Chapter 112: Phonosurgical Procedures

Paul W. Flint, Charles W. Cummings

While still in its infancy, laryngeal phonosurgery has grown to encompass a variety of procedures designed to effect alterations in the voice. These procedures may be classified into several categories, including (1) microlaryngeal procedures for excision of benign or malignant disease, (2) vocal fold injection for augmentation and medialization, (3) laryngeal framework surgery, (4) laryngeal reinnervation procedures, and (5) reconstructive and rehabilitative procedures after tumor resection. Laryngeal framework surgery has been further categorized by Isshiki (1989) into four types of surgical procedures based on functional alteration of the vocal folds: medial displacement (type I), lateral displacement (type II), shortening or relaxation (type III), and elongation or tensioning procedures (type IV).

This chapter focuses on laryngeal framework surgery, reinnervation procedures, and vocal fold injection as applied to rehabilitation of the paralyzed larynx, while specifically addressing the management of glottal insufficiency and airway compromise resulting from unilateral and bilateral vocal fold motion impairment. Controversies about the role of Teflon injection, thyroplasty, and reinnervation procedures are reviewed. In addition, management of sulcus vocalis, vocal fold bowing, and surgical procedures specifically designed to alter vocal pitch is discussed. Excision of pathologic tissue and rehabilitation after laryngectomy is covered elsewhere in this text.

Historical Aspects

The predominate focus of phonosurgical procedures has been rehabilitation of the paralyzed larynx. With a few exceptions, primary repair by end-to-end anastomosis after injury to the recurrent laryngeal nerve has been universally unsuccessful (Tashiro, 1970). Failure of primary repair is ascribed to a random process of axonal regeneration at the site of injury resulting in the simultaneous contraction of antagonistic muscle groups, otherwise known as synkinesis (Crumley, 1979; Flint et al, 1991). Alternative methods of reinnervation have been explored using ansa hypoglossus nerve-muscle pedicle implants into the posterior cricoarytenoid muscle and phrenic nerve to recurrent laryngeal nerve anastomosis for bilateral vocal fold paralysis (Baldissera et al, 1986; Crumley, 1983; Tucker, 1978). Ansa hypoglossus nerve-nerve anastomosis and nerve-muscle implant techniques have also been applied to unilateral vocal fold paralysis (Crumley et al, 1988; Tucker, 1977). Despite the significant efforts in establishing appropriate reinnervation and function after injury to the recurrent laryngeal nerve, debate continues about the efficacy of these procedures, and most surgeons prefer the alternative phonosurgical procedures for rehabilitation.

The first report of a phonosurgical procedure appeared when Brünings (1911) introduced the concept of vocal fold medialization by injecting paraffin within the body of the paralyzed fold. This was followed by Payr's (1915) description of an external approach for medialization using a posterior vertical incision through the thyroid lamina, whereby the anterior flap is collapsed inward, resulting in limited medialization. Neither approach gained acceptance. Almost four decades later, Meurman (1952) reported a series of patients with vocal cord paralysis in which external medialization procedures were performed using a vertical parasagittal incision in the anterior thyroid cartilage and autologous rib cartilage grafts placed between the thyroid ala and inner perichondrium. Meurman's procedure resulted in a high incidence of complications, probably as a result of perichondrial and mucosal perforations occurring with the anterior midline approach. In the 1960s, Arnold (1962) reintroduced vocal fold injection using the more biocompatible material Teflon. Subsequently, absorbable material has been introduced (Gelfoam), allowing performance of temporary procedures for medialization. More recently, alternative material for injection, including autologous fat and collagen, have been investigated (Ford and Bless 1986; Jiang et al, 1991). Adequate information about the long-term effectiveness of this material is currently not available; nonetheless, initial reports are encouraging.

Several authors have since modified Meurman's external approach, including Kamer and Som (1972), Beck and Richstein (1982), Kleinsasser et al (1982), and Isshiki (1975). Isshiki was the first to introduce the concept of alloplastic implant material for medialization using an external approach and is credited with the ultimate success and popularity of this procedure.

Although external procedures result in dramatic improvement in glottal efficiency and sound production, a small group of patients continue to have difficulty during phonation as a result of a larger posterior glottal chink or vocal folds at unequal levels. To address this problem specifically, Isshiki (1975) introduced the arytenoid adduction procedure for unilateral vocal cord paralysis. By using a suture placed around the muscular process of the arytenoid, pull in the direction of the lateral cricoarytenoid and thyroarytenoid muscles results in medial rotation of the arytenoid and downward displacement of the vocal process, thus closing the posterior gap and placing the paralyzed vocal folds at equal levels.

The advantages of an external approach to modify vocal fold tension and position without altering the structural components (mucosal fold and underlying muscle body) have expanded the role of laryngeal framework surgery. Isshiki (1989), Isshiki et al (1974), and Koufman (1989) have reported their experience with medialization and tensioning procedures for the management of vocal fold bowing due to androphonia, presbylarynx, and dysphonia resulting from sulcus vocalis and soft tissue deficits.

Management of Glottal Insufficiency Associated with Unilateral Vocal Fold Motion Impairment and Soft Tissue Deficits

Several procedures are available to manage glottal insufficiency, including vocal fold injection for medialization, medialization thyroplasty, arytenoid adduction, and a variety of reinnervation procedures. Selection of the appropriate procedure depends on the duration of symptoms, degree of impairment, presence of anatomic defect or previous surgical ablation, and potential for recovery. In addition, the patient's overall condition and life expectancy should be considered before embarking on a potentially unnecessary surgical adventure.

Patient evaluation and selection

Degree of impairment may be determined by subjective criteria based on the patient's symptoms such as breahiness, aspiration, or exertional intolerance or on more objective criteria obtained through a variety of tests. Currently available studies for objective assessment of laryngeal function include perceptual assessment, simple phonatory function tasks such as mean or maximum phonation time, acoustical parameters (ie, spectrographic analysis, measurement of fundamental frequency, perturbation of frequency and amplitude, signal/noise ratio), and measurement of phonatory airflow either directly by pneumotachography or indirectly using hot wire anemometry (Isshiki et al, 1989; Kitajima, 1985; Woo, 1986). Although these parameters are useful for study purposes and evaluating outcome of therapy, their role in patient selection has not been established. In selected cases, the flow-volume loop provides objective means to assess and monitor changes in airway function (Hyatt and Black, 1973; Kashima, 1991).

