Chapter 118: Voice Rehabilitation

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Malignancy of the larynx is a dreaded disease because of its destruction of self-presentation and human dignity itself. Language expressed through speech is a fundamental characteristic of the human intellect that separates us from other animal species. The loss of vocal communication threatens the essence of human existence as well as survival. Cancer of the larynx is of central importance to head and neck surgery because of the variety of treatment methods and with each proposed therapy the alternatives for voice preservation.

The 117-year history of treatment of laryngeal carcinoma includes the names of the greatest surgeons of the period and is characterized by controversy, innovation, and failure. The first survival after laryngectomy for carcinoma of the larynx is attributed to Billroth in 1873. In the preantibiotic era a controlled pharyngostoma was placed to divert contaminated secretions from the healing wound and from the tracheostoma, contributing to the success of the procedure. The pharyngostoma was eventually linked to the tracheostoma with a modified tracheostomy tube designed by Gussenbauer (1874) (Fig. 118-1).

The tracheostomy tube diverted exhaled air from the tracheostoma to the pharynx through the pharyngostoma. The expired air vibrated a metal reed, as in a reed wind instrument, and this vibrating air column produced an audible tone in the pharynx. It was reported that this early patient had an intelligible but monotonous voice representing the first “artificial larynx”. It is significant that the first total laryngectomy was reported with the first efforts for vocal rehabilitation.

Total extirpation of the larynx has not always been readily accepted by patients or even physicians over the years. As a result there has been a continuous evolution of alternative treatments aimed at vocal preservation. Some of the greatest progress in the management of cancer in the twentieth century has been made with the development of conservation surgery of the larynx (see Chapter 115). Histopathologic studies and documented long-term follow-up have demonstrated the safety and efficacy of these techniques (Ogura, 1955).

The discipline of radiation oncology has greatly contributed to laryngeal preservation over the past 70 years. Treatment methods are improving, with higher cure rates and reduced complications (Fletcher, 1977; Flynn et al, 1972). It is generally accepted that radiation therapy is an effective treatment for earlier stage lesions with satisfactory cure rates and little disturbance of voice quality. With more advanced lesions it is an important component of combined treatment programs with surgery (Hibbs et al, 1969).

Rehabilitation of the laryngectomized patient is usually a delayed process after recovery from surgery. Initially many patients try lip speech occasionally enhanced by buccal air trapping and progress no further with their communication skills. Most will rely to varying extents on written language expression as the primary method of communication. At some time in the convalescence the majority of laryngectomized individuals are introduced to esophageal voice rehabilitation and are encouraged to try it. This method of alaryngeal speech rehabilitation requires repeated training sessions to develop the ability to insufflate the

esophagus by either inhalation or injection of air by the coordinated muscle activity of the tongue, cheeks, palate, and pharynx. Voluntary release of air or "regurgitation" of small volumes vibrates the pharyngoesophageal junction, hypopharyngeal mucosa, and other remnants of the vocal tract to produce sound. The passage of the resultant sound across the normal speech articulators (that is, the lips, teeth, palate, and tongue) results in understandable speech.

Esophageal speech has been the preferred method of alaryngeal communication, but it is complicated by the inability of even highly motivated patients to effectively acquire it. Recent prospective studies have challenged the historical reports of acquisition rates of 65%, readjusting the acquisition rate to 30% (Gates et al, 1982; Snidecor, 1975). Esophageal voice training is often time consuming, tedious, frustrating, and unavailable and frequently does not meet the social needs of the patient. Current treatment methods for laryngopharyngeal cancer, which include myocutaneous flap reconstruction, visceral interposition, microvascular free tissue transfer, and postoperative radiation therapy, further reduce the probability of satisfactory esophageal voice acquisition (Gates and Hearne, 1982).

Appropriate resources for laryngectomee rehabilitation may be located through the International Association of Laryngectomees, American Cancer Society, and local "Lost Cord" Clubs (Lauder, 1983). Workshops, voice institutes, and conventions meet regularly to share information on rehabilitation, new products, and pertinent literature, as well as support groups for coping with voicelessness. Volunteer laryngectomees are available in many communities for patient counseling and may also be reached through the above organizations.

Some patients prefer artifical larynges to esophageal voice. The most common type is a portable battery-powered device applied to the neck to transmit electrically generated sounds to the air spaces of the pharynx, which are transformed by the articulators into speech. Effective placement of the unit requires instruction and is dependent on a properly selected location on the neck. A similar device is the intraoral artificial larynx, which is also an electric sound generator and is recommended for patients who cannot transmit sounds across the cervical tissues. There are reports of similar devices (that is, electric sound generators), incorporated in dentures (Lowry, 1981; Zwitman and Disinger, 1975).

Another type of mechanical larynx includes the "pneumatic" devices that use exhaled air to vibrate a reed rahter than electricity for sound production. This results in an intense intraoral sound. The pneumatic artificial larynx is not in common use. Electrolarynges are frequently effective and satisfy communication needs for most patients rapidly and inexpensively. Their conspicuous artificial sound and appearance limit their enthusiastic acceptance. Although it is feared that the artificial larynx inhibits the acquisition of esophageal speech, there is no scientific evidence to support these claims.

Vocal Rehabilitation with Tracheoesophageal Shunts

Voice production by exhaled air is the basis of a number of tracheoesophageal shunt methods for alaryngeal voice rehabilitation. The voice is produced by the vibration of the pharyngoesophageal mucosa above the expiratory air stream. The resultant sound is converted to understandable speech by the intact articulatory structures of the residual vocal tract as discussed with the artificial larynges. Shunt techniques have always been limited by a number

of problems. Patency depends on an adequate fistula or epithelial tract that is vulnerable to stenosis from the chronic inflammation of radiated tissue or tissues exposed to continuous salivary drainage. Over time the shunts collapse, dehisce, or form strictures. The meatus at either end is particularly prone to stricture formation.

