the hypopharynx and cervical esophagus. The swallowing function is excellent. It can be used to reconstruct defects up to 20 cm in length because of its segmental blood supply, which is readily identified using the transillumination technique (Fig. 2). F2 Total and subtotal esophageal reconstructions extending to the thoracic esophagus are usually reconstructed with pedicled colon, gastric pull-up, or pedicled jejunal flaps with distal revascularization in the neck.[39,40] The jejunal segment must be transferred in the isoperistaltic direction; otherwise, the patient will have difficulty swallowing. The jejunum has a high metabolic rate and should be revascularized as soon as possible. To prevent redundancy, the final length of the transferred jejunum should be adjusted after revascularization, because a devascularized jejunal segment will become elongated after being revascularized.

Overall successful swallowing can be achieved in 88 to 100 percent of patients, with functional T5, AQ:4 voice outcomes (Table 5). Stricture rates for jejunum are comparable to gastric pull-up and colon (0 to 22 percent). The published fistula rates are AQ: 5 0 to 32 percent less than 10 percent failure rates (Table 5).[1,18,19,22,23,31,41–47]

Free Colon

The free colon flap is less often used for esophageal and hypopharyngeal reconstruction. The use of free ileocolon for voice restoration is discussed below. Disadvantages of the use of this flap center around the size mismatch between the co-

Table 4. Other Microsurgical Flaps

Type of Reconstruction	Reference	Defect	No. of Patients	Successful Swallowing (liquid or solid) (%)	Stricture (%)	Fistula/Leak (%)	Flap Failure Rate (%)	Medical Complications (e.g., pulmonary, cardiac) (%)	Immediate Mortality (%)	Patients Who Received Voice Prosthesis (%)	Functional Voice Prosthesis
Jejunum plus other free flaps	Clark et al., 2006[21]	Hypopharynx	15 RFFF, 11 ALT, 30 jejunum	84	14	27	5	12	—	44†	—
	Antohi et al., 2003[30]	Pharyngoesophagus	8 RFFF, 13 scapular plus LD 13, 6 gastroomental, 3 jejunum	81	19	25	2	15	3	—	—
RFFF	Azizzadeh et al., 2001[31]	Pharyngoesophagus	20	85	20	20	0	—	0	20	(5/5) 100%
	Disa et al., 2003[32]	Hypopharynx	52	95	2	1	4	—	—	—	
	Murray et al., 2008[33]*		242	(35/53) 66%	18	14	1.5	—	1‡	22	(47/54) 87%‡
ALT	Murray et al., 2008[33]*		67	(40/43) 98%	11	16	2.3	—	1‡	52	(31/35) 88%‡
	Yu et al., 2006[34]	Pharyngoesophageal	26	(21/22) 95%	15	8	4	0		35	(8/9) 89%
Range				81–98	2–20	1–27	1.5–5	0–15	1–3	20–35	87–100

RFFF, radial forearm free flap; ALT, anterolateral thigh; LD, latissimus dorsi.
*Extensive review of fasciocutaneous flaps, meta-analysis.
†Includes all free flaps and pectoralis major.
‡Includes RFFF and ALT.

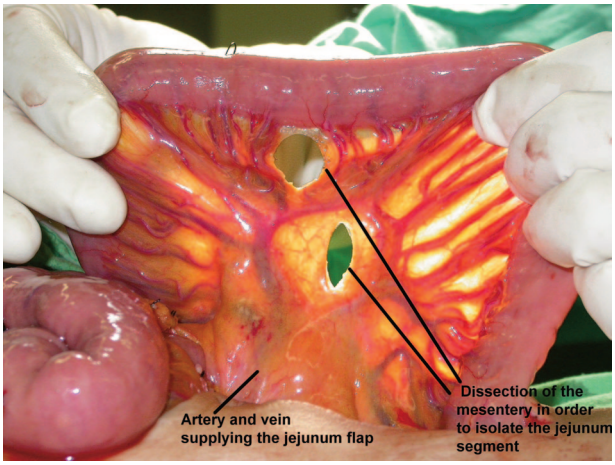

Fig. 2. Small bowel with vascular arcade using the transillumination technique.