Videostroboscopy remains the most useful objective test for preoperative and postoperative evaluation of patients with unilateral vocal fold impairment, providing visual assessment of glottal closure and status of the mucosal wave. Reinnervation or denervation may be determined by the presence of abnormal or asymmetric mucosal wave patterns during stroboscopy; however, the absence of a mucosal wave does not necessarily imply denervation, because the mucosal wave is a passive phenomenon established by adequate vocal fold tension and subglottic pressure. In other words, the presence of functional motor units is not a prerequisite for the development of the mucosal wave.

Electromyography is the only test available at this time for evaluating the integrity of laryngeal innervation in the presence of vocal fold motion impairment. Laryngeal electromyography is useful for prognosticating and determining the presence of denervation or reinnervation potentials. It is assuming a more active role in the timing and choice of surgical procedures for the paralyzed larynx. Despite normal voluntary electrical activity, however, vocal fold immobility may be present as the result of laryngeal synkinesis, joint ankylosis, or cicatricial web formation. Distinction between these processes can be made only by palpation of the vocal process during direct laryngoscopy. With documentation of denervation by electromyography (EMG), medialization thyroplasty should be considered early in the presence of aspiration or severe dysphonia. Given the reversibility of these procedures (unlike Teflon injection), return of vocal fold mobility does not contraindicate medialization. If there is evidence of recovery visually, or by EMG, medialization with Gelfoam injection may be considered as a temporizing procedure initially. Patients suffering from dysphonia alone, however, should be counseled to allow spontaneous recovery to occur before considering medialization, as the quality of voice after reversal of type I thyroplasty has not been determined.

Prognosis, when combined with objective studies, will be useful for patient selection. Vocal fold paralysis associated with a favorable prognosis occurs after blunt trauma, endotracheal intubation, idiopathic vocal fold paralysis, and paralysis associated with viral pathogens (Ramsey Hunt syndrome). In this setting, severity of aspiration, dysphonia, and EMG findings may be used to determine the choice of procedure and timing of intervention, as outlined previously. Paralysis associated with poor prognosis for recovery includes those patients with injury after complete nerve section during surgical resection of tumor, invasion of cranial nerves by tumor, and paralysis associated with progressive neurologic disorders. Unlike peripheral recurrent laryngeal nerve injuries, high vagal injuries may result not only in loss of abductor/adductor function, but also in cricothyroid muscle function and deafferentation of sensory fibers. In this setting, vocal folds are more likely to be lateralized with marked bowing and atrophic changes. These patients generally have greater difficulty with dysphonia and aspiration. Where denervation is documented or history portends a poor outcome, early medialization by thyroplasty is warranted.

Percutaneous medialization by injection should be considered in patients with short life expectancy and aspiration or severe dysphonia. Because percutaneous medialization can now be performed easily in clinic, the time and expense of medialization thyroplasty or reinnervation procedures may not be justified.

Vocal fold medialization by injection

The use of injectable material for vocal fold medialization remains a standard procedure for laryngeal rehabilitation. In the absence of arytenoid ankylosis and when adequate residual vocal fold structure remains to allow needle placement for augmentation, medialization of a paralyzed vocal fold by injection may be performed using either Gelfoam or Teflon. Recently, transoral and percutaneous approaches have added a new dimension to the management of vocal fold paralysis (McCaffrey and Lipton, 1989; Ward et al, 1985). In selected patients, medialization can be accomplished quickly and effectively in the office setting. These procedures are relatively simple and yield immediate results with little discomfort to the patient.

When vocal cord paralysis has been documented to be permanent, Teflon may be used to medialize the vocal fold. If recovery of vocal fold function is likely, Teflon is contraindicated and alternative methods must be considered (see Medialization thyroplasty). Gelfoam may be used as a temporizing measure in this setting. The use of Gelfoam injection as a trial before Teflon injection should be discouraged, as this will result in redundant surgical procedures. Percutaneous injections may be performed without sedation using local anesthesia alone. Flexible fiberoptic laryngoscopy is required to visualize position and adequacy of injection. Given their advantages and ease of performance, percutaneous injections are becoming the preferred method in the majority of patients. However, when airway management is a potential problem, injection in a controlled setting during direct laryngoscopy should be considered.

A distinction should also be made between vocal fold medialization and intrachordal injection. With injection for medialization, the material is injected lateral to the vocalis muscle leaving the mucosa overlying the vocal fold unaltered. With intrachordal injection, used for sulcus vocalis or eliminating soft tissue defects, the injectable material is placed into the muscle body or between the vocal fold mucosa and vocalis muscle (Fig. 112-1).

Percutaneous injection

We prefer a lateral, percutaneous approach through the thyroid ala at the level of vocal fold determined by palpating the thyroid notch and inferior border of the thyroid ala anteriorly (Fig. 112-2). The vocal fold lies perpendicular to this line at the midpoint. Alternatively, an anterior approach may be used through the cricothyroid membrane, approaching the vocal folds from below (McCaffrey and Lipton, 1989; Ward et al, 1985). As the needle is inserted, it is angled superior and laterally under direct visualization using a flexible fiberoptic nasopharyngoscope.

Both techniques require a minimal amount of local anesthesia. Using the lateral approach, a Bruening pistol grip syringe with modified laryngeal needle is loaded with Teflon or Gelfoam paste and inserted as described previously. Controlled pressure is required to pass through the thyroid lamina. During flexible fiberoptic examination, the position of the needle can be visualized submucosally, and great care is taken not to violate the endolaryngeal mucosa. With the needle placed laterally and anteriorly to the vocal process, a single click of the trigger is administered followed by a brief period of observation as the paste is extruded. This maneuver is repeated until the vocal process is medialized. A second injection is usually administered anteriorly to the junction of the anterior and middle third of the vocal fold.

Transoral injection

Transoral injection may be performed in selected patients. Topical 4% lidocaine solution is applied to the pharyngeal and laryngeal mucosa. With the patient holding the tongue forward, allowing indirect visualization, the injection is performed using a curved laryngeal needle. Right and left needles are available so that the bevel is directed away from the midline to minimize the possibility of an intramucosal injection (Fig. 112-3).

Laryngoscopic injection

Ideally, the procedure is performed under local anesthesia to monitor the changes in vocal quality during injection. When local anesthesia is inadequate, the injection may be performed under general anesthesia with jet ventilation using the Sanders device, avoiding the use of an endotracheal tube. Superior laryngeal nerve blocks with lidocaine should be avoided, as they will alter vocal fold tension due to cricothyroid muscle paralysis and adversely affect voice quality.

