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A Comparison of Type I Thyroplasty and Arytenoid Adduction

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Summary: Glottal incompetence is a common laryngeal disorder causing impaired swallowing and phonation. The resultant voice has been characterized as weak and breathy with a restricted pitch range. Currently, medialization thyroplasty and arytenoid adduction are two of the surgical treatments for patients with glottal incompetence. However, few studies have evaluated the changes in objective measures of speech with type I thyroplasty and arytenoid adduction. In this study, 59 patients with glottal incompetence underwent either type I thyroplasty or arytenoid adduction. Acoustic (jitter, shimmer, and harmonics-to-noise ratio) and aerodynamic (airflow, subglottic pressure, and glottal resistance) measures were obtained both pre- and postoperatively. No significant differences were found among acoustic or aerodynamic measures for operation type. However, a significant pre/postsurgery effect was observed for translaryngeal airflow. In addition, no significant differences were found among the measures for patients with traditional compared with nontraditional operative indications. Patients who developed glottal insufficiency due to previous laryngeal surgery (e.g., vocal fold stripping) demonstrated no statistically significant improvement in acoustic or aerodynamic measures following thyroplasty or arytenoid adduction. **Key Words:** Voice—Thyroplasty—Arytenoid adduction—Laryngoplasty—Dysphonia—Phonation.

Glottal insufficiency is a common laryngeal disorder affecting the ability of the larynx to serve as a vibrator during phonation and as a sphincter during swallowing. This disorder affects both young and old, male and female, chronically ill and otherwise healthy patients (1). Etiologies include recurrent laryngeal nerve (RLN) paralysis secondary to neoplasms or injury, primary vagal nerve paralysis, and primary diseases of the vocal folds. The voice of a patient with glottal insufficiency is characterized as breathy and harsh, often with restricted pitch range, reduced loudness, and shortened phrasing in connected speech. The resultant difficulties in communication greatly impair self-image, social interaction, and job performance (2,3). Some patients regain function spontaneously while other patients develop compensatory laryngeal postures. However, those who continue to manifest glottal incompetence not only experience dysphonia, but are also at risk for life-threatening aspiration.

The ideal surgical procedure for correction of glottal incompetence would improve both sphincteric function and sound production while preserving the glottal airway. Existing therapies medialize the vocal fold by altering the laryngeal framework or augment the vocal fold with Teflon, gelfoam, or fat. Due to the difficulties with Teflon injection (4–7), medialization laryngoplasty has gained favor for treatment of glottal insufficiency (8–11). Isshiki et al. (10,12) described four thyroplasty operations. Type I thyroplasty provides lateral compression to the paralyzed cord; type II thyroplasty creates a

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lateral expansion of the glottis; type III thyroplasty shortens and relaxes the vocal folds; and type IV thyroplasty lengthens and stretches the vocal folds. Isshiki (12) recommended using type I thyroplasty for a unilateral RLN paralysis and a combination of type I and type IV thyroplasties for combined unilateral superior and recurrent laryngeal nerve paralyses. In that study, the voices were evaluated subjectively as "improved" or "rough," and the mechanical function of the larynx was studied with laryngoscopy alone. Other authors have reported "good" results using type I thyroplasty to treat unilateral vocal fold paralysis in humans (13–15). In contrast to these early findings, persistent communication difficulties forced many patients to change their employment despite reported subjective improvement (16).

Adduction of the arytenoid cartilage was devised by Isshiki et al. (17) as a new treatment for glottal incompetence. In this procedure, a suture is placed from the muscular process of the arytenoid to the anterior thyroid cartilage and tied with enough tension to adduct the arytenoid to the midline. Postoperatively, all five patients in that study had improved voices as demonstrated on spectrograms. Complications of arytenoid adduction include laryngospasm, overmedialization of the vocal fold, and laryngeal edema with resultant airway obstruction requiring emergent reintubation or tracheostomy. Because of significant laryngeal manipulation and the risk of airway obstruction, arytenoid adduction is best suited for young patients with vocal fold paralysis who exhibit poor closure and wide glottal gaps.

No consensus exists regarding the optimal surgical treatment for glottal insufficiency; however, all methods have been reported to improve the voice. Most authors report a subjective assessment of vocal function (13,14,18) without using objective measures to assess treatment outcome. In this study, we will report several objective measures of voice and aerodynamics [jitter, shimmer, harmonics-to-noise ratio (HNR), airflow, subglottic pressure, and glottal resistance] for a population of patients who underwent either type I thyroplasty or arytenoid adduction as a treatment for glottal incompetence.

