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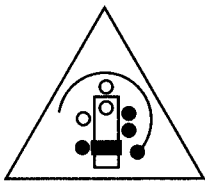
TREATMENT OF UNILATERAL TRUE VOCAL CORD PARALYSIS

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PREFACE

“Treatment of Unilateral True Vocal Cord Paralysis” is part of the AST Continuing Education Independent Study Series. The series has been specifically designed for surgical technologists to provide independent study opportunities that are relevant to the field and support the educational goals of the profession and the Association.

Acknowledgments

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INTRODUCTION

Purpose

The purpose of this module is to provide a review of laryngeal anatomy and physiology and to acquaint the learner with the diagnosis, etiology, and treatment of unilateral true vocal cord paralysis. Upon completing this module, the learner will receive 2 continuing education (CE credits) in category 8.

Objectives

Upon completing this module, the learner will be able to do the following:

1. Discuss the anatomy of the larynx including the nerves and muscles and their functions in speaking.
2. Discuss diagnostic techniques, etiology, and the goals of treatment of unilateral true vocal cord paralysis.
3. Describe current concepts of treatment of vocal cord paralysis, the historical developments of each treatment, and indications and contraindications of each treatment as well as their advantages and disadvantages.

Using the Module

1. Read the information provided, referring to the appropriate figures.
2. Complete the enclosed exam without referring back to the text. The questions are in a multiple-choice format. Select the best answer from the alternatives given.
3. Mail the completed exam to AST, CEIS Series, 7108-C S. Alton Way, Suite 100, Englewood, CO 80112-2106. Please keep a copy of your answers before mailing the exam. You must return the original copy of the answer sheet; this exam may not be copied and distributed to others.
4. Your exam will be graded, and you will be awarded continuing education credit upon achieving a minimum passing score of 70%. If you are an AST member, your credits will be automatically recorded and you do not need to submit the credits with your yearly CE report form.
5. You will be sent the correct answers to the exam. Compare your answers with the correct answers to evaluate your level of knowledge and determine what areas you need to review.

Studying Technical Material

To study technical material, find a quiet place where you can work uninterrupted. Sitting at a desk or work table will be most conducive to studying.

Having a medical dictionary available as you study is very helpful so you can look up any words with which you are unfamiliar. Make notes in the margins of any new definitions so that you can review them.

The ultimate test of how well you learn this material is your ability to relate your knowledge to what is happening in the surgical field. Apply your knowledge to what you observe during the surgical procedure.

TREATMENT OF UNILATERAL TRUE VOCAL CORD PARALYSIS

Surgical treatment of symptomatic unilateral true vocal cord paralysis dates back to 1911 when Brunings first described intracordal injection of paraffin. In 1915, Payr reported the first laryngeal framework procedure, where the cord was medialized through an anteriorly based rectangular thyroid cartilage flap. Neither of these techniques gained widespread acceptance, because paraffin led to a foreign body reaction, and Payr's technique did not produce significant voice improvement. It was not until the extensive work on intracordal injection by Arnold that Teflon injection became the standard procedure for unilateral vocal cord paralysis. Since then, many other procedures have been developed for the treatment of vocal cord paralysis. This module reviews the historical developments and current concepts in the treatment of unilateral vocal paralysis.

Anatomy

The larynx serves several functions. In addition to acting as a conduit for the passage of air, it acts as a valve preventing the passage of food into the trachea and controls the expulsion of air to produce sound.

The thyroid and cricoid cartilages act as the framework that lends structural support to the larynx. The paired true vocal folds are stretched between the thyroid laminae anteriorly and the vocal processes of the arytenoid cartilages posteriorly. The vocal ligament lies at the medial margin of the true cord, lending structural support to the cord. Lateral to the vocal ligament lies the thyroarytenoid muscle.