Studies of airflow and pressure for the intact larynx for voice production are compared to estimate the requirements for shunt performance. Adequate laryngeal-voiced vowel production is reported to occur at an airflow of 50 to 100 cc/sec at H2) resistances ranging from 35 to 42 cm/L/sec (Smitheran and Hixon, 1981). An effectively patent shunt allowing airflow in the stated range also presents no effective barrier to the aspiration of secretions into the airway. As the distance from the trachea increases (that is, shunt length) a mechanical link is required from the airway to the pharyngoesophagus. This requirement has been addressed by a number of innovative tracheal cannulas (Shedd et al, 1975; Taub and Spiro, 1972).

The phonatory fistula is a useful method, but it is compromised by increased hygienic requirements, possible disruption of deglutition or aspiration, and subsequent pulmonary complications. For these reasons, esophageal voice or artificial larynges have been the preferred methods of rehabilitation. Primary closure or reconstruction of the pharynx at laryngectomy became the standard by the end of the nineteenth century and advanced laryngectomy from its introduction by Billroth. If shunts were to be used for voice restoration, they would require planned placement either during or after the laryngectomy. By the late 1940s this restorative concept reappeared in the work of Briani (1952) and later Conley et al (1958). The Italian investigator Briani constructed a lateral cervical pharyngostoma and connected it to the tracheostoma with a plastic and rubber cannula. This successfully permitted voice acquisition in a series of patients.

In the USA, Conley et al proposed a tracheoesophageal shunt constructed from a vertical tube of esophageal mucosa (Fig. 118-2). Alternatively Conley et al tried a vein graft shunt introduced through a subcutaneous tunnel between the trachea and the esophagus. These methods required either a shunt stent for patency or a modified tracheostomy tube. They were eventually discarded because, according to Conley et al (1958), the technical problem to overcome consisted of creating a passageway that would permit free flow of air from the trachea into the esophagus without passage of food or saliva from the gullet into the trachea. The great inconvenience caused by an inadvertent small pharyngeal or esophageal fistula would unquestionably condemn any such uncontrolled communication.

Undaunted by the experience reported by Conley et al, Asai (1965), a Japanese investigator, described a shunt method that became the best known of its time. The superior trachea was incorporated in a skin-lined shunt extending to the hypopharynx (Fig. 118-3). The procedure was staged and was not applied to previously radiated patients. Voice was produced by covering the tracheostoma and diverting air through the shunt and into the hypopharynx. The shunt speech was widely accepted as superior to esophageal voice, but aspiration was a chronic problem that could only be controlled by compressing the shunt.

Amatsu (1980), another Japanese investigator, introduced a single-stage procedure that was part of the initial laryngectomy or considered a primary voice restorative procedure. The laryngectomy was modified by resection of the anterior two thirds of the tracheal cartilage from the first through the fourth rings, leaving the membranous trachea intact against the

cervical esophagus. A side-to-side tracheoesophageal anastomosis was completed, and the remaining tracheal flap was gtubes to form a shunt from the tracheostoma to the esophagus (Fig. 118-4).

Initial results reported by Amatsu were satisfactory, with successful speech in 76% of the series, but salivary aspiration was present in 30% of the patients. Few patients had been exposed to radiotherapy in their treatment programs, and cure rates were reported to be similar to the experience with total laryngectomy. Recently Amatsu has improved the technique by circumscribing the tracheal shunt at its inferior position with two strips of muscle developed from the cricopharyngeus muscle to form a sphincter for tracheal protection from aspiration.

Reconstructive Procedures

During the early 1960s research efforts included both laryngeal implant prostheses and whole organ transplantation. With the success of prosthetic valve and vascular grafts, investigators designed laryngeal replacements. Ogura et al (1962) developed a number of larynx substitutes from biocompatible materials that included Teflon, Dacron, and Marlex. These approaches were complicated by the necessity to place the implants in a field distinctly different from the sterile environment of vascular replacement prostheses. The implants bridged the trachea and pharynx and were bathed by contaminated secretions and saliva, dooming the subjects to extrusion, wounds, and pulmonary infections. Over 80 experimental animals were investigated before this approach to prosthetic laryngeal replacement was discarded.

At the same time, whole organ transplant procedures excited investigators and laryngeal transplantation was explored. The earliest efforts were by Work and Boles (1965). They pointed out the complexity of reanastomosis of connective tissue, mucosa, vascular supply, and innervation. Ogura et al (1962) noted satisfactory preservation of the larynx based on one superior thyroid artery, but reinnervation remained insurmountable. Takenouchi et al (1967) later devised the technique of nerve-muscle pedicle reinnervation of the larynx successfuly in laboratory animals and provided the experimental basis for human laryngeal reinnervation (Tucker, 1978).

The formidable technical problems of laryngeal transplantation were complicated by the problem of graft rejection and the need for effective immunosuppression. Ethical questions are raised because the larynx is not considered a vital organ, and immunosuppression of cancer patients may be a precursor to additional malignancy and incurability. The benefit of earlier efforts for laryngeal transplantation has been the development of successful reinnervation procedures.

Implantation of a sound source represents a promising approach to this problem (Fredrickson et al, 1985; Young et al, 1980). Although considered a type of artificial larynx, an electrically generated sound from an implant in the neck or retropharynx would be more convenient. The technical considerations are not insurmountable; however, the development of a “natural” sound source that avoids the typical mechanical, monotonous quality remains challenging. Investigations continue with this approach with plans for introduction of a new device underway.