lon and esophagus. However, when the defect involves the oropharynx, resulting in a wide defect, a free colon flap can be used. The "funnel flap" (free ileocolon flap with a valvuloplasty of the ileocecal valve) can solve the problem of matching the circumference at both ends of high pharyngoesophageal defects. The flap must be inset in a reverse direction and an ileocecal valve valvuloplasty must be performed (Fig. 3).[48] F3

Complications include leakage at the lower end (anastomosis with the thoracic esophagus) (which can be prevented by careful sutures and proper drainage, failure, and infection. Fistula rates vary between 8 and 46 percent, with minimal necrosis and 23.5 percent complication rates.[49,50]

VOICE RECONSTRUCTION METHODS

Normal Sound Production

Sound production originates in the larynx as a fundamental tone, which 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. The vocal folds open and close in rapid cycles, allowing the air to exit the supraglottic vocal tract 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.[51] At the beginning of phonation, the vocal folds are closed in 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 airflow 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. In recent decades, a wide variety of surgical and nonsurgical methods of voice restoration has been developed and used to help these patients attain better communication ability and quality of life.

METHODS OF VOICE REHABILITATION

Speech impairment occurs in at least 34 to 70 percent of head and neck oncologic patients.[52–54] There are nonsurgical methods of voice rehabilitation, which include the electrolarynx (Fig. 4), pneumatic artificial larynx (Fig. 5), and esophageal speech. The focus of this article is surgical methods of voice reconstruction. F4 F5

Surgical Methods of Voice Reconstruction

Neoglottis

After the creation of a fistula between the trachea and the esophagus, local flaps are raised and arranged in a way to maintain this fistula open. This method of reconstruction has a high rate of regurgitation of food and liquid into the trachea and a high incidence of fistula closure. The arrangement of tissues does not have a one-way valve as do many of the other mechanisms available. This method does, however, use only native tissue and does not require a foreign device. Nevertheless, it has been abandoned by our team and by most others performing voice reconstruction.

Tracheoesophageal Puncture and Prosthesis

A fistula is created between the posterior wall of the trachea and the anterior wall of the esophagus. A prosthetic device with a one-way valve mechanism is inserted. The patient occludes the trachea stoma with one of his or her fingers and the air is diverted into the esophagus where the air movements vibrate the walls of the esophagus and pharynx creating sound. This sound is transferred to the mouth where, with the help of the tongue, teeth, and lips, articulation produces intelligible speech. Because of the presence of a one-way valve, air is conducted from the trachea into the esophagus, while food and liquid are maintained in the esophagus and are not allowed to regurgi-

Table 5. Jejunum

Reference	Defect	No. of Patients	Successful Swallowing (liquid or solid) (%)	Stricture	Fistula/ Leak (%)	Flap Failure Rate (%)	Medical Complications (e.g., pulmonary, cardiac) (%)	Immediate Mortality (%)	Patients Who Received Voice Prosthesis (%)	Functional Voice Prosthesis (%)
Schusterman et al., 1990[18]	Cervical esophagus	48	88	22	16	6	4	2	—	—
Carlson et al., 1992[1]	Cervical esophagus, hypopharynx	26	80	16	20	4	19	0	—	—
Triboule et al., 2001[19]	Hypopharynx, cervical esophagus	77	98.4*	12	32		7	5*	—	—
Chang et al., 2002[41]	Laryngopharynx	168	—	—	14	—	—	—	—	—
Uchiyama et al., 2002[42]	Hypopharynx	126	—	—	5	2	15	—	—	—
Benazzo et al., 2002[43]	Hypopharynx, cervical esophagus	29	100	10	3	10	3	0	68	(20/20) 100%
Disa et al., 2003[31]	Hypopharynx	90	88	7	10	3	—	—	—	—
Okazaki et al., 2005[44]	Pharyngoesophageal	20	90	0	5	0	—	—	—	—
Pesko et al., 2006[22]	Pharyngoesophagus	6	—	—	0	0	33	17	—	—
Sarukawa et al., 2006[45]	Esophagopharyngeal	191	94	13	9	4	—	0	—	—
Yu et al., 2006[34]	Pharyngoesophageal	31	(17/26) 65%	19	3	6	16	0	29	(2/9) 22%
Ferahkose et al., 2008[23]	Cervical esophagus, hypopharynx	14	98	7	0	7	43	7		
Present study	Cervical esophagus	12	83	0	0	0				
Range			88–100	0–22	0–32	0–10	3–43	0–17	29–68	22–100

*Represents gastric pull-up, colon, and jejunum.