The intrinsic muscles of the larynx are essential in controlling the expiration of air in phonation (Figure 1). The cricothyroid muscles, innervated by the external branch of the superior laryngeal nerve,

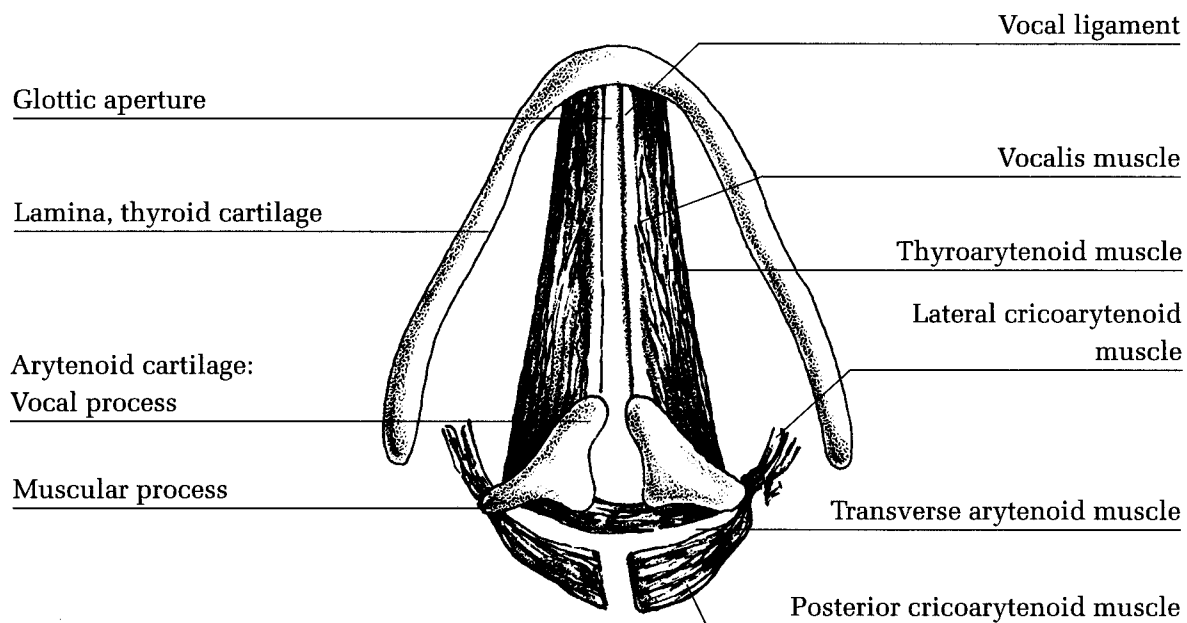


Figure 1.
Action of certain laryngeal muscles.

are located on the external surface of the larynx. They arise from the anterior and lateral aspects of the arch of the cricoid cartilage, radiating upward to insert on the inferomedial surface of the thyroid cartilage. Contraction increases anteroposterior tension on the vocal cords. All the remaining muscles are innervated by the recurrent laryngeal nerve.

The posterior cricoarytenoid muscles arise from the posterior arch of the cricoid cartilage and insert on the muscular process of the arytenoid cartilage, resulting in abduction of the vocal cords. The lateral cricoarytenoid muscles pass between the lateral portion of the arch of the cricoid cartilage and the muscular process of the arytenoid cartilage, causing adduction of the vocal cords. The thyroarytenoid muscles border the vocal ligaments within the true vocal cords, act to lessen tension in the vocal ligament, and assist in adduction. The cricothyroid and thyroarytenoid muscles precisely adjust vocal fold tension and pitch. The interarytenoid muscle traverses the arytenoid cartilages and assists in adduction. Together the action of these muscles fine tune speech as we recognize it and protect the airway against aspiration of foreign material.

Previously it was thought that innervation of the laryngeal musculature was quite precise, and that the cord position could be predicted based on the cause of the paralysis. Several studies have shown this not to be reliable. There appears to be no predictable relationship between cord position and site of nerve injury.

Diagnosis

All new patients with dysphonia should undergo a full history and head and neck examination. Flexible fiberoptic laryngoscopy should be performed to evaluate for the cause of dysphonia. When true cord paralysis or irregularities (other than cancer) are identified, further evaluation may be performed. These studies are often performed in conjunction with a speech pathologist. Video documentation of the laryngeal anatomy is standard. Videostroboscopy examines mucosal waveforms of the true cords and the extent of glottic incompetence caused by paralysis. Many other types of voice analysis are available today, but are mostly used from a research standpoint. In cases where the origin of the paralysis is unknown, computerized axial tomography (CT) scanning of the head and entire course of the vagus/recurrent laryngeal nerve is performed to examine for a lesion causing the paralysis.