Vertical reconstruction

The earliest description of horizontal resection of the glottic larynx with vertical reconstruction is attributed to Foederl (1896). The epiglottis and aryepiglottic folds were approximated to the stump of the trachea. This early method of laryngectomy reconstruction continues to have a number of European advocates and is considered a subtotal laryngectomy. Serafini and Arslan (1972a) investigated these concepts in canine models and later applied them to selected patients failing the criteria for conservation laryngectomy. The proposed technique preserved the hyoid bone and suprahyoid epiglottis, maintaining the vallecula. The perichondrium is reflected from the thyroid alae and preserved for the closure. The trachea is transected at the first ring and is advanced to the level of the hyoid bone. The antero-inferior edge of the pharyngeal mucosa (pharyngotomy) is sutured to the posterior edge of the tracheal stump. Anteriorly the tracheopharyngeal anastomosis is completed by approximating the epiglottis to the trachea (Fig. 118-5).

The hyoid bone is used to support the anastomosis and suspend the trachea. The procedure is descriptively referred to in the European literature as cricohyoidoepiglottopexy or reconstructive laryngectomy.

Reporting the experience clinically, Serafini and Arslan (1972b) described a 35-patient series. All patients had successful speech, and importantly, 30% were able to breathe through the “neolarynx” and eventually undergo tracheal decannulation and closure of the tracheostoma. Bronchopneumonia from aspiration was encountered in four patients, and four others had protracted difficulty managing liquids. Local recurrence occurred in eight patients, requiring completion laryngectomy, radical neck dissection, and radiation therapy. Twelve patients experienced cervical lymph node metastasis over a 3-year period. The overall survival rate was 25 of 35 patients (71.5%), with the cause of death local recurrence in four patients, recurrent neck disease in two, distant metastases in one, and intercurrent disease in three.

Neoglottic reconstruction

An alternative method for primary tracheopharyngeal shunt construction was proposed by Staffieri and Serafini (1976). A wider laryngectomy was described, preserving retrocricoid mucosa and anterior hypopharyngeal mucosa. The phonatory shunt, or “neoglottis fonatoria”, is developed by exteriorization of mucosa through a 5 to 8 mm “button-hole” in the anterior pharyngoesophageal wall. Only mucosa is mobilized and is supported by the underlying layers of muscle composing the normal pharynx. The mucosa is sutured to the edges of the buttonhole defect, forming a chink resembling the glottis (Fig. 118-6). The anterior wall and neoglottis are then anastomosed to the superior trachea, which has been preserved at the first cartilaginous ring to form an end-to-side tracheohypopharyngeal shunt.

Ideal function of the neoglottis is to close during the passage of food and saliva and to open readily during the phonation when expiratory air is diverted by stoma occlusion. A series was reported describing 97 patients, with 91 evaluated for a long period. The results in 84 patients (92.3%) were judged satisfactory, 21 (23%) required revision of an inadequate shunt, and four required completion laryngectomy or surgical salvage.

Staffieri and Serafini (1976) described neoglottic speech as natural and easily produced. The actual incidence of “primary incontinence” of the neoglottis was not reported, but stenosis or obstruction from edema could occur and was treated by retrograde dilation. The late onset of incontinence was observed after months or years and resulted in aspiration. It was postulated that this complication was related to atrophy of the walls of the shunt and could be revised.

American experiences with the neoglottis were best described in a series of patients that included delayed incontinence and chronic aspiration limiting long-term effectiveness and acceptability (McConnel and Teichgraeber, 1982; McConnel et al, 1977). Other investigators reported oncologic limitations in which six regional recurrences in 26 cases were identified and three stoma recurrences were observed in another 50 cases (Leipzig et al, 1980; Sisson and Goldman, 1980).

Near-total laryngectomy

Pearson et al (1980) described a near-total laryngectomy technique that is a type of extended laryngectomy. The operative procedure involves resection of approximately one half of the cricoid ring, ipsilateral larynx, and hyoid bone. The remaining endolaryngeal mucosa, including arytenoid and vocalis muscle remnant, forms a shunt between the trachea and the pharynx, sometimes augmented with a mucosal flap from the hypopharynx. In theory, the fistula is described as muscular and innervated by branches of the vagus nerve, and the recurrent nerve is preserved for arytenoid innervation.

Of 33 patients, 30 (91%) use “fistula speech” effectively with minimal effort. Some aspiration occurred in six ptients without pulmonary complications, and two others required endoscopic revision. No local recurrences have been reported. Five patients received unplanned preoperative radiation therapy, and four had postoperative radiation therapy. Radical neck dissection was performed at some point in the treatment course on 23 patients. Pearson (1981) concludes from this experience that this method may replace total laryngectomy as the optimal procedure for T3 laryngeal cancer.

Tracheoesophageal Puncture

The voice restoration method of tracheoesophageal puncture (TEP) and voice prosthesis valve developed as an alternative to the shunt procedures, reconstructive techniques, and esophageal voice. It was initially proposed by this author and a coworker as a secondary method for alaryngeal speech failure (Singer and Blom, 1980). As experience accumulated over the past 12 years, the puncture technique has been increasingly applied as a primary method for laryngectomy rehabilitation. At the time of this writing, the techniques to be described have become established as effective and repeatable for voice restoration after total laryngectomy (Ward et al, 1988).

The recurring problem of shunt patency versus stenosis, in spite of efforts to solve it by meticulous techniques, led to the necessity for a hollow stent that could serve as a one-way valve. The design concept called for a simple valve that was biologically compatible, removable, and inexpensive. Empirically the caliber of 3.3 mm (Fr. No. 14) was selected, a rubber catheter was used as the stent tube, and the most simple valve concept was a slit

through the long axis of the tube (Fig. 118-7). The length varied from 1.8 to 3.6 cm, and the end opposite the stent/valve was open with a second window on the inferior (ventral) surface.