With the patient in the supine position and after initiation of appropriate anesthesia, a Holinger anterior commissure laryngoscope is introduced and suspended using a Lewy suspension apparatus. Care is taken not to place unnecessary tension at the anterior commissure resulting in distortion of the vocal folds. The arytenoid cartilages are palpated with a spatula to ensure mobility, and the false vocal fold is lateralized exposing the ventricle (Fig. 112-4). The laryngeal needle is then inserted lateral to the vocal fold 2 mm deep at the level of vocal process. Teflon or Gelfoam paste is injected at single click intervals. Again, it is mandatory to wait after each click, as there is continued extrusion of material for several seconds after the trigger is activated. A second injection is placed lateral to the vocal fold at the junction of the anterior and middle thirds. After injection, a spatula is used to massage the vocal fold to distribute the Teflon more evenly. The scope is then relaxed and the patient asked to phonate. Repeat injections are performed as necessary. Before removing the scope, the airway is assessed to ensure adequate ventilation postoperatively.

Complications of vocal fold injection include underinjection requiring repeat procedures, overinjection with airway compromise, improper placement of Teflon causing subglottic extension and potential stenosis, migration of Teflon, intrachordal injection of Teflon impairing vibratory capability, and granuloma formation (Fig. 112-5).

Management of overinjection is a difficult task and should be counteracted immediately by incising the mucosa over the site of injection and removing excess material by suction. Immediate removal is preferred because delayed removal is made difficult by scar tissue and possible granuloma formation. If necessary, delayed removal is generally attempted during microlaryngoscopy using cupped forceps or the CO_2 laser. Koch et al (1987) evaluated the safety of using the CO_2 laser on Teflon and found no evidence or reports of untoward side effects. Teflon granulomas also require surgical excision. Endoscopic removal should be attempted initially, although open procedures (thyrotomy) may be required for recurrent or subglottic granuloma.

Medialization thyroplasty

Although introduced in 1915 by Payr, the concept of medialization by external approach has only recently gained acceptance in the surgical community and is now considered by many to be the procedure of choice for management of the paralyzed vocal fold. Also classified as a type I thyroplasty by Isshiki, this procedure offers the following advantages: (1) it is performed with local anesthesia with minimal or no discomfort to the patient; (2) patient positioning is more anatomic, allowing better assessment of voice during the procedure; (3) it is potentially reversible; and (4) because the prosthesis is placed lateral to the inner perichondrium of the thyroid lamina, structural integrity of the vocal fold is preserved, allowing medialization in the presence of a mobile vocal fold. Disadvantages include the following: (1) the patient is subjected to an open procedure, (2) the procedure is technically more difficult, and (3) intubation for surgery subsequent to medialization may result in displacement of the prosthesis or mucosal erosion secondary to endotracheal tube pressure.

Medialization thyroplasty is currently applicable for management of vocal fold paralysis, vocal fold bowing resulting from aging or cricothyroid joint fixation, sulcus vocalis, and soft tissue defects resulting from excision of pathologic tissue (Isshiki et al, 1989; Koufman, 1986). Treatment for paralytic dysphonia is indicated when the likelihood of recovery is negligible. When recovery is anticipated, medialization thyroplasty may be considered for management of aspiration or severe dysphonia as an alternative to repeated injections with Gelfoam. Generally, dysphonia by itself should be managed conservatively if recovery is anticipated.

Technique

Although modifications of Isshiki's description of medialization thyroplasty are abundant, the basic principles remain the same. Medialization is performed through a window in the thyroid lamina at the level of the vocal fold. The inner perichondrium should remain intact. Factors that affect outcome include size and shape of the implant, position of the implant, maintaining proper position of the implant, and limiting the duration of the surgical procedure. Although carved silastic implants are used in most centers, we use prefabricated dense hydroxylapatite implants with matched-sized templates, allowing rapid determination of the correct implant position and size (Figs. 112-6 and 112-7).

With the patient in the supine position and prepared for a sterile procedure, a paramedian horizontal incision is outlined over the middle aspect of the thyroid lamina. Local anesthesia is administered subcutaneously and in four quadrants over the ipsilateral lamina. A 5 to 6 cm incision is made through the platysma. Superior and inferior flaps are elevated in the subplatysmal plane exposing the thyroid notch and inferior border of the thyroid cartilage. The strap muscles are split in the midline and retracted laterally off the thyroid lamina, leaving the outer perichondrium intact. A single large skin hook is implanted in the anterosuperior aspect of the contralateral ala and retracted laterally, providing exposure of the ipsilateral lamina. The perichondrium is scored with electrocautery applied to a window template placed 8 mm posterior to the ventral midline with the superior edge at the level of the vocal fold. The outer perichondrium is incised and elevated off the window. Cartilage and osteoid material are removed precisely from the rectangle. Where ossification has occurred, the window may be drilled out or removed with a Kerrison punch. Regardless, care must be taken to preserve the inner perichondrium, which is now elevated in circumferential fashion off the thyroid lamina using a No. 4 Penfield elevator. One of four sizing prosthesis templates (3 to 6 mm) is inserted through the window and rotated 90 degrees with the bevel directed inferiorly. All retractors are removed and the patient asked to phonate while moving the template through all four quadrants of the window to determine the optimal position. Smaller or larger templates may be selected as needed. Once the appropriate size and position have been determined, the retractors are replaced and the implant is inserted and secured with the corresponding shim. If the window is fashioned correctly, the shim will fit securely preventing migration of the implant. The wound is then irrigated with antibiotic solution. A 1/4" Penrose drain is placed deep to the strap muscles and brought out through the incision. Strap muscles and platysma are approximated with 4-0 chromic suture and skin is closed with a running 4-0 nylon suture. A dry fluff compression dressing is applied for 24 hours, at which time the Penrose drain is removed. Decadron is given preoperatively to minimize edema and prophylactic antibiotics are continued for 5 days.

We prefer to use the largest possible prosthesis possible while maintaining quality of voice. Overmedialization is supported by Isshiki et al (1989), who found deterioration in voice quality over time as intraoperative edema resolved in the postoperative period. Where early medialization is performed, muscle atrophy may also result in voice deterioration postoperatively. Minimizing operative time is critical in obtaining optimal results (Isshiki et al, 1989). Fabricating implants before the procedure and rapid determination of size and position will facilitate the procedure.

Complications associated with type I thyroplasty include penetration of the endolaryngeal mucosa, wound infection, chondritis, implant migration or extrusion, and airway obstruction. Airway compromise is a potential problem and requires inpatient observation for a minimum of 24 hours (Maves et al, 1989).