Laryngeal electromyogram (EMG) can be used when there is a question that motor function may return by testing both the cricothyroid (superior laryngeal nerve, SLN) and thyroarytenoid (recurrent laryngeal nerve, RLN) muscles. Fibrillation potentials indicate a loss of neural innervation that can be present for 1 to 3 weeks following injury. Loss of nerve function results in a decrease in frequency of firing, but normal amplitude is present as long as some fibers remain. Polyphasic reinnervation potentials indicate loss of neural function with reinnervation starting, but can not predict the timing of recovery.

Etiology

There are many varied causes for true vocal paralysis, and reported series vary widely as to their percentage distribution. Surgical trauma, neoplasms, and idiopathic causes are the most common. Trauma, congenital disease, neurologic disease, and infection are less common. In children, neurologic conditions, idiopathic conditions, and birth trauma appear to be more prevalent.

Goals of Treatment

Two parameters are essential to normal vocal cord vibration and voice production: glottal gap and normal symmetric vocal cord stiffness. Functional characteristics of normal phonatory posture include posterior commissure closure, symmetric thyroarytenoid stiffness, and equal vertical cord position.

Current Therapeutic Techniques

There are currently three basic techniques for treatment of unilateral true vocal cord paralysis. Injection of the true vocal cord with a wide variety of alloplastic or autogenous substances that cause medialization was the mainstay of therapy for 30 years. Surgical medialization, either through variations of phonosurgery or arytenoid adduction, is currently the most popular procedure. Reinnervation of the recurrent laryngeal nerve and innervated muscular transfer procedures have been proposed by several authors. A combined procedure of surgical medialization and reinnervation has also been used. All of these procedures are in use today by various surgeons and have their own strong supporters.

True Vocal Cord Injection

In 1911, Brunings was the first to develop a technique for vocal cord injection using paraffin through a special syringe. Although early voice results were excellent, long-term studies revealed that the paraffin was absorbed and also resulted in a foreign-body reaction. Not until Arnold,¹ performed pioneering animal studies 50 years later was a substance suitable for injection identified. During a 10-year period, Arnold tested several substances, including cartilage paste, bone paste, and tantalum powder in glycerin. In 1962, he presented the use of Teflon paste in glycerin, injected through a Bruning syringe, as an effective and well-tolerated implant. The use of injectable Teflon soon became standard practice for the treatment of true vocal cord paralysis.

Teflon still remains the first choice in treatment of true vocal cord paralysis by many surgeons. Other substances utilized for injection include collagen, autogenous fat, and a Gelfoam/glycerin paste.

The procedure of cord injection can be performed under local or general anesthesia. Local anesthesia allows the surgeon to visualize directly the cords during phonation and theoretically enables the surgeon to inject an appropriate volume of Teflon. Limitations include patient tolerance and the need for excellent topical anesthesia. Although general anesthesia provides for good patient cooperation, it does not allow phonation, and the endotracheal tube is in the way of the injection. For these reasons, local anesthesia is favored. In the transoral technique, the laryngoscope and microscope are used to visualize the cords. To avoid complications, it is essential that the injection is performed laterally to the thyroarytenoid muscle. The first injection is placed at the midportion of the cord, with further injections placed posteriorly, laterally to the arytenoid and medially to the arytenoid if needed. If an anterior gap is still present this may be carefully injected. Overinjection is a major error in technique, which will prevent cord closure. A percutaneous injection technique is proposed by some authors, with insertion of the needle through the cricothyroid membrane to the undersurface of the true cord, under indirect visual control with the flexible scope.