This stent was called a “duckbill” valve, which described the slit, and over time it became known as a “duckbill voice prosthesis”. The rubber tubing was compatible with the trachea and esophagus and eventually was replaced by medical-grade silicone tubing to become in 1980 the first widely available duckbill voice prosthesis for the laryngectomized patient. The voice prosthesis was held in position by taping matching straps to the peritracheal skin with paper adhesive tape. Initially the prosthesis was routinely removed by the patient on a daily basis for cleaning and was replaced in position by the patient. Early experience pointed to the problem of accidental extrusion of the prosthesis sometimes complicated by aspiration of the device. For this reason, a retention collar was added to the valve end that improved the maintenance of the proper position in the shunt, with no added difficulty in replacement in the puncture.

The establishment of the puncture is an important aspect of the operative technique. I concluded that the shunt should traverse the short distance across the tracheoesophageal common wall starting at the superior aspect of the tracheostoma. This location permitted direct visibility for patient and physician, and in the event of the need for closure, the technical requirements at the superior stoma would be less. The shunt could be established by a planned midline “puncture” across the stoma and into the esophagus. The midline location would prevent either vascular injury or esophageal transection. The procedure can be done endoscopically providing direct vision for the esophageal aspect of the puncture, and, using a rigid esophagoscope the needle tip enters the endoscope, protecting the posterior esophageal wall (Fig. 118-8).

After the puncture is safely placed, the defect is serially dilated until a Fr. No. 14 catheter passes as a stent. This is fixed in place and directed into the distal esophagus. The patient can be released on an ambulatory basis and permitted a normal diet. Analgesics are rarely required, and a 48-hour course of prophylactic antibiotics is preferred. The patient may use an electrolarynx or limited esophageal voice. The stoma will require regular hygiene, and increased tracheal secretions are expected.

Safety is the chief concern underlying this elective voice restorative technique. The mechanical aspects of the puncture placement are reviewed above, and a broader consideration of the voice-restoring procedure is now discussed. The accepted limits of total laryngectomy should not be compromised by the rehabilitative procedure, which is a criticism of the neoglottic procedures and of the near-total laryngectomy. Excessive pharyngeal or tracheal conservation jeopardizes surgical margins and cure rates. This tendency is suggested by the reports of stoma and regional recurrences and is consistent with established concepts of surgical oncology. Another aspect of the proper treatment of laryngeal cancer is the use of radiotherapy. Procedures for voice restoration that are incompatible with accepted radiation therapy or avoid its use risk the cure of patients with advanced laryngeal malignancy. Reviewing the European reports, it is striking that consistent adjunctive radiation therapy is not used in view of accepted North American treatment practices.

Long-term safety demands a method that does not expose the patient to chronic airway soiling. Reports of trace leakage and gradations of aspiration are misleading in the absence of longitudinal studies of pulmonary function in the affected patients with special reference to those whose baseline function is already disturbed. Chronic pulmonary aspiration cannot be accepted as physiologic and over time is deleterious to patients with limited pulmonary reserves. Rarely mentioned in results reporting is the effect of nocturnal aspiration, which is a problem even with an intact larynx.

Thus a safe and effective voice restoration after total laryngectomy must meet these conditions. First, the accepted principles of surgical oncology must not be altered by the modification of the laryngectomy. Second, the procedure must be successful in the milieu of radiated tissue without tissue necrosis and chronic infection. Finally, chronic salivary aspiration is not acceptable over time in spite of patient denials and optimistic clinical reports of traces or “droplets”.

Patient acceptance is dependent not only on the quality and ease of voice production, but also on the simplicity of prosthesis function and use. A complicated daily regimen of increased stoma hygiene and prosthesis application is usually a deterrent to routine voice prosthesis use even when the voice is dramatic and functionally superior to other methods. The earlier designs of voice prostheses requiring daily maintenance and replacement have given way to improved retention with replacement on a less frequent basis. Patients demand fluent speech, which is effortless; otherwise, there is a tendency to resume previous methods of speech, in particular, the electrolarynx. The voice requires consistent valve function without frequent plugging or leaking. The pressure of reliable social communication without reliance on artificial backup requires near-perfect valve performance.

Considerations for rapid rehabilitation of voice after total laryngectomy have great appeal to patients in addition to cost factors that include physicians’ fees, prosthesis costs, possible hospitalization and length of stay, and recovery time to return to gainful employment. Prosthetic voice restoration can return to understandable voice in 3 to 5 days, with skilled use possible within 3 weeks. Supervised clinical time may vary from 3 to 5 hours per week and is often less. Care of the prosthesis adds a few minutes each day to the regular stoma hygiene program. Prostheses require replacement because of valve failure after 9 to 12 weeks.

Successful use of a voice prosthesis requires tracheostoma occlusion for voice production. Initially patients are able to cover the stoma manually and with varying pressure achieve fluent voice with little air leak. Although this remains the most common and preferred method for voicing, the requirement of “hand-on” speech is not normal, is a hygiene problem, and is a social handicap. A valve is available for closing the tracheostoma for voicing (Blom et al, 1982). Its successful use is limited by the need for adhesive attachment to the peritracheal skin, varying intratracheal pressures, cough, chronic obstructive pulmonary disease, and increased requirements for maintenance of the stoma. Although desirable, the tracheostoma valve for “hands-free” speech has limited application, generally being usable by less than 50% of the laryngectomized population.