Arytenoid adduction

Successful vocal fold medialization using the type I thyroplasty technique may be limited in the presence of a large posterior glottal chink or if there is a difference in the level of the two vocal folds (Isshiki et al, 1978). This situation commonly occurs with high vagal nerve injuries when denervation of the ipsilateral cricothyroid muscle and recurrent laryngeal nerve injury coexists. Inability to close the posterior gap surgically by medialization techniques is due to the superior projection of the cricoid cartilage medial to the thyroid lamina. Unequal vocal fold levels may result from asymmetric rotation through the cricothyroid joint due to loss of cricothyroid muscle activity, or simply secondary to absence of adductor forces (Isshiki, 1989). The cylindric shape of the cricoarytenoid joint results in downward displacement of the vocal process during adduction and upward displacement during abduction. The arytenoid adduction procedure results in rotation of the arytenoid with downward displacement of the vocal process and closure of the posterior gap (Isshiki, 1989).

This procedure may be performed separately or in combination with type I thyroplasty. Disadvantages include the degree of difficulty and irreversibility. Because the cricoarytenoid joint is opened, ankylosis results in permanent motion impairment. Arytenoid adduction is contraindicated if spontaneous recovery of function is anticipated.

Technique

The procedure, as described by Isshiki et al (1978), is performed using local anesthesia with the patient in the supine position (Fig. 112-8). The neck is extended and the head rotated slightly to the contralateral side. The same incision used for medialization thyroplasty is extended just beyond the posterior aspect of the thyroid lamina. The pharyngeal constrictor muscle is incised at its attachment to the thyroid lamina exposing the posterior margin. The inner perichondrium is elevated from the posterior aspect of the ala. The cricothyroid joint is disarticulated to allow exposure and elevation of the piriform sinus mucosa. At this point penetration of endolaryngeal mucosa may occur requiring termination of the procedure.

The muscular process of the arytenoid is identified by palpation beginning at the cricothyroid joint and moving obliquely up the cricoid cartilage. The process will be located at the same level as the vocal fold or at the midpoint between the thyroid notch and the inferior margin of the thyroid cartilage. The cricoarytenoid joint is opened by incising the posterior cricoarytenoid muscle posterior to the muscular process, allowing identification of the articulating surface. Adduction is performed by tying two 4-0 nylon sutures around the muscular process and passing the ends out through the thyroid lamina in directions that simulate the pull of the thyroarytenoid and lateral cricoarytenoid muscles (Fig. 112-9). This maneuver can be facilitated by passing the ends through the barrel of an 18-gauge needle. The degree of rotation may be increased as necessary by having the patient phonate while tension is applied gradually to obtain optimal voice quality. Each suture is then tied over the thyroid lamina. The wound is irrigated with antibiotic solution, drained with a 1/4" Penrose drain, and closed with 5-0 chromic suture in the subcuticular layer and 4-0 nylon in the skin.

Reinnervation procedures

The details of the reinnervation surgical technique are described by Tucker (1977). In the absence of ankylosis determined by direct laryngoscopy or history, and when spontaneous recovery is not anticipated, reinnervation may be attempted under local or general anesthesia. After preparation and draping for sterile surgery, a horizontal incision is made at the lower half of the thyroid lamina extending from the anterior midline posteriorly to the sternocleidomastoid muscle (Fig. 112-10). The jugular vein and omohyoid muscle are exposed while the ansa hypoglossus and nerve branches to the anterior belly of the omohyoid muscle are identified. The nerve is carefully dissected to the muscle insertion site. The nerve typically travels several millimeters between muscle fibers before reaching the motor end plate region. Two stay sutures are placed adjacent to the insertion site and a block of muscle is removed, 2 to 3 mm per side. A posterior-based perichondrial flap is elevated and an inferior window created belof the level of the vocal fold. It is possible to use the same window created for the type I thyroplasty; however, the inner perichondrium must be opened and the thyroarytenoid muscle incised superficially. The muscle pedicle is sutured in place using the previously placed stay sutures, being careful not to place tension on the pedicle. The wound is irrigated with saline and closed in layers. A 1/4" Penrose drain brought out through the incision is removed at 24 hours. Perioperative antibiotics are administered for 5 days.

Crumley et al (1988) uses a modification of this technique. Using the ansa hypoglossus nerve anastomosed directly to the recurrent laryngeal nerve, they reoprt marked improvement in voice 3 to 4 months postoperatively with no return of vocal fold motion. Simultaneous Gelfoam injection is also recommended at the time of surgery because nerve sprouting does not occur for several months (Crumley, 1990). Vocal fold medialization at the time of the procedure offers the patient immediate temporary improvement.

Reinnervation procedures are limited to management of abductor or adductor paralysis and require the presence of an appropriate donor nerve or nerve-muscle pedicle. If aspiration is a major concern, reinnervation as the primary procedure is not recommended because significant medialization does not occur. Results in patients with aspiration have not been reported. A combination of thyroplasty and nerve-muscle pedicle reinnervation has been proposed by Tucker (1990). However, implantation of the nerve-muscle pedicle may be compromised because the inner perichondrium is left intact during thyroplasty.

Special considerations: Teflon injection versus thyroplasty versus reinnervation

Although Teflon injection and thyroplasty have been accepted as appropriate procedures for rehabilitation of the paralyzed larynx, debate remains about the efficacy of the reinnervation procedures espoused by Tucker and Crumley. Crumley (1990) recently reviewed these procedures with respect to operative time, ease of performance, time interval to improvement, reversibility, changes in vocal fold structures, complications, indications, cost, and success with respect to phonatory improvement. Unfortunately adequate studies comparing phonatory improvement using the three basic procedures are not currently available.

Time of procedure and ease of performance are operator dependent and vary with the surgeon's expertise. Vocal fold injection is technically the simplest procedure to perform and requires either local or general anesthesia. Reinnervation is the most time consuming and is usually performed under general anesthesia. Thyroplasty, technically more versatile, allows intraoperative modifications of implant size, shape, and position, thereby customizing the procedure. Both Teflon injection and thyroplasty yield immediate results, whereas nerve-nerve anastomosis or nerve-muscle transplant reqyuire 2 to 3 months for reinnervation to occur. Gelfoam paste injected simultaneously into the ipsilateral vocal fold provide immediate improvement during the interval of nerve regeneration.