METHODS

Subjects

Fifty-nine patients (39 men and 20 women), ages 16–87 years (mean age 55 years), with a vocal fold paralysis were enrolled in this study. Nine patients had received a previous endoscopic vocal fold surgery as the etiology of glottal insufficiency (e.g., vocal fold stripping, removal of benign vocal fold lesions, and laser laryngoscopy). Forty-nine patients underwent type I thyroplasty, while 10 patients were treated with an arytenoid adduction. The surgical procedure for each patient was assigned by anatomic and clinical criteria. Young patients with posterior glottal gaps underwent arytenoid adduction, while patients with midglottal gaps or older patients underwent type I thyroplasty. The indications for treatment of glottal insufficiency in 42 patients were classified as "traditional," including iatrogenic RLN paralysis, idiopathic RLN paralysis, vagal paralysis secondary to skull base tumors, and traumatic RLN paralysis. Seventeen of the patients in this study underwent laryngeal framework surgery for "nontraditional" operative indications, including presbylarynx, sulcus vocalis, glottal gap with unilateral slowing of a traveling wave without apparent vocal fold paralysis, and previous vocal fold surgery (i.e., vocal fold stripping, laser surgery of vocal fold masses, and vertical hemilaryngectomy with imbrication reconstruction). All patients with presbylarynx and sulcus vocalis underwent bilateral type I thyroplasties. The patients were evaluated both pre- and postoperatively. The average postoperative evaluation occurred 6 months after the surgery.

Thyroplasty

Type I thyroplasty has been well described by Isshiki et al. (10,19). We utilized a three-sided anteriorly based cartilage window, instead of the four-sided window described by Isshiki. The window is based anteriorly at the midline of the thyroid cartilage. The superior horizontal cartilage cut is made parallel to the anterior inferior rim of the thyroid cartilage, half the distance from the midline thyroid notch to the inferior thyroid cartilage margin (Fig. 1). The inferior horizontal thyroid cartilage incision is made parallel to the superior cartilage incision, as low as possible without jeopardizing the integrity of the inferior thyroid cartilage rim. The posterior vertical cartilage incision is placed at the midpoint of the inferior thyroid cartilage tubercle. The thyroid cartilage window is then medialized with a freer elevator. In this technique, the cartilage window is not removed and remains hinged to the midline of the thyroid cartilage. In calcified cartilage, the an-

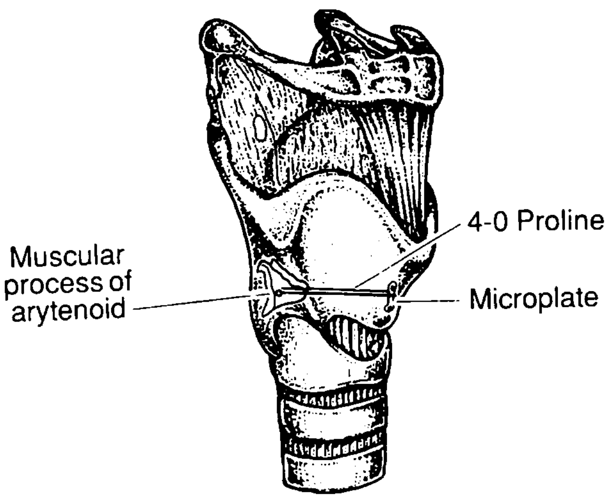

FIG. 1. Anatomic guidelines for creation of a three-sided anteriorly based thyroplasty window.

terior margin of the thyroplasty window must be scored prior to medialization. Since the anterior aspect of the thyroid cartilage is considerably thinner than the lateral portion of the thyroid cartilage ala, care must be taken to avoid tearing the anterior hinge of the thyroplasty window when medializing the cartilage with the freer elevator. In addition, the inner perichondrium of the posterior thyroid ala is elevated to create a pocket for the Silastic implant.

A Silastic implant is carved to fit this window. A three-sided triangular wedge is carved such that the posterior angle is ~30°, the anterior medial angle is 90°, and the anterior lateral angle is ~60° (Fig. 2). The width of the Silastic wedge is cut to fit within the vertical dimension of the cartilage window. An inferiorly based flange is created on the Silastic wedge to assist in retention of the Silastic implant.