Method of patient selection

Initially patients were selected who had failed esophageal voice therapy or were dissatisfied with the electrolarynx. This indication for tracheoesophageal speech expanded with increased experience to any laryngectomee desiring this method. The widened indication was the result of experience that confirmed the comparability to superior esophageal voice with acceptable morbidity and demands on the patient. The limitations are the size of the tracheostoma, which should be a minimum diameter of 1 cm, readily visible, and tolerant of instrumentation. Patients with a radiation history exceeding 70 Gy to the stoma are at increased risk of tracheostomal necrosis and subsequent stenosis and aspiration. Chronic pharyngoesophageal stricture, flap reconstructions, and visual or motor problems are not contraindications to the prosthesis. The patient should be adequately healthy to tolerate general anesthesia.

It has been suggested that preoperative esophageal insufflation is an important assessment test to predict the likelihood of successful speech and to assess the probability of dysfluency from pharyngeal constrictor “spasm” (Blom et al, 1985). The TED traverses the upper tracheostoma and enters the esophagus inferior to the reconstituted cricopharyngeus muscle and upper esophageal sphincter (UES). Distension of the esophagus, which occurs with air injection, results in a reflexive increase in tone in the pharyngeal constrictor muscles. This finding is supported by early manometric studies of the region in normal, nonlaryngectomized patients (Creamer and Schlegel, 1958). It is assumed that this change in UES tone is related to the process of swallowing and motor changes in the body of the esophagus.

Insufflation of the esophagus in the clinical setting requires the placement of a catheter through the nose into the upper esophagus. Air is injected into the esophagus either by the examiner or by adapting the tube to a special connector fixed to the tracheostoma. The subject’s exhaled air intermittently enters the esophagus, and as it does, attempts at voice and connected speech are made. This may result in sound, that is, “ah”, a low-pitched rumble or eructation, or a series of connected words as in counting. The examiner is directed to assess fluency of speech. There are no definitive guidelines for successful duration of speech, airflow, and pressures (pharyngeal or intratracheal), nor is there a controlled series of patients with a comparison of preoperative and postoperative results.

Esophageal insufflation for preoperative planning should not be used for determination of the need for open neck exploration and pharyngeal constrictor relaxation (see below). At this time, it is a subjective evaluation of the laryngectomized patient’s response to catheter insufflation of the esophagus. It may or may not correlate with the patient’s experience after TEP. There are patients who may have increased pharyngeal constrictor tonicitiy during tracheo-esophageal voicing, but there is no information at this time that provides the incidence of patients who will succeed despite equivocal catheter insufflation testing. Until these data are provided by methodologic analysis, the insufflation “test” should not be used for operative planning.

Application of voice prosthesis

The placement of the voice prosthesis or fitting is simple and should not be mysterious. The surgeon, nurse, or speech therapist can perform this aspect of the voice restoration process with equal facility. The basic concept involves proper assessment of the horizontal distance from the membranous trachea to the anterior surface of the esophagus. An approximation of this distance by the closest voice prosthesis completes the fit.

The first step in the fitting process is to remove the stent from the puncture first placed in the operating room and to measure the distance as mentioned (Fig. 118-9). The vocal tract is then tested before placing the prosthesis by covering the tracheostoma and introducing air with exhalation. The patient will phonate easily and will be capable of connected speech in most cases. The second step involves the placement of the voice prosthesis. The prosthesis is fixed to an “insertion stick” and is introduced into the puncture at an angle corresponding to presentation of the retention collar edge. The collar is a soft silicone disk and will deform, allowing the introduction of the prosthesis shaft into the puncture. When the collar passes with slight resistance into the esophageal lumen, it will unfold and a “lock” sensation will be detectable.

The prosthesis is oriented by vertical placement of the silicone strap above the tracheostoma and is fixed to the skin with paper adhesive tape. Efforts to produce and sustain voice may now be made with the prosthesis in place. Initial efforts may be different from the preliminary experience with the “open” nonvalved puncture because of differing resistance at the level of the prosthesis or of the vocal tract as well.

The next group of maneuvers varies from individual to individual and includes (1) careful stoma occlusion for efficient airflow, (2) proper hygiene practices and management of secretions, (3) varying breath control and diaphragmatic pressure, (4) diminishing injection behavior from earlier esophageal voice, and (5) experience with prosthesis removal and replacement. These skills develop on an individual basis and can be tedious for some persons. Although relegated to the speech therapist, they can be readily developed under the direction of any observant nurse or practitioner. Initial recommendations were made to change the prosthesis daily and in some cases alter the length incrementally by the patient, which places considerable responsibility on the patient and may actually frustrate the user. A more current recommendation is to avoid patient responsibility for prosthesis changes entirely. After an effective fit is achieved, the prosthesis should remain in situ and be cleaned externally without removal. Although candidiasis has been detected on some prostheses, its incidence is unknown, and its effects are often innocuous (Mahieu et al, 1986).

The initial experience with the duckbill prosthesis and an accumulating population of tracheoesophageal speakers rapidly developed a subpopulation of voice failures estimated as 25% to 40% of cases, with the variability related to the strictness of criteria for successful voice acquisition (Singer et al, 1981). A proposed solution to this problem was the development and introduction of a "low-pressure" voice prosthesis (Blom et al, 1982). The valve prosthesis was changed from a slit to a trap valve recessed within the tube itself, which decreased the airflow resistance to nearly the normal values discussed earlier (that is, water pressure of 30 cm/L/sec). The lower resistance valve for selected users was helpful and preferred because of the need for less effort in voicing. The low-pressure valve stimulated the

commercial introduction of a number of other similar low-resistance valves domestically and internationally.