Reversibility of these procedures has not been adequately determined. Teflon injection is the least reversible of the three procedures, requiring endoscopic removal with potential disruption of mucosa and muscle body of the vocal fold. Scar formation after removal is probably more detrimental to vibratory function than the actual removal of Teflon. In short, Teflon augmentation should not be considered a reversible procedure and is contraindicated if recovery of function is anticipated. Thyroplasty, on the other hand, is reversible and is not absolutely contraindicated if recovery is anticipated. Because the implants are placed lateral to the inner perichondrium of the thyroid ala and not in direct contact with the vocal fold, removal of the implant should result in lateralization of the vocal fold to its preoperative state. However, phonatory function after removal of the implants has not been determined. Likewise, results after reversal of reinnervation procedures have not been studied.

Although uncommon, complications have been reported for Teflon injection, thyroplasty, and reinnervation procedures (Crumley, 1990; Gardner and Parnes, 1991; Maves et al, 1989). Although no single study is large enough to predict the relative complication rates, Teflon injection appears to have the highest incidence of complications, including overinjection, migration of Teflon, misdirected injections, granuloma formation, and airway compromise. Complications associated with thyroplasty include mucosal perforation, infection, dislodgement of implants, extrusion of implants, and airway compromise. One fatality has been reported as a result of airway compromise (Maves et al, 1989). Undermedialization is probably the most common problem encountered with thyroplasty, resulting from intraoperative edema or postoperative denervation muscle atrophy. Reinnervation procedures are associated with the fewest complications. Hematoma and wound infection have been reported by Tucker (1982) and Crumley (1990), respectively.

The relative cost is of importance when considering the choice of surgical procedures. In concurrence with Crumley (1990), Teflon injection in our institution is the least expensive. Thyroplasty and reinnervation procedures are at least twice as costly. If a combination of procedures is performed, the relative cost will be even greater. As an example, thyroplasty combined with reinnervation, as proposed by Tucker (1990), theoretically will medialize the vocal fold, improve muscle tone, and add the ability to tense the vocal fold. To justify the expense of two procedures, it is crucial to demonstrate a functional improvement greater than either of the individual procedures alone. Objective data comparing the combined procedure with either thyroplasty or reinnervation alone are not available.

Clearly, before we can judge which procedure or combination of procedures is optimal and justified, we must have objective data comparing these procedures. Gardner and Parnes (1991) suggest that thyroplasty is superior to Teflon injection. Both procedures normalized the mucosal wave and vibratory characteristics of the paralyzed fold; however, Teflon injection was more likely to worsen with time. Although glottic closure was accomplished, stiffening of the vocal fold (most often the result of granuloma formation) resulted in loss of the ipsilateral mucosal wave in 5 of 11 patients. The thyroplasty group (eight patients) did not experience deterioration over time, and patients experienced improved glottic closure postoperatively. Watterson et al (1990) reported absent mucosal waves in five of five patients injected with Teflon and concluded that Teflon injection results in a decrease in compliance or stiffening of the vocal fold. The actual site and technique of injection is not given in the latter report (intrachordal versus intrafold), nor is any mention made of possible overinjection or granuloma, which is suggested by the poor outcome in all five patients.

Although Crumley (1990) and Tucker (1990) both report improvement in voice associated with changes in vocal fold tone and muscle mass after reinnervation procedures, documentation of changes in vibratory characteristics or acoustic parameters are not available. Theoretically, the increased muscular tone and ability to tense the vocal fold after reinnervation in combination with medialization thyroplasty would result in significant improvement in voice quality.

Although the majority of experimental animal studies focus on reinnervation of the posterior cricoarytenoid muscle for bilateral vocal fold paralysis, conflicting results with respect to functional recovery after unilateral recurrent laryngeal nerve section, regardless of electromyographic evidence of reinnervation, have been reported. Iwamura (1974), using split vagal nerve transfer to adductor muscle and phrenic nerve to abductor muscle, reported return of spontaneous adductor function and partial return of abductor function. Sato and Ogura (1978) also reported return of adductor function with primary recurrent laryngeal nerve repair and division of the abductor branch. Ansa cervicalis nerve-muscle implant to the posterior cricoarytenoid muscle resulted in functional abduction. In contrast, Rice (1982) found chronic adduction only after external superior laryngeal nerve to recurrent nerve anastomosis and suggested the functional improvement seen in other studies resulted from the intact cricothyroid muscle activity. This finding would imply that clinical improvement after reinnervation in the absence of vocal fold motion is the result of increased vocal fold tone. This conclusion is supported by Green et al (1991) who, despite histologic evidence of reinnervation, failed to demonstrate functional improvement in the absence of electrical stimulation after ansa cervicalis to recurrent laryngeal nerve anastomosis.

The role of cell adhesion molecules has only recently been explored with respect to nerve injury and repair. Immunocytologic studies have demonstrated that muscle denervation is required for nerve sprouting to occur after nerve or nerve-muscle implantation (Covault and Sanes, 1985; Daniloff et al, 1986; Martini and Schachner, 1988). After denervation, the expression of specific cell adhesion molecules is upregulated and nerve sprouting occurs. In normal adult muscle and after reinnervation of muscle, expression of cell adhesion molecules is downregulated and nerve sprouting inhibited. In the event of laryngeal nerve injury and inappropriate reinnervation (synkinesis), subsequent nerve-muscle implantation would not be expected to result in successful nerve sprouting. Based on cell adhesion molecule expression studies, ansa cervicalis to recurrent laryngeal nerve anastomosis is theoretically superior to nerve-muscle pedicle implants. In the denervated condition, however, more rapid reinnervation and stronger contractile force occurs after ansa hypoglossus nerve-muscle pedicle implantation when compared to direct nerve implants (Hall et al, 1988). The role of cell adhesion molecules after laryngeal denervation and reinnervation that affect outcome remains to be determined. Investigations in this area will ultimately have significant impact on the direction of research in laryngeal reinnervation.

Bilateral Vocal Fold Motion Impairment

The predominant causes of bilateral vocal fold motion impairment have changed as medical care has become more sophisticated and as society has become more mechanized. Trauma to the larynx or to the recurrent laryngeal nerve secondary to a direct blow or traction is assuming a major role. Blunt and open trauma to the neck is far more common today than it was half a century ago, and the victims are more likely to survive. Indications for surgical treatment of thyroid disease have diminished rather markedly as a result of improvements in the methods of diagnosis and management of thyroid disorders. Surgery usually is now indicated only when there is a high likelihood of malignancy. Furthermore, the otolaryngologist-head and neck surgeon has become better versed in the anatomic vagaries of the recurrent laryngeal nerve as it courses through the neck (in addition to the current standard that the nerve is almost always identified during surgery). Other cervcal surgery may contribute to laryngeal nerve deficits, although bilateral involvement is very unlikely. These types of surgery include carotid endarterectomy, anterior cervical fusion, and cervical esophageal surgery; in short, any anterior cervical procedure in which traction and retraction play a role.