Fig. 3. Schematic of the ileocolon flap after ileocecal valve valvuloplasty, appendectomy, and inset into the pharyngoesophageal defect in an antiperistaltic direction. Note the size match on both the pharyngeal end and the esophageal end.

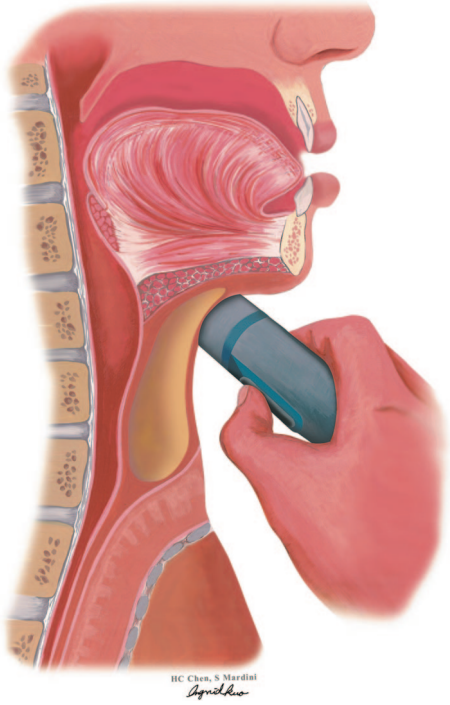

Fig. 4. Schematic of electrolarynx in use.

tate into the trachea. Various prosthesis are used for this purpose, including the Blom-Singer, Provox, and Nijdam; all with their advantages and disadvantages (Fig. 6).[55–59]

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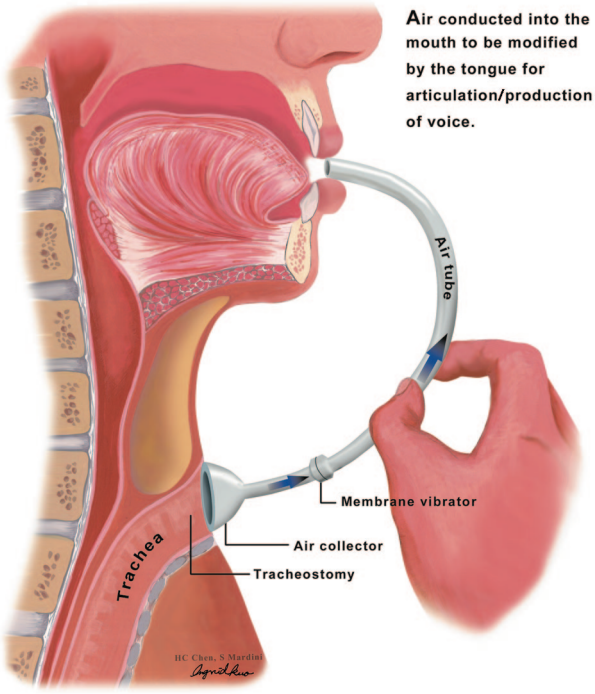

Fig. 5. Schematic of pneumatic artificial larynx for voice production.

In general, tracheoesophageal puncture is usually performed secondarily; however, it can be performed safely in the primary setting, but there may be an increased incidence of stricture.[60–62] 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 percent in laryngectomy patients with the use of tracheoesophageal puncture.[63,64] Disadvantages include the potential for (1) obstruction of the prosthesis by secretions or food particles; (2) tissue maceration around the prosthesis, which results in dilation of the tracheoesophageal fistula (the enlarged tracheoesophageal fistula may cause aspiration by allowing food particles and fluid to leak around the device); (3) inability to use a voice prosthesis after repeated changes when the largest size of voice prosthesis has been used (smallest size, approximately 6 mm; largest size, approximately 12 mm, at which point the tracheoesophageal fistula has to be closed); (4) growth of fungus and bacteria on the voice prosthesis, which can predispose the patient to airway infections; (5) dislodgement of voice prosthesis into the trachea, leading to aspiration, which can occur despite fixation to the skin; (6) tracheal stenosis; (7) esophageal perforation;