Several authors have reported excellent voice results and tolerance of Teflon injection. Maran et al² presented 102 cases in 1986: 87% of patients achieved a good or fair result, and 12 patients received more than one injection. No airway complications were reported. Best results were obtained in patients with division of the RLN. Rontal and Rontal³ reported on 250 patients, with only four requiring reinjection for a poor voice, and three having granuloma formation. Dedo⁴ utilizes indirect laryngoscopy with the

patient in a sitting position to perform injection, with all 400 patients having a good response. Dedo also states that Teflon can be readily removed with through incision and wedge resection of excess material in the cord. He considers Teflon injection the procedure of choice because it is the easiest to perform, has the lowest cost, and has no significant side effects.

Other authors report poorer results. Nakamaya et al⁵ found that just over half of patients had a good result. Montgomery et al⁶ initially observed 80% with voice improvement, but found only 60% improved after long-term follow-up. Several reports of complications exist, with Teflon granulomas and migration of Teflon the most difficult to manage. Removal is usually quite difficult.⁷ Voice improvement can be obtained in most patients after removal, though rarely returning to preoperative levels. Those with the worst results should have never been injected, often having fully mobile cords. The carbon dioxide laser has been used safely to remove Teflon from the vocal cord. Ignition of Teflon has been observed only in an oxygen-rich environment with high laser power. If these conditions are avoided, the laser may be used to safely remove Teflon. Teflon in situ for less than 1 month remains highly flammable and should not be treated with the laser.⁸

Collagen injection for paralysis has been studied by Ford and Bless and Remacle et al. Ford and Bless⁹ initially utilized Zyderm collagen in 26 patients who had unilateral cord paralysis, with all patients receiving some voice improvement. This remained stable after an average 8-month follow-up. Hypersensitivity to collagen was a concern and was observed in one patient. All patients must be tested with a subcutaneous injection and followed for 1 month for a possible reaction. GAX collagen is more resistant to collagenase, induces hypersensitivity in less than 1% of patients, and is now used for study. Remacle et al¹⁰ found that in 39 patients, all had a favorable voice result for at least 3 years with GAX injection under general anesthesia. In 1993, Ford and Bless¹¹ reported on 11 patients with unilateral cord paralysis who were not suitable for other treatments but were given GAX collagen injection. All experienced some improvement after an average 12-month follow-up, and there were no reactions. Currently in the United States, collagen is not approved for true vocal cord injection, though Ford and Bless continue to support and study its use.

Fat injection of the true vocal cord was first reported by Brandenburg et al¹²; 11 patients had good voice results. One patient required reinjection 2 years later for deterioration of voice. No complications were noted when fat was injected directly into the thyroarytenoid muscle. Fat is beneficial because it is readily available from the patient, produces no foreign-body reactions, and produces lasting results.

Gelfoam paste can be used for temporary cord medialization with good voice results, lasting 8 to 10 weeks.¹³ No significant tissue reaction has been identified, and reinjection can be carried out without difficulty. Gelfoam injection is most useful for temporary use when return of function is expected or when given as a test injection. Glycerin alone is also useful as a short-term test injection, although it lasts less than 3 days.

All authors now agree that Teflon should not be injected into a mobile vocal cord. Another consensus is that patients with RLN lesions have the best outcomes overall. Teflon injection is an effective procedure for restoration of voice, though it is not easily reversible, and complications such as Teflon granuloma can be difficult to manage. Further study of fat and collagen injection are needed to determine the long-term results of these procedures.

Surgical Medialization

In 1915, Payr reported the first medialization procedure with an anteriorly based thyroid cartilage flap, though voice results were not good because of inefficient medialization. This concept sat idle until

1952, when Meurman¹⁴ used a vertical parasagittal thyroid cartilage incision to place a rib cartilage graft lateral to the perichondrium. Difficulty was encountered, however, in dissecting the perichondrium anteriorly where it is very thin, and several airway problems occurred. Opheim¹⁴ placed thyroid cartilage medial to the inner perichondrium, which resulted in airway obstruction in his only patient. In 1968, Sawashima et al¹⁴ combined the techniques of Meurman and Opheim. After the patient was given local anesthesia, cartilage was harvested from the superior thyroid ala and placed in a subperichondral pocket through a vertical anterior incision. Kamer and Som¹⁴ placed cartilage from the superior thyroid ala through an inferiorly based subperichondral pocket.