Trauma secodnary to endotracheal intubation, especially in the chronic setting, has become more frequent and is a therapeutic challenge. Although vocal fold paralysis on the basis of pressure from the endotracheal tube may occur after brief periods of intubation, the most frequent pathologic finding is subglottic or interarytenoid fibrosis and cricoarytenoid ankylosis after prolonged intubation. Involvement of the cricoarytenoid joint by an arthritic process in rheumatoid arthritis occurs more frequently than is generally appreciated. Chronic arthritis of the cricoarytenoid joint or the cricothyroid joint obviously would produce ankylosis rather than paralysis, a factor to be confirmed by direct laryngoscopy EMG before treatment.

Infiltrative disorders (amyloid), granulomatous diseases (tuberculosis, sarcoidosis), and neoplastic disease do play a role in impairment of laryngeal function. Neoplastic disease is usually unilateral and may include squamous cell tumors from the upper aerodigestive tract or primary thyroid neoplasms, which are aggressively malignant. Benign infiltrative disorders and granulomatous disease are more commonly bilateral and result in impairment of both abduction and adduction in spite of intact neuromuscular function. Airway limitation and dysphonia tend to be more severe due to the decreased compliance associated with an infiltrative process.

Many of the etiologic processes are neurologic. Certainly, the incidence of neuropathy in patients with longstanding diabetes and in those with small vessel peripheral vascular disease is higher. Parkinson's disease, craniocervical dystonias, and the progressive demyelinating processes (such as amyotrophic lateral sclerosis) may present with laryngeal involvement as one of the earliest signs. A complex form of laryngeal neuropathy may evolve subsequent to trauma affecting the higher centers of the central nervous system. Closed head injury and stroke can cause abnormalities of laryngeal function that are particularly difficult to assess and treat, as the findings change as the lesion evolves.

The symptoms of bilateral vocal fold motion impairment are typically described as if there were a single deficit, either abduction or adduction, but this situation is rarely true. In the individual with a predominance of abductor loss, the vocal folds tend to be near the midline and predispose the person to a compromised airway in the presence of a relatively good voice. The individual with a predominantly adductor deficit has a relatively good airway, a very breathy voice, and most likely a significant problem with aspiration. In the presence of bilateral paralysis without ankylosis, the compromised laryngeal inlet may close off completely during forced inspiration as the two cords are drawn together by the negative intratracheal pressure. This phenomenon is less likely to occur when the cricoarytenoid joints are ankylosed.

Patient evaluation and selection

A word of caution is appropriate at this point. Recall that a tracheotomy bypasses the larynx and thus diminishes the demands for the vocal cords to abduct during inspiration (Sasaki et al, 1973). This situation may lead to an error in diagnosis if one assumes that because there is no abductive effort during indirect laryngoscopy in the tracheotomized patient, there is a break in neurologic continuity. The tracheotomy tube must be occluded at the time of examination to properly assess abduction.

Indirect laryngoscopy, either with the traditional laryngeal mirror or with the aid of a fiberoptic system, is the best method for discerning vocal fold mobility on inspiration and phonation. EMG is becoming a more common means to evaluate the neurologic integrity of the laryngeal musculature. Neither test, however, allows for absolute exclusion of fibrosis or cricoarytenoid ankylosis. Radiographic evaluation of the swallowing mechanism is an important part of the diagnostic workup to exclude previously unapparent, more general neurologic deficits.

The flow-volume loop (FVL) examination is a useful and easily obtained measurement of respiratory flow rate limitation (Hyatt and Black, 1973). The FVL documents air flow rate and volume, the site of obstruction, and nature and severity of the obstructing lesion. Two distinct FVL patterns are seen with bilateral vocal fold motion impairment (Fig. 112-11). Selective inspiratory limitation and normal expiratory flow rate (variable extrathoracic obstruction) are seen with bilateral vocal fold paralysis, cricoarytenoid ankylosis, interarytenoid fibrosis, and laryngeal webs (Dennis and Kashima, 1989; Kashima, 1991). Limitation of flow during inspiration and expiration (fixed obstruction) is seen with infiltrative disorders, either benign or malignant, resulting from mass effect and loss of compliance. FVL provides objective serial measures for assessment of improvement or progression of respiratory flow limitations and assessment of treatment outcome. The minimal acceptable inspiratory flow rate for an average adult at midvital capacity is $\approx$ 1.5 L/sec, and strong consideration for surgical intervention should be considered if flow drops below this level.

Finally, direct laryngoscopy should be used to ensure a correct diagnosis. The ankylosed joint becomes apparent on direct palpation of the vocal process, as evidenced by lack of mobility, in contrast to the laxity in suppleness of the joint in the paralyzed state. Furthermore, lateral deflection of the arytenoid on one side should have no effect on the opposite arytenoid. If the contralateral arytenoid moves toward the midline as the other is deviated laterally, then interarytenoid fibrosis with tethering is likely (Fig. 112-12). If the patient has been tracheotomized, occlusion of the tracheotomy tube and avoidance of paralyzing medication will introduce a temporary state of CO_2 accumulation, thus stimulating the respiratory drive and inducing maximal lateralization of the arytenoid if the neuromuscular system is intact.

Management of bilateral vocal fold motion impairment with airway obstruction

The results of any surgical intervention should be compared with the results produced by tracheotomy alone, since the patient accepts the nuisance of a tracheotomy to gain assurance of a good airway, and the probability of a good voice. Most procedures that enlarge the laryngeal airway, and thus eliminate the need for a tracheotomy, result in a voice of poorer quality and increase the possibility of aspiration.

The least invasive of the lateralizing procedures involves endoscopic surgery. An arytenoidectomy may be performed through the laryngoscope (Fig. 112-13) but this is a difficult procedure for all but the very experienced (Thornell, 1949). Lateralization of the vocal cord by suture placement is an alternative procedure (Fig. 112-14) (Kirchner, 1979) but visualization through the laryngoscope is difficult. The laser has been suggested as a method for excising a portion of the vocal cord. Although this method has proved successful in removing the anterior two thirds of the vocal cord, the posterior third represented by the arytenoid is more difficult to remove successfully with the CO_2 laser. Furthermore, partial arytenoidectomy predisposes the patient to a greater incidence of postoperative chondritis. If total arytenoidectomy is performed with the laser, significant scar formation ensues, which may bring the remaining ligamentous portion of the vocal cord medially (rather than laterally, as intended).