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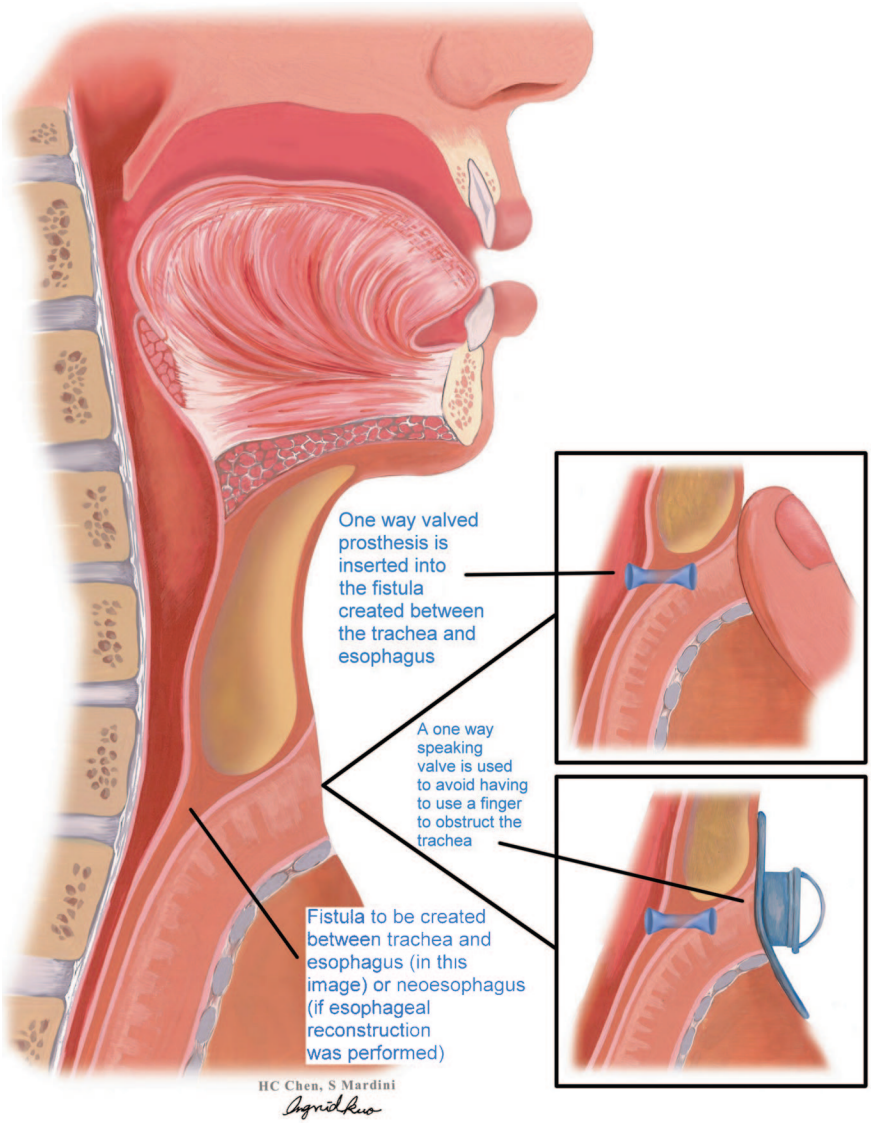

Fig. 6. Schematic of tracheoesophageal prosthesis.

and (8) valve failure and regurgitation of food and liquid into the trachea.[65]

Tracheoesophageal Puncture and Prosthesis in Patients with Colon Interposition, Jejunum, 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 pedicled 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 mature for a few weeks, and a prosthesis is inserted into this fistula (Table 5).