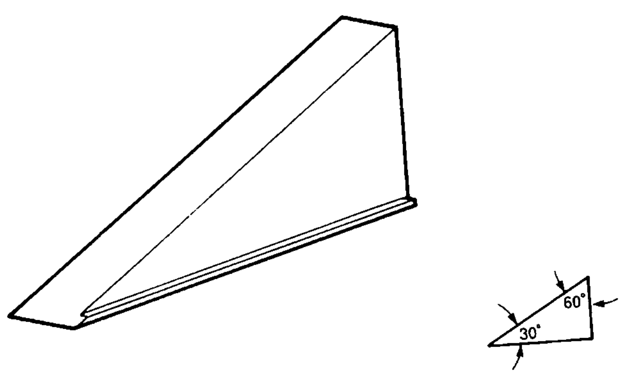

FIG. 2. View of the inferior surface of the triangle-shaped Silastic implant. The inset demonstrates the posterior angle (~30°) and lateral angle (~60°).

The wedge is inserted into the cartilage window deep to the posterior thyroid cartilage and superficial to the inner perichondrium of the thyroid ala such that the 30° angle medializes the vocal process of the arytenoid (Fig. 3). Placement of the Silastic wedge between the inner perichondrium and thyroid cartilage prevents intralaryngeal migration of the prosthesis. Once the Silastic implant is inserted, the anterior portion of the cartilage window bends slightly upon itself such that the Silastic wedge is further secured within the thyroplasty window. The excess Silastic lateral to the surface of the thyroid cartilage is then removed (Fig. 3). The inferior flange of the Silastic wedge is placed medial to the inferior thyroid cartilage rim to prevent extrusion of the implant. The Silastic wedge is further secured with one or two 4-0 Prolene sutures placed through the Silastic wedge and the thyroid cartilage outer perichondrium.

Arytenoid adduction

Arytenoid adduction was described by Isshiki et al. in 1978 (17). In performing an arytenoid adduction, the posterior margin of the thyroid cartilage is first exposed. The mucosa of the pyriform sinus is elevated from the inner surface of the thyroid cartilage and is reflected medially until the muscular process of the arytenoid cartilage is identified. However, unlike Isshiki et al. (17), we do not find disarticulation of the cricothyroid joint necessary to gain adequate exposure to the muscular process of the arytenoid cartilage. A 4-O Prolene suture is placed through the muscular process of the aryte-

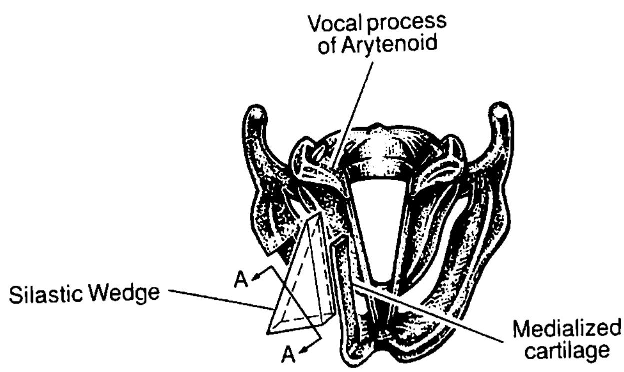

FIG. 3. Placement of the Silastic wedge into the anteriorly based thyroplasty window. Note the slight buckling of the anterior aspect of the thyroplasty window and the medialization of the vocal process of the arytenoid by the posterior portion of the Silastic wedge. The region indicated by A is removed at the conclusion of the procedure.

noid and then passed through a 16-gauge angiocath placed through a hole in the anteroinferior aspect of the ipsilateral thyroid cartilage and passed immediately medial to the thyroid ala (Fig. 4). The suture is then tied over a two-hole microplate used as a bolster. The suture is not tied over the muscular process so that the procedure may be easily reversed if overmedialization occurs. The hole in the thyroid cartilage is placed using these guidelines: (a) vertical distance—three-fourths of the distance from the thyroid notch to the inferior border of thyroid cartilage; and (b) horizontal distance—one-third of the distance from the midline of the thyroid cartilage to the insertion of the inferior constrictor muscle (Fig. 5). Fiberoptic or direct laryngoscopy is used to verify correct suture placement and tension before securing the suture.