A simpler and more practical technique of laser cordotomy was introduced by Dennis and Kashima (1989) and Kashima (1991) as an alternative to cordectomy (Fig. 112-15). Using the CO_2 laser, a transverse incision is made through the vocal fold immediately anterior to the vocal process, resulting in a wedge-shaped widening of the posterior glottis due to retraction of the divided thyroarytenoid muscle. Contracture of the thyroarytenoid muscle with secondarily increased anterior vocal fold mass minimizes the postoperative dysphonia associated with cordectomy. In selected cases, vestibulectomy (removal of the ipsilateral false vocal fold) may improve exposure and facilitate the cordotomy (Kashima, personal communication).

The most efficient form of arytenoidectomy is the more direct midline thyrotomy approach with subperichondrial dissection or transmucosal incision (Figs. 112-16 to 112-18). Alternatively, the lateral external approach described by Woodman (1953) avoids potential wound contamination and disruption of the anterior commissure (Fig. 112-19). In both the midline and lateral approaches, a suture is used to fix the vocal process in a lateralized position, at least until scar tissue forms, which must be confirmed by intraoperative endoscopy (Baker, 1916; Woodman, 1953). Submucosal cordectomy (Hoover, 1932) may also be performed to increase the glottic aperture if arytenoidectomy, as described earlier, fails (Fig. 112-20).

The success rate for any of these procedures is generally no greater than 70%, a point to be remembered when counseling the patient or making therapeutic decisions. If the patient has paralysis with a supple cricoarytenoid joint, one might consider a reinnervation procedure as a first option before performing a more irreversible operation. Tucker (1979) introduced the concept of neuromuscular pedicle transposition into the paralyzed posterior cricoarytenoid muscle to enhance the ability to abduct the vocal cord by establishing a reinnervated muscle (Fig. 112-21). His high success rate of over 80% (judged by the ability to decannulate the patient) has not been reproduced by others. Critics believe that rather than reestablishing neuromuscular integrity in the posterior cricoarytenoid muscle by using the ansa cervicalis nerve pedicle, movement of the extralaryngeal muscles is transmitted to the arytenoid by scar tissue. Although still unresolved, the reinnervation has rekindled interest in therapeutic surgery for the paralyzed larynx. Currently nerve implantation into the paralyzed muscle, either with a split phrenic nerve or with a branch of the ansa cervicalis, is undergoing clinical assessment.

Management of bilateral vocal fold motion impairment with weak voice and aspiration

Bilateral adductor paralysis is a very unusual condition characterized by weak voice and aspiration. In the acute phase (when there is hope for neurologic return), bilateral vocal fold augmentation with Gelfoam can be used to close off the airway temporarily. Those methods effective with unilateral adductor paralysis, specifically injection of Teflon paste, surgical medialization, or arytenoid adduxction, are not effective in this setting. Usually, a more specific surgical approach to the laryngeal inlet is indicated to confront the problem of aspiration. A narrow-field laryngectomy is the most effective method for prevention of aspiration; however, it results in the elimination of the larynx as an organ of communication. Other surgical approaches, including the epiglottic sew-down procedure, surgical approximation of the vocal folds, or tracheal diversion procedures, have their place in conditions that can be judged reversible. Management of intractable aspiration is discussed elsewhere in this text.

Special Considerations in Phonosurgery

Surgical procedures to alter vocal pitch

Lower pitch

Procedures designed to shorten the vocal folds and decrease tension or pitch have been advocated for adductor spasmodic dysphonia, mutational falsetto, and gender transformation. The use of these procedures for management of spasmodic dysphonia has not been proven effective, and until compared in controlled studies, type III thyroplasty should not be considered a treatment option for spasmodic dysphonia. At best, with short-term follow-up (7 months to 2 years), Tucker (1988) reported relief of spasm in only 63% of patients (n=16), which is no better than results with recurrent laryngeal nerve section (Aronsen and DeSanto, 1983).

Type III thyroplasty for mutational falsetto and gender transformation may be considered only after 3 to 6 months of voice therapy and, when indicated, psychologic evaluation and therapy. Dysphonia resulting from increased vocal fold stiffness has been associated with laryngeal trauma, radiation therapy, chronic laryngitis, sulcus vocalis, and vocal fold atrophy (Isshiki, 1989). Clinically, patients present with high vocal pitch associated with a narrow glottal chink and small amplitude mucosal wave seen during stroboscopic evaluation.

Technique. The surgical procedure was first described by Isshiki et al (1983) as outlined below. The incision and surgical approach are the same as performed for type I thyroplasty. After the thyroid ala is exposed, a vertical incision is made between the anterior and middle one third of the thyroid ala (Fig. 112-22). The inner perichondrium is elevated 3 to 4 mm off the medial and lateral edge. The second cut is made 2 to 3 mm posterior and parallel to the first cut, and the cartilage strip is removed. The degree of pitch change is then determined while the patient phonates. If further change is desired, a second cut may be performed removing 1 to 2 mm in width on the ipsilateral side. Unilateral excision results in tension imbalance and lower pitch, manifested only by phase lag seen during stroboscopy (Isshiki et al, 1977). Dysphonia is generally not a problem with unilateral procedures; however, excision greater than 5 to 6 mm is not recommended. If further alteration in pitch is desired, bilateral excision of 2 to 3 mm may be performed. Closure of the lamina defect may be performed by edge-to-edge approximation or by overlapping the lateral and medial margins of the lamina. Overlapping edges may produce an even greater change in vocal pitch; thus, the method of closure depends on the resultant voice characteristics.

Elevate pitch

Lengthening the vocal folds and elevating vocal pitch may be achieved by advancing the anterior commissure or by cricothyroid approximation. Lengthening procedures have been advocated for vocal fold bowing resulting from aging or trauma, postsurgical defects, androphonia, and gender transformation (Isshiki, 1974; 1983; 1989). Although lengthening procedrues have been effective in management of unilateral cricothyroid muscle paralysis and androphonia, long-term results with elderly patients suffering from presbylarynx have not been encouraging. In this setting, consideration should be given to bilateral medialization procedures (Koufman, 1989).