In 1974, Isshiki et al¹⁵ reported on several types of thyroplasty performed on dogs. Type 1, or lateral compression, consisted of making a cartilage window in the thyroid ala. Cartilage was harvested from the superior thyroid ala and placed as a stent inside the window in a subperichondral pocket to force cord medialization (Figure 2). In 1980, the procedure was performed under local anesthesia and was revised to use a Silastic stent in place of the cartilage for medialization.

The Isshiki type 1 thyroplasty has gained popularity throughout the 1980s and for most surgeons has become the procedure of choice for treatment of vocal cord paralysis. Reports by most authors reveal good results with 80% to 95% achieving improved voice. With reoperation and placement of an appropriate size implant, higher rates of voice improvement can be attained.

Complications are noted to be uncommon, but include airway compromise and implant extrusion. Tucker et al¹⁶ reported a series of 60 patients with four extrusions and six cases of airway compromise requiring temporary tracheotomy. Two of the four cases of extrusion maintained a good voice result. Maves et al¹⁷ had no extrusions in a series of 25 patients, in which two cases had cord edema/hematoma, but no tracheotomies. Koufman and Isaacson¹⁴ had 45 patients, with two extrusions. One of these patients had airway obstruction.

Netterville et al¹⁸ recently reported on 100 patients undergoing thyroplasty: 32 of these patients underwent primary medialization under general anesthesia at the time of surgical resection with vagus sacrifice. Fourteen patients also underwent arytenoid adduction; 16 of the 100 required revision with a larger implant or arytenoid adduction. The authors recommend carving several implants beforehand that can be rapidly modified. Also, the inner perichondrium should be incised with a small knife at the superior, posterior, and inferior margins of the window to allow for adequate medialization. Arytenoid adduction was performed if adequate posterior closure of the glottis could not be achieved. No cases of

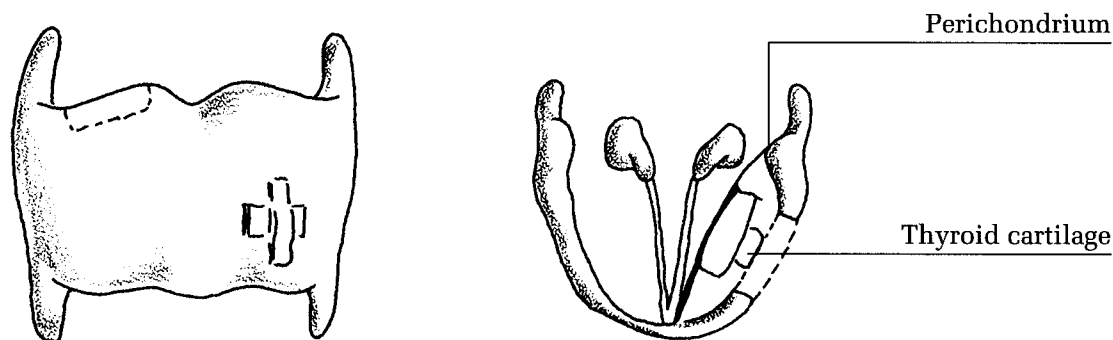


Figure 2.
Isshiki thyroplasty.

implant extrusion were seen, and one radiated patient developed laryngocutaneous fistula. The majority of patients achieved voice improvement, with 5% to 10% having a persistent weak, breathy voice. The authors recommend thyroplasty at the primary surgical resection to provide early glottal competence and to allow faster rehabilitation.

Montgomery et al⁶ recently described a more precise version of thyroplasty utilizing a standardized window size and prefabricated implants. The implant is constructed of two parts that consist of a locking outer portion and a medical grade polymer inner portion that provides medialization of the cord. A large posterior tip is designed to medialize the posterior cord, through contact with the vocal process of the arytenoid. Four prefabricated sizes are available for men and women. Incision of the inner perichondrium is performed horizontally within the window. All wounds are drained, patients are observed overnight, and antibiotics and steroids are routinely administered postoperatively. Fifty-four patients were treated with two revisions for a larger implant; 53 patients had subjective voice improvement. Two patients had laryngeal edema, though no airway obstruction or implant extrusion was observed.