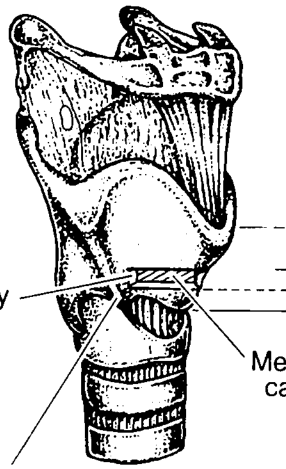

FIG. 5. Lateral view of an arytenoid adduction, demonstrating the guidelines for placement of the hole in the thyroid cartilage.

Phonatory evaluation

After a subject was identified as a candidate for inclusion in this study, an initial evaluation was performed. Each subject sustained the vowel /a/ as long, steadily, and clearly as possible at conversational levels of loudness and pitch. The acoustic signal was monitored by a cantilever-mounted microphone (Sony model ECM77B) located 5 cm from the lips, at ~45° azimuth. A 2-s sample near the middle of the vowel production was amplified, low-pass filtered at 8 kHz, and digitized at 20 kHz at 12-bit quantatization.

Oral airflow was monitored with a pneumotachographic mask connected to a differential pressure transducer (Glottal Enterprise) and placed over the patient's face. Intraoral air pressure was sensed by a small diameter catheter placed through a port in the mask and positioned behind the lips. The patient repeated the syllable /pi/ at a rate of ~1.5 syllables/s. A 10-s sample of phonation was amplified, low-pass filtered at 3 kHz, and digitized at 8 kHz.

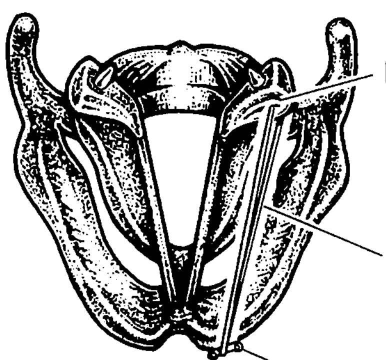

FIG. 4. Axial view of an arytenoid adduction. Note the direction of pull of the suture placed between the muscular process of the arytenoid and the ipsilateral anterior thyroid cartilage.

Percent jitter, mean shimmer, and HNR were measured using an interactive acoustic analysis system. Perturbation was calculated using parabolic interpolation for peak-marked data and linear interpolation when a zero-crossing was marked (20). Aerodynamic properties were measured using techniques described by Smitheran and Hixon (21). System calibration for pressure was performed against a U-tube water manometer arranged in parallel with the intraoral catheter. In addition, system calibration for flow was performed with a vane air pump whose output was directed through an air rotameter arranged in series with the pneumotachometer. Peak intraoral pressure obtained during lip closure for /pi/ served as an estimate of subglottal pressure. Vocal tract airflow was measured at the middle of the vowel during the /pi/ utterance. Vocal tract resistance was calculated as the ratio of mean subglottal pressure to mean oral airflow. Given that most resistance during phonation occurs at the larynx, this measure reflects resistance at the level of the vocal folds.

Statistical analysis

An initial series of analyses of variance (ANOVAs; surgery type by pre/postsurgical measurement, with repeated measures on pre/postsurgical condition) was used to examine differences in initial values of the acoustic and aerodynamic measures between the arytenoid adduction and type I thyroplasty groups and to examine the effects of the two surgeries on the dependent variables. Separate analyses were conducted for each dependent measure, with p values adjusted for multiple comparisons. In these analyses, a main effect of surgical type would indicate statistically significant differences of the dependent variables between the surgical groups. A main effect of pre/postsurgical condition would reflect changes in vocal function with treatment. A significant interaction between surgery and the pre/postfactor means that one surgery improved vocal function (as measured by that dependent variable) more than the other.

A second group of repeated measures ANOVAs compared patients who had undergone treatment prior to surgery with those who had no previous treatment for glottal insufficiency. Separate tests were once again undertaken for each dependent measure, with probabilities adjusted for multiple comparisons. As described, a significant main effect of group (previous treatment versus no previous treatment) would reflect a priori differences in levels of the dependent variables for the two groups, a main effect of pre/postsurgical condition would reflect improvement with the current treatment, and an interaction effect would reflect improvement by one group, but not the other. A final group of analyses compared pre/postsurgical measures for patients with traditional indications for type I thyroplasty or arytenoid adduction (e.g., iatrogenic unilateral RLN paralysis) with those with nontraditional indications (e.g., vocal fold stripping) for laryngeal framework surgery.