Tracheoesophageal Puncture and Prosthesis in Patients with a Neoesophagus Created by Using Free Skin, Jejunum, and Colon Flaps

Patients who have undergone a pharyngolaryngectomy followed by esophageal reconstruction with a free tubed skin flap, a free jejunum flap, or a free colon flap can regain voice function by use of the technique of creating a tracheoesophageal fistula and voice prosthesis insertion. In a procedure similar to that performed for patients with native esophagus, 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. Traditionally, a skin flap was used for esophageal reconstruction and a voice prosthesis for resto-

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ration of vocal function. This method is successful in patients who have undergone either anterolateral thigh or radial forearm free flap reconstruction (Table 4). For patients with a longer life expectancy, we prefer to reconstruct the voice tube using a segment of jejunum, or ileum with ileocecal valve, to prevent complications associated with long-term use of voice prosthesis.

Free Jejunum for Reconstruction of the Esophagus and Creation of a Voice Tube

The jejunal flap has a proven role in esophageal reconstruction. It provides excellent swallowing function and a relatively quick recovery time. It is a tubed structure with excellent peristaltic activity and has a great role in reconstruction of upper esophageal defects. Upon 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, and 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 form proper speech. Because there is no inherent valve in this mechanism, various designs have been made to prevent food regurgitation into the airway.[66] One method is to inset the voice tube/esophagus junction in a way to create a valve-like structure (Figs. 7 and 8). F7-8, AQ:7

Ileocolon Flap for Reconstruction of the Esophagus and Creation of a Voice Tube

The ileocolic region can provide tissue for reconstruction of a circumferential esophageal defect and for creation of a voice tube.[67] After pharyngolaryngectomy, if the defect starts in the oropharynx, an ileocolon flap is used where the pharynx and cervical esophagus are reconstructed using the ascending colon segment and a voice tube is created using a segment of ileum (Fig. 9). The advantages F9 that this construct have to offer is the ideal size match between the oropharynx and the colon and the fact that the ileocecal valve acts as a one-way valve to prevent regurgitation of food into the voice tube. When the patient wants to speak, he or she can occlude the tracheostoma with a thumb or finger so

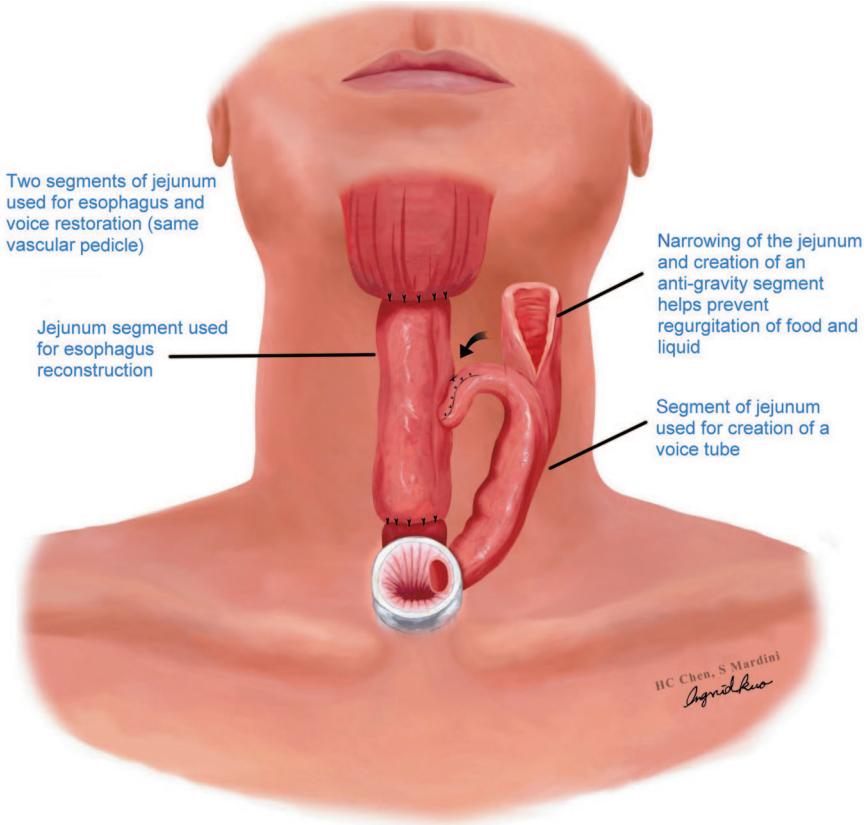

Fig. 7. Schematic demonstrating voice tube/esophagus junction in free jejunum flap for esophageal and voice reconstruction.