The design configuration of the low-pressure voice prosthesis introduced a significant new problem for the patient and physician that has affected the acceptability of this method of voice restoration. The tapered or "obturator" tip of the duckbill voice prosthesis gave way in the new design to a short bevel and retention collar. This complicated the introduction of the prosthesis into the puncture and resulted in an inability to insert it into the lumen of the esophagus. Commonly the retention collar resides within the lumen of the puncture itself, producing a cicatricial ridge anterior to the meatus of the esophageal puncture. The patient experiences stenosis of the esophageal meatus with increasing voicing efforts, extrusion of the prosthesis, and actual closure of the puncture when the esophagus was inadequately stented (Singer et al, 1989).

Therefore, with the above discussion, the patient is better served to leave the prosthesis in position rather than apply the frequent changing pattern originally suggested. If an overgrowth of normally colonizing *Candida* organisms occurs and interferes with valve function, daily topical antifungals may be used, for example, Mycelex troche, to reduce this problem. The removal of the patient from the prosthesis insertion program reduces voice failures, the TEP stenosis problem, extrusions, aspiration, and emergency calls.

The stoma coverage or occlusion has been simplified for some patients by the application of a tracheostoma valve (Blom et al, 1982). This is a two-way respiratory valve that closes for voice production with the required increased expiratory airflow and then opens for inhalation and relaxed respiration. It is fixed to the peritracheal skin with ostomy adhesive and a plastic connector ring. The valve is prone to failure because the intratracheal H_2O pressures during phonation exceed 60 cm/L/sec for many patients, the skin changes, and the stoma develops irregularities after laryngectomy and radiation therapy - all of which interfere with an effective bonding. Patients who are successful with the tracheostoma valve, however, acquire a very natural and inconspicuous alaryngeal speech and have two hands free for normal occupations and daily life. The tracheostoma valve is recommended for interested patients with a fore-warning of the high incidence of failure. Newer, more trouble-free valves may be introducted in the future.

Voice failure

The subpopulation of voice failures is largely the group of patients described above who elevate the upper esophageal sphincter pressure during esophageal distension above the threshold for voice fluency. The patients may be capable of only a few syllables, a fluent "ah", or counting up to 5 or 6 but may also exhibit considerable effort to voice, with the characteristic effects of the Valsalva maneuver. Sometimes this behavior pattern is identified with the preoperative insufflation, but its subjectivity may be misleading. Also, some patients initially demonstrate the Valsalva pattern but with breath control and internal feedback can reduce the esophageal distension and the resultant UES tonicity over time. The use of muscle relaxants and tranquilizers has not been effective.

This dysfluent speech pattern may change over a 4- to 6-week period, but if it has not improved, and at least 15% to 25% will not improve, then further investigation and intervention are required. Voice is reassessed by the open tract test of removing the voice prosthesis and open voicing, which in a small number of individuals will be successful and, if it is, is often the result of a failed voice prosthesis. If the device is too long and impaling the posterior esophageal wall, it should be replaced by a shorter prosthesis. If it is too short to span the length of the TEP, it should be replaced with a longer prosthesis. The persistent voice failure with the open tract test should be systematically evaluated.

The most effective method is to observe the patient under fluoroscopy with a barium-coated neopharynx and esophagus. The lateral view is most informative. An "at rest" view is first obtained and is then followed by several views of attempted voice. The pharynx is reviewed for the mass of constrictors seen in the retropharyngeal x-ray plane as a "bar" (Fig. 118-10; Singer and Blom, 1981). The axial length is noted with reference to the proximity to the tongue base and its overall breadth. This study is then supplemented with a pharyngeal plexus block with local anesthetic.

This procedure is done with 150 to 200 mg of 2% lidocatine without adrenalin. It is injected with a 23-gauge 11.5 inch needle placed at the level of the prevertebral fascia and then extracted 1 to 2 mm before injection. The neck skin is entered at the level of C2-3 immediately parapharyngeal and mecial to the carotid sheath. After 3 to 5 minutes, the patient is instructed to attempt voicing, which is nearly always effective, effortless, and fluent. The voicing events are now fluoroscoped, and the typical appearance will reveal a "reduction" in the mass of the constrictor muscles, including the axial length. In effect, the "pinchcock" effect of the constrictors during esophageal distension is temporarily ablated by the anesthetic injection and documented by the radiographic examination.

The initial approach to this problem was the introduction of a secondary pharyngeal constrictor myotomy to reduce the tonicity of the UES, and this remains an effective method. Further refinement of the technique has led to the less traumatic pharyngeal plexus neurectomy, which will be discussed below. An effective myotomy can be undertaken with a Fr. No. 36 dilator in place in a manner analogous to a cricopharyngeal myotomy for dysphagia in the intact patient (Singer and Blom, 1981). The complications of this procedure are low but include salivary leakage and possible fistula formation, hypotonic voice, and reflux. In an effort to reduce these problems and as part of the ongoing investivation of this problem in alaryngeal voice restoration, denervation of the pharyngeal constrictors has been evaluated and recommended (Singer et al, 1986).

The operative approach to the secondary neurectomy is similar to the constrictor myotomy. The pharynx is distended with a mercury-filled dilator and the parapharyngeal tissues are dissected to the level of the prevertebral fascia, which opens readily in the laryngectomized patient. The carotid sheath contents are reflected laterally, and the preferred neck approach is the contralateral side to previous neck dissection. The pharynx is rotated away from the carotid sheath, exposing the posterolateral wall of the pharyngoesophagus.

A fine dissection of the fascia overlying the constrictor muscles is undertaken. The dissection is the middle pharyngeal constrictor muscle, which is bulkier than the inferior pharyngeal constrictor and represents only 20% of the axial length of the upper esophageal

sphincter (UES) and corresponding neopharynx. The middle pharyngeal constrictor is important because at its junction with the inferior pharyngeal constrictor an anatomic hiatus is present. It is at this location that the main branches of the pharyngeal plexus course before dividing and innervating the underlying constrictor muscle fibers (Fig. 118-11).