An alternative approach to elevate pitch is to decrease vocal fold mass, thereby increasing the frequency of the vibratory cycle. Decreased vocal fold mass may be achieved by removing tissue with the CO_2 laser or by mechanically inactivating the vocalis muscle (Isshiki, 1974; 1989). Longitudinal incisions parallel to the true vocal folds have been used to elevate pitch. This procedure theoretically results in sectioning vocalis muscle fibers, which normally oppose lengthening of the vocal fold by the cricothyroid muscle. Studies in dogs (Tanabe et al, 1985) and clinical evidence (Isshiki et al, 1983) suggest that the effectiveness of the procedure is related to scar formation. Long-term results are not available and the procedure should be considered experimental. Other techniques designed to decrease mass, including vocal fold stripping, laser vaporization, and steroid injection, are less well controlled and may potentially result in deterioration of vocal quality.

Lengthening procedures. ***Expansion of the thyroid ala.*** Alar expansion to elevate pitch was first described by Isshiki et al (1977, 1983). Unilateral alar expansion is performed by incising the thyroid lamina in the vertical dimension at the junction of the anterior and middle one third of the thyroid ala. A silastic strip implant is secured between the edges (Fig. 112-23). Greater pitch elevation may be achieved with bilateral alar expansion, and, if indicated, simultaneous medialization may be performed.

Alar expansion is the most technically difficult of the lengthening procedures. Effectiveness of the advancement may be limited by the thickness of the anterior cartilage and the obtuse angle of the thyroid cartilage (Isshiki, 1989).

Anterior commissure advancement: LeJeune procedure. Advancement of the anterior commissure was first described by LeJeune et al (1983) using an inferiorly based cartilaginous flap (Fig. 112-24). Tucker (1985) modified this procedure using a superiorly based flap that allows greater advancement of the anterior commissure (Fig. 112-25). A silastic or tantalum shim is used to maintain position of the flap. Anterior commissure advancement may also be combined with a medialization procedure by developing a pocket between the inner perichondrium and thyroid lamina via the anterior cartilage incisions (Koufman, 1989).

The anterior flap technique is simpler in design and results in a more direct pull on the vocal fold than alar expansion. The relatively thin tissue lining the inner aspect of the thyroid lamina anteriorly, however, results in a higher incidence of perforation. In addition, calcification of the thyroid cartilage may limit the ability to advance the anterior commissure.

Cricothyroid approximation. Surgical approximation of the cricoid and thyroid cartilage to simulate contraction of the cricothyroid muscle was first described by Isshiki et al (1974) (Fig. 112-26). Four nonabsorbable mattress sutures are placed, first through the cricoid cartilage and then through the thyroid cartilage. Sutures should be placed anteriorly, 3 to 4 mm off midline, parallel to the rectus division of the cricothyroid muscle. Silastic or cartilage bolsters are used to distribute pressure over the thyroid lamina as the sutures are gradually tightened, alternating right and left while an assistant approximates the cricoid and thyroid cartilages. Maximum closure should be obtained, as some relaxation generally occurs postoperatively.

Cricothyroid approximation is the simplest and safest of the lengthening procedures. Disadvantages include greater risk of reversion to lower pitch and potential narrowing of pitch range (Isshiki, 1989).

Sulcus vocalis

Sulcus vocalis is a term used often in the literature to describe a congenital soft tissue deficit or linear furrow running longitudinally along the free edge of the true vocal fold. The review by Arnold (1958) of *dysplastic dysphonia* includes 12 cases of sulcus vocalis among 1250 adults referred for voice disorders. Greisen (1984) reported a similar incidence among patients presenting with voice complaints. Arnold credits Salvi (1901) with the first complete description of sulcus vocalis: "a degenerative sign allegedly more frequent among criminals".

Seen as a fine longitudinal furrow on the medial edge of the vocal fold, the size of the furrow may vary in length and depth. In extreme cases where the sulcus divides the medial edge into an upper and lower lip, a double vocal fold appears. The process may be unilateral or bilateral and is frequently found in association with other laryngeal abnormalities, such as an accessory ventricle.

The etiology of sulcus vocalis is unknown. An association has been made with tuberculous and luetic involvement of the larynx, although this link was more than likely coincidental given the high incidence of tuberculosis and syphilis when these reports appeared (Arnold, 1958). A congenital abnormality or variant is supported by the presence of a normal sulcus in primates and other mammalian species (Kelemen, 1949).

Symptoms are related to incomplete glottal closure and are manifested by a decrease in phonation time and breathy high-pitched turbulent airflow. The disorder is frequently overlooked or misdiagnosed as a primary functional disorder and commonly associated with secondary changes such as edema, polyps, and chronic inflammation. These changes presumably result from a compensatory increase in muscular tension in an attempt to overcome the glottal inefficiency (Greisen, 1984).

Speech therapy has not been successful in managing symptomatic patients, and surgery has been directed toward correcting the incomplete glottal closure (Arnold, 1958; Greisen, 1984). Intrachordal injection with cartilage paste or paraffin was initially proposed by Arnold (1958). Hirano (1975) presented results of intrachordal injection and reported an 80% success rate. In addition to both lengthening and shortening procedures, medialization thyroplasty has been used successfully in managing patients with sulcus vocalis (Isshiki, 1989; Isshiki et al, 1974). Intrachordal collagen injections, recently advocated for management of soft tissue deficits resulting from surgical trauma (Ford and Bless, 1986), will likely find a role in the treatment of these patients.

Summary

Unilateral vocal fold motion impairment most commonly results in phonatory dysfunction and aspiration. Laryngeal framework surgery, such as medialization thyroplasty and percutaneous Gelfoam or Teflon injection, has improved out armamentarium for rehabilitation of the paralyzed larynx. Furthermore, the development of phonosurgical techniques for the management of vocal fold motion impairment has enhanced the surgeon's ability to manage voice disorders secondary to neuromuscular disease, aging, and soft tissue deficits.

Bilateral laryngeal paralysis or ankylosis is an unusual condition, and the diagnosis of paralysis versus ankylosis should be established before definitive therapy is undertaken. It is always best to consider conservative types of treatment; in fact, tracheotomy may represent the best available approach. It is also wise to consider stepwise management, progressing from the least to the most invasive procedure, depending on clinical need.

Finally, the role of reinnervation procedures in the management of vocal fold motion impairment is an unresolved issue. Ultimately, the goal should be not only to develop and improve procedures for laryngeal rehabilitation, but also to understand why primary repair fails. This goal requires an understanding of the very basic developmental issues that result in selective innervation. How do developing motoneurons reach the appropriate target muscles? The answer to this question is the key to selective reinnervation and functional recovery after laryngeal paralysis.