Cummings et al¹⁹ described the use of a prefabricated hydroxylapatite implant in five sizes, similar to that of Montgomery. Subjective voice improvement was reported in 31 of 35 patients. Complications include one implant extrusion and one airway compromise managed conservatively without tracheotomy. The authors suggest that the established biocompatibility of hydroxylapatite makes it a superior material compared to Silastic. Reversibility was not addressed.

A recent article by Desrosiers et al²⁰ reported on an adjustable implant using miniplates and adjustable screws to medialize the vocal through a standard thyroplasty window. The authors believe that this will allow more precise medialization and fine adjustments, however, this procedure has only been studied in a cadaver model.

A novel canine experiment was carried out by Kuriloff et al²¹ using a tissue expander placed through a thyroplasty window with a subcutaneous injection port. Initial medialization was good. However, after several weeks a fibrous capsule developed that decreased the amount of lateralization that could be obtained. Valve leakage also occurred because of increased filling pressures required for medialization. The long-term effects of such a device are unknown, and its use remains very experimental.

Arytenoid adduction was described initially by Morrison in 1948 as the "reverse King operation," which fixed the arytenoid medially on the cricoid cartilage. In 1966, Montgomery performed "cricoarytenoid arthrodesis" by fixation with a stainless steel pin. In 1978, Isshiki et al²² described the technique of arytenoid adduction for treatment of an excessively widened posterior glottic chink or a difference in level of the vocal cords that is in use today.

Arytenoid adduction is performed on a patient under local anesthesia, and a horizontal incision is made similar to thyroplasty. The posterior border of the thyroid cartilage is identified, and the inner surface is elevated subperichondrally. The cricothyroid joint is disarticulated. Mucosa overlying the pyriform sinus is rotated superiorly so as to avoid entering the pharynx. The muscular process of the arytenoid is palpated, located obliquely superior and posterior from the cricothyroid joint. Posterior cricoarytenoid muscle is then incised, and the cricoarytenoid joint is opened. Two 3-0 nylon sutures are tied around the muscle process of the arytenoid and then brought anteriorly through the thyroid ala. Tension on the sutures is optimally determined while the patient phonates, and the sutures are then tied anteriorly. Several authors report the use of this procedure separately or in conjunction with thyroplasty to close the posterior commissure with good results. Netterville¹⁸ recommends that the need for arytenoid adduction be determined intraoperatively only after posterior closure can not be obtained with routine type 1 thyroplasty.

Reinnervation Procedures

Ideally, reinnervation of the laryngeal musculature would provide the optimal and most dynamic voice restoration. Several authors have attempted reinnervation through different approaches, including ansa cervicalis-to-RLN anastomosis, omohyoid nerve-muscle pedicle transfer to the lateral cricoarytenoid muscle, and cricothyroid muscle pedicle transfer to the lateral cricoarytenoid muscle. These procedures are ideal for isolated, known damage to the RLN, though the first two may also be used for a complete vagus injury.

Crumley initially presented his technique for ansa cervicalis-to-RLN anastomosis in 1986²³ and reported a series of 20 cases in 1991.²⁴ The procedure is performed by first isolating the ansa cervicalis inferiorly in the neck. The RLN is then identified in the tracheoesophageal groove (for vagal or intrathoracic RLN injury) or as it enters the larynx just above the cricoid (for RLN injury in the neck), because the reanastomosis must be made distal to the site of injury. With both nerves isolated, the RLN is transected and swung laterally, and the ansa's branch to the sternothyroid is transected and swung medially. Microsurgical nerve anastomosis is then performed with 10-0 nylon. Voice improvement generally takes 4 to 12 weeks to be observed. Gelfoam injection may be performed to give voice improvement while waiting. Of 12 patients with at least 6-month followup, 11 had excellent voice results. Reinnervation does not produce movement of the vocal cord. Instead, an increase in the resting tone of the laryngeal muscles is observed, producing normal compliance and tension of the vocal cord. The author believes that this is the most physiologic repair available and produces the best voice.