The nerve fibers are approximately 60% of the bulk of the recurrent laryngeal nerve and somewhat less than the bulk of the superior laryngeal nerve. They are distinctly different from these nerves when confirmed by electrostimulation of the trunks, which is necessary for their positive identification. When stimulated, the innervated constrictor muscles will finely contract from superior to inferior to the level of the upper esophagus, which is in distinction to stimulation of the superior laryngeal nerve. This structure, when stimulated, will initiate a swallow followed by motor discharge into the wall of the pharynx. Secondary stimulation of the residual recurrent nerve will produce weak muscle activity at the level of the upper esophagus and cricopharyngeus.

After identification of the pharyngeal plexus, which represents one to three nerve branches at this level, the fibers are electrocoagulated and then divided. The procedure is performed unilaterally, the wound is drained away from the stoma, and the defect is closed. The patient may resume a normal diet postoperatively and speech rehabilitation the following day. Moderate soft tissue edema may result in the radiated patient as well as tracheitis from intubation. Radiated patients with significant edema either preoperatively or postoperatively should be checked for hypothyroidism and begin thyroid hormone replacement. The most reliable screening test for this is the TSH level.

Results

A prospective study of 47 patients for secondary voice restoration by TEP was reported (Blom et al, 1986). All patients successfully acquired tracheoesophageal speech after TEP, voice prosthesis, and selected pharyngeal constrictor myotomies. Speech acceptability was rated 3.41 out of 5.0 by outside naive listeners in contrast to preoperative mean speech acceptability of 1.05. Maximum duration of phonation of "ah" in nonmyotomized patients ranged from 7.2 to 17.2 seconds, whereas in myotomized patients the range was from 7.4 to 27.4 seconds. The preoperative group's mean speech intelligibility was 78.15% and improved to 91.51% postoperatively. The average rate of speech was 118.9 words/min, which exceeds superior esophageal speakers.

Other evaluations of speech results have been reported (Robbins et al, 1984). Peak sound pressure levels of 98 dB as the low and 101 dB as the high were consistent. The mean fundamental frequency varied widely from subject to subject with a mean between 64 and 81 Hz as mot representative. Intelligibility was similar to esophageal speakers with an advantage in noisier environments for the TEP group.

Complications

Although reported as few, problems with this method of speech rehabilitation do exist. The presence of the TEP in the superior tracheostoma may induce and inflammatory process that has been attributed to a low incidence of tracheostomal stenosis ranging from 1% to 4% (Singer et al, 1989). Closure of the TEP occurred in 10% of cases because of extrusion of the

prosthesis, radiation therapy, or inadequate stoma hygiene. Tracheal granulations developed in 4% of the patient users, and prolapse of esophageal mucosa through the TEP was noted in 2%. Leakage at the TEP or aspiration was identified in 5% of the patients and was correctable. Aspiration of the prosthesis itself occurred in 3 of 128 reported patients.

The significant problem of TEP aspiration was usually corrected by reconstruction of the tracheoesophageal common wall by the interposition of a sternocleidomastoid muscle flap, or, in heavily irradiated patients, by the placement of a pectoralis major myofascial flap (Singer et al, 1989). The prosthetic problems were corrected by changing the insertion mode and improved patient education. The problem of tracheal granulation was improved by removing the airflow port on the prosthesis to decrease contact with the TEP.

Voice Prosthesis During Laryngectomy

After the initial introduction of TEP procedures as an effective and relatively safe voice restoration technique following total laryngectomy, a number of other investigators found it to be reliable. It has been stated (Johns and Myers, 1988):

Surgical approaches for voice restoration have undergone an enormous evolution over the past 10 years; from the point where esophageal speech was the standard and a variety of reconstructive surgical procedures were available (none of which was terribly effective) to the present where the tracheoesophageal puncture (TEP), is considered to be state-of-the-art.

With the growing acceptance of the method, it became important to apply it to the laryngectomy procedure and to assess the results of primary voice restoration.

It has been a principle to avoid any oncologic alteration of the total laryngectomy procedure. To place a TEP primarily introduces no compromise but does require the careful construction of the tracheostoma and a pharyngeal constrictor relaxation procedure. A pharyngeal plexus neurectomy is the preferred procedure at this time. The alteration of the basic laryngectomy is minimal and is presented below.

The TEP is placed after the stoma is constructed and before the pharynx is closed (Singer et al, 1989). The upper tracheal rings are fixed anteriorly and inferiorly to the skin flap rather than through a concentric skin defect. After this, a right-angled hemostatic clamp is placed against the membranous trachea through the pharyngotomy (Fig. 118-12). A No. 15 knife blade is used to transect the membranous trachea transversely for 3 to 4 mm to permit the tips of the hemostat to protrude into the tracheostoma. Care must be taken to avoid separating the tracheoesophageal common wall, and if it is, it should be closed to prevent saliva dissecting into this space. The tip of the hemostat is used to direct a Fr. No. 16 silicone Foley catheter into the esophagus to serve as a stent for the TEP and simultaneously as a feeding tube. The hemostat can alternatively be used to place the initial voice prosthesis and to "thread" it with a Fr. No. 12 urethral catheter for feeding tube purposes. The catheters and voice prosthesis are sutured to the peritracheal skin for fixation.

The pharyngeal constrictor relaxation can be accomplished at this point with a constrictor myotomy performed in the posterior midline raphe or, as currently recommended, by a pharyngeal plexus neurectomy. The neurectomy is preferred over the myotomy because

it is less traumatic to the pharyngeal wall and effectively reduces the rise in wall tension (sphincter tone) during esophageal distension. The elasticity of the constricot muscles and vascularity are preserved. The theoretic advantage is a more pliable pharynx capable of a better pitch range because scarring is less and elasticity is maintained.