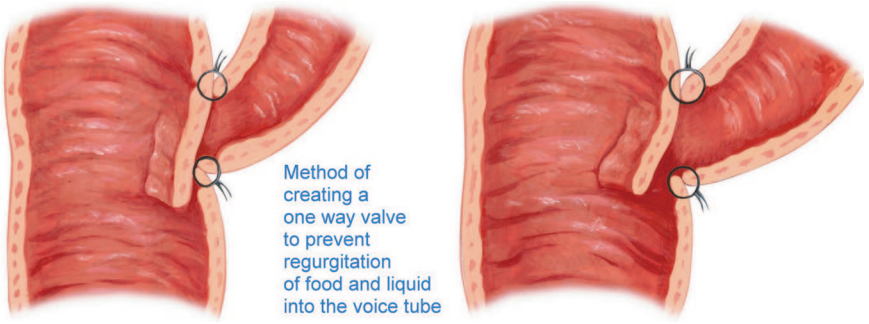

Fig. 8. Schematics demonstrating creation of valve-like structure.

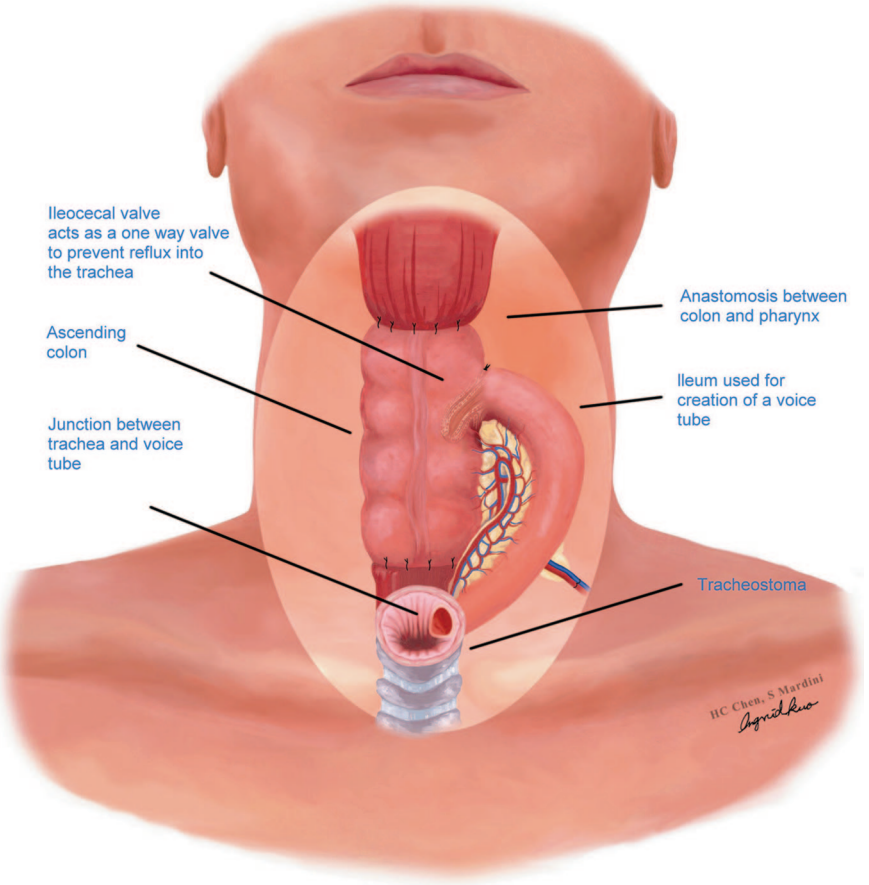

Fig. 9. Schematic of isoperistaltic ileocolic flap with cross-section of valve.

that the air is shunted from the trachea into the voice tube, through the one-way ileocecal valve and to the neopharynx (the colon) and then into the pharynx and eventually the mouth for articulation. The ileocecal valve is plicated to ensure that reflux of liquid and solids is prevented.

In patients with a total laryngectomy, with only a partial defect of the esophagus (less than one-third of the circumference), the ileo-ileocecal valve flap is used with a small patch of cecum (Fig. 10). The 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 the trachea.