In 1981, Tucker and Rusnov²⁵ reported a different method to achieve reinnervation using a nerve muscle pedicle in 31 patients. Through a neck incision, the anterior belly of the omohyoid is identified, and a small flap of muscle pedicled on the ansa is made. A thyroid cartilage window is made, and the nerve-muscle flap is then transposed onto the fibers of the lateral cricoarytenoid muscle and secured with sutures. Again, voice improvement takes from 4 to 18 weeks. Twenty-six patients had a greatly improved or normal voice, one had minimal improvement, and four had none. May and Beery²⁶ reviewed 20 patients treated with the muscle-nerve pedicle, with 19 obtaining voice improvement. Again, improvement is due to increased vocal cord tone and mass, and not active cord movement. Theoretically, the procedure is also reversible because it leaves the RLN intact.

Most recently, Nonomura et al²⁷ described seven patients undergoing anastomosis of fibers from the cricothyroid muscle to the lateral cricoarytenoid muscle, with surgical access gained by splitting the cricoid anteriorly. This requires that the SLN be intact. All patients had improved voice immediately postoperative, and vocal cord tension continued to improve for several months. Four patients obtained remobilization of the cord. Results were best for patients with minimal cord atrophy. Other authors with more patients will need to confirm these findings.

Combined Procedures

In 1990, Tucker²⁸ reported 29 patients treated with combined type 1 thyroplasty and muscle-nerve pedicle reinnervation. The surgical exposure for both procedures is almost identical. Thyroplasty gives the advantage of immediate results, whereas reinnervation adds vocal cord tension and some ability to control pitch, and theoretically should provide the closest return to normal function possible. All patients had immediate voice improvement, and 19 of 29 had further improvements in quality and pitch control 2 to 6 months later.

Netterville et al suggest combining type 1 thyroplasty with ansa-RLN reinnervation. They suggest that if the nerve is known to be sectioned, or no EMG reinnervation potentials are seen at 1 to 2 years after

injury, the reinnervation procedure should be performed at the time of thyroplasty. However, no data is presented on patients in which this was performed, stating that there is inadequate follow up.

Conclusion

It is very difficult to compare the results among these procedures as reported in the literature for several reasons. Evaluation of patients' voice results is always very subjective, and it is also dependent on their preoperative status, cause of paralysis, and overall state of health. Adequate controls can not be established among the different procedures to compare results, and we must rely on each proponent's subjective evaluation and statements concerning the efficacy of their procedure.

In general, all three procedures produce similar functional results with good voice improvement and few complications. All procedures also have advantages and disadvantages, which are discussed in the following section.

Teflon injection is rapidly performed, inexpensive, and well tolerated. It tends to be permanent, however, with most authors reporting difficulty in treating poorly placed Teflon injections and Teflon granulomas, both of which can result in very poor voice results. Also, a learning curve is associated with Teflon injection and there is no room for error. Teflon should never be used on a patient with a mobile cord or potential for recovery. Further studies of fat and collagen injection are needed before any conclusions can be drawn concerning these modalities.

Type 1 thyroplasty does require a surgical incision, is longer to perform, and is more expensive. However, the procedure is easily reversible and repeatable. The outcome is more predictable than with Teflon, and it is easy to train other physicians to perform. Several people are working on modifications of Isshiki's original procedure, which may improve the ease and predictability of the surgery. There is a well-defined role for arytenoid adduction, primarily in treating a widened posterior glottic chink that can not be closed using other methods.

Reinnervation procedures initially hoped to bring normal movement back to the larynx. However, it appears that only increased cord tone and maintenance of muscle mass is achieved. Most series remain small, though patients who respond achieve significant voice improvement. Disadvantages are increased operative time and expense, and in the case of ansa-RLN transfer, the need to be assured that RLN function will not return.

Most promising is the combination of thyroplasty with muscle-nerve pedicle reinnervation. This provides immediate voice improvement through medialization, and if the reinnervation is successful, allows greater control of vocal cord tension and pitch. This reinnervation leaves the RLN intact and is reversible if RLN function were to return.

No particular procedure has proven benefits over another in the literature. A surgeon must select the procedures that achieve the best results and are most comfortable with, and the surgeon must follow the literature. This will remain an area of debate for years to come as each procedure maintains its own group of vocal supporters.

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