The pharyngeal plexus is identified more easily in this setting than the secondary setting already discussed. When the larynx is intact after neck dissection and before the specimen is blocked for resection, it is rotated to the midline (Fig. 118-13). The cornu of the thyroid cartilage and the greater cornu of the hyoid form a space that includes the middle pharyngeal constrictor muscle and the previously described hiatus through which the plexus fibers travel. The nerves are electrically stimulated for identification, confirming their motor activity to the constrictor muscles; they are then electrocoagulated and divided, completing a unilateral neurectomy.

The laryngectomy is facilitated either by a midline esophagotomy at the level of the posterior cricoarytenoid muscles of by entrance at the vallecula. Scissors dissection is preferred, with one blade introduced into the lumen while the other remains external. The critical aspect of the resection, after identification of the lesion, is the incision of the pharyngeal mucosa of the uninvolved side and the constrictor muscles as a unit, which contrasts with the well-known method of separating the constrictors at the oblique line of the larynx. This approach spares the vascularity of the residual mucosa and constrictors without undermining the mucosa for a more secure pharyngeal closure. Tension and mucosa ischemia are the most likely causes of pharyngeal dehiscence, salivary contamination, and possible fistula formation.

Results

The data collected over 9 years were grouped in an initial 4-year group and a subsequent 4-year group for analysis. The disease-free incidences of the overall group of stage III and IV cases were consistent with historical controls (Singer et al, 1989). The more recent 4-year period was 71%, and the longer period was 56% (Table 118-1). The recurrence rates are within the expected range for this patient population, while the stoma recurrence of 3% to 4% is reasonable.

The first group of 48 patients had a voice failure rate initially of 29%, which was reduced to 13% by revision procedures. The more current group failed 15% of the time with five revisions reducing it to 9%. This represents an improving trend for voice rehabilitation in the populations over the last 9 years that includes the development of improved voice prostheses, more effective patient training, and refinement of the operative techniques. Speech after laryngectomy was possible 10 to 35 days postoperatively, with an average time of 22 days. Deglutition resumed 4 to 25 days after laryngectomy with an average of 10 days to return to a normal diet.

The occurrence of pharyngocutaneous fistula delays recovery, eliminates oral intake, alters the effective scheduling of radiotherapy, prevents voice acquisition, promotes stricture formation, and may lead to eventual carotid artery hemorrhage. In this series of 128 patients, 20 (22%) developed salivary leakage with no previous radiotherapy exposure, whereas 10 of the irradiated patients (26%) developed fistulas. There were four persons (5%) who

experienced significant pharyngeal strictures requiring secondary flap reconstruction. One of the patients, previously irradiated, developed progressive pharyngocutaneous necrosis that resulted in a carotid hemorrhage.

Future Directions

The treatment of laryngeal carcinoma has evolved over the last 117 years since the first laryngectomy. The last 12 years are characterized by a willingness to return to shunts and near-total procedures and to considerations of improving the total laryngectomy procedure itself. Laryngeal cancer treatment has been advanced significantly by the development of conservation laryngectomy procedures and refinements in radiation therapy methods.

Evaluation

The primary concern for treatment of extensive laryngeal cancer (T3) is that operative techniques are adequate. If a less than total procedure is considered, then careful histopathologic study of specimens is as important now as it formerly was to demonstrate the oncologic foundation for conservatin surgery. Patients with transglottic carcinomas, for example, are not acceptable candidates for conservation procedures because of multiple lymphatic compartment involvement.

As discussed above, adjunctive radiation therapy is considered desirable, if not the treatment of choice, for T3 or stage III laryngeal carcinoma. Frequently, radiation therapy is criticized because of anecdotal failure cases, reminiscences of orthovoltage treatment failures, or lack of information regarding original tumor staging and treatment planning. It is scientific to include radiation therapy, when carefully planned and delivered, as an indispensable part of the treatment for laryngeal cancer. More larynges are saved by radiation therapy than by surgery. The proposed reconstructive techniques must be effective in the irradiated milieu. Restricting the application of radiation therapy until recurrent disease is evident threatens long-term survival.

Future progress will come through diligent efforts of investigators as described earlier in this chapter with refinements of earlier ideas and treatment methods. Better understanding of the mechanism of human voice production is required, and its clinical measurement will provide important performance standards. Basic scientific investigation is a prerequisite to expansion of our understanding of the problem.

The treatment of selected advanced laryngeal cancer patients currently demands immediate or primary reconstruction of voice production. The complications are limited and are manageable. The delay in rehabilitation of the speech restoration if it is deferred longer than 6 months may lead to dependence, isolation, and depression. Immediate voice restoration by prosthesis represents a compromise to the necessity for safe deglutition and an airway permanently separated from the digestive tract. As the voice prosthesis is a link from the trachea to the esophagus, the concept of TEP and prosthesis can be considered a bridge to improved procedures in the future.

The challenge for future investigators is to restore the respiratory function of the laryngopharynx and upper respiratory tract after total laryngectomy. Restoration of the upper airway is a complex task without the coordination and protection of the inact structures. If the residual trachea can be protected by a biologic valve of hypopharyngeal mucosa and musculature, voice, swallowing, and respiration could be restored and the tracheostoma could be closed. Voice restoration is the most simple of these goals and has been with us since the initial laryngectomy. The restoration of the upper airway would be the greatest advance since the earliest laryngectomies. The scientific basis for such an advance has not yet been established, but imaginative clinical efforts and interest in providing better treatment will eventually solve the problems ahead.