F10

Creation of a Voice Tube with No Esophageal Defect

In patients with lack of voice only or only a very small esophageal defect, two options for reconstruction are (1) the ileo-ileocecal valve flap with a small patch of cecum (Fig. 10) and (2) the appendix flap. The ileo-ileocecal valve flap is inset in

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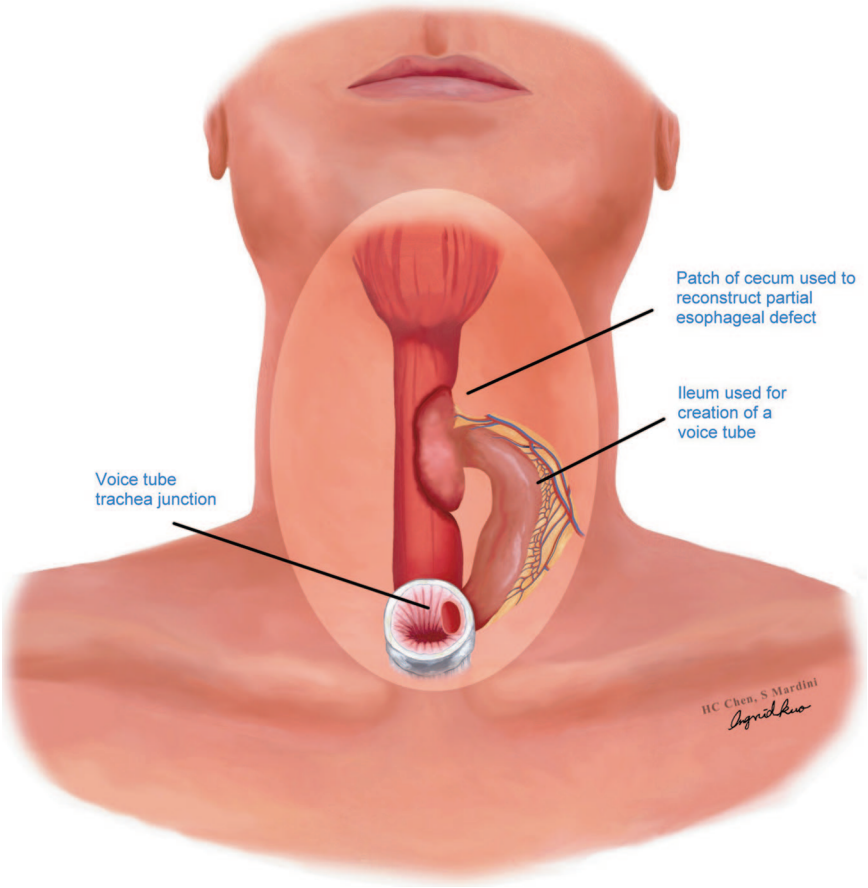

Fig. 10. Ileo-ileocecal valve flap with a patch of cecum for small, noncircumferential esophageal defects.

a similar manner as in patients with a partial esophageal defect, with a smaller patch of cecum. The appendix, if chosen, is used to create a voice tube that will shunt air from the trachea to the esophagus or neoesophagus.[46,68]

Laryngeal Transplantation

Over the past 12 years, the pace of research designed to establish laryngeal transplantation as a therapeutic option for patients faced by laryngeal function that is irreversibly damaged by tumor or trauma has increased steadily. The most significant milestone in this field was the world's first true laryngeal transplant, performed in Cleveland, Ohio, in 1998.[69] Laryngeal transplantation yields excellent results of voice production and speech intelligibility, with high success rates and quick return of voice function.[70] Psychological implications, however, may play a role as a result of the presence of "another person's voice." Hearing the sound of a dead person may cause discomfort or fear for the patient and/or family. Transplantation of the larynx will have broader indications when medications and methods to decrease immunogenicity are more developed. Although immunosuppressive medications have improved significantly, long-term and some short-term side effects have not been eliminated.[71] For this reason, an ideal indication for this procedure is in patients already receiving immunosuppression for other reasons such as transplant of a life-saving organ (e.g., heart, liver, lung, or kidney).

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