RESULTS

As determined by the initial series of ANOVAs (surgery type by pre/postsurgical measurement, with repeated measures of pre/postsurgical condition), a significant pre/postsurgical effect was observed for flow: Flow rates declined significantly with treatment for both surgical groups [Table 1; $F(1,29) = 9.24$, $p < 0.013$]. No statistically significant pre/postsurgical effects were seen for subglottic pressure, glottal resistance, jitter, shimmer, or HNR. In addition, no main effects of operation type were observed for any dependent variable. In addition, no significant interaction effects were observed for any dependent variable. Therefore, the type I thyroplasty and arytenoid adduction groups were combined for all subsequent analyses.

TABLE 1. *Values of airflow (L/s) for surgical groups*

	Presurgical		Postsurgical	
Surgical group	Mean	SD	Mean	SD
AA	0.49	0.23	0.3	0.31
TP	0.47	0.39	0.26	0.2

AA, arytenoid adduction; TP, type I thyroplasty.

In the second group of repeated measures ANOVAs (comparing patients who had undergone treatment prior to surgery with those who had no previous treatment for glottal insufficiency), significant interactions between previous treatment status and pre/postsurgical condition were noted for jitter [$F(1,17) = 13.54$, $p < 0.013$] and shimmer [$F(1,19) = 11.12$, $p < 0.013$] (see Table 2). Patients with no previous treatment had statistically significant decreases in jitter and shimmer, while patients who had received previous treatment showed no statistically significant improvement in any acoustic or aerodynamic measure.

In the final series of ANOVAs (comparing pre/postsurgical measures for patients with traditional indications for surgical therapy with those with nontraditional indications), no significant effects of indication type or pre/postsurgical condition were observed for any of the dependent variables. In addition, no significant interactions occurred for any dependent measures.

DISCUSSION

This study was undertaken to examine differences between arytenoid adduction and medialization laryngoplasty in patients with vocal fold paralysis using objective measures of speech. In this study, a significant decrease in airflow was obtained in the postoperative condition for patients in both the thyroplasty and the arytenoid adduction groups. As described earlier, we perform a type I thyroplasty for most patients with glottal insufficiency and reserve arytenoid adduction for younger patients with wide glottal gaps, especially those with large posterior glottal gaps. We are somewhat reluctant to perform an arytenoid adduction on older patients due to our experience with a few patients who developed airway obstruction secondary to "overadduction" or edema. From these analyses, we conclude that either operation is equally effective at reducing the higher than normal airflows encountered in patients with glottal insufficiency. A

TABLE 2. *Mean values of jitter and shimmer for patients with and without previous treatment for glottal insufficiency*

	No previous treatment				Previous treatment			
	Preop		Postop		Preop		Postop	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Jitter (%)	1.251	1.17	0.742	0.485	0.972	0.663	0.989	1.031
Shimmer (mean)	0.65	0.345	0.413	0.176	0.478	0.188	0.546	0.372

research design using random assignment of patients to surgical treatments would provide greater confidence in guarding against threats to internal and external validity.

In evaluating changes in pre- versus postoperative subglottic pressure measures for either surgical group, no statistically significant changes were noted. This finding suggests that despite the degree of glottal insufficiency, patients adjust airflow to maintain near normal subglottic pressure. This supports the notion that the glottis is driven by a constant pulmonary pressure system (22).

In this study, no statistically significant effects were observed for any perturbation measure for either surgical group. These data reflect inherent difficulties in the measures of shimmer, jitter, and HNR. These measures were originally devised to analyze objectively the cycle-to-cycle variation in the acoustic waveform in normal speech. Subsequently, they have been applied to dysphonic voices without careful evaluation of their validity. We used an interactive, hand-marking analysis system to measure the acoustical signals in the patients in this study. In this analysis system, one must first reliably locate repeating events in the acoustical signal. If an acoustical signal is bicyclic ($F_0/2$ subharmonic series) or highly irregular, we classify the signal as too aperiodic for analysis. In our data, 15 preoperative and four postoperative patients had acoustical signals that were classified as too aperiodic to analyze. Therefore, a greater degree of improvement in perturbation measures may have occurred than is reflected by the repeated measures analyses of shimmer, jitter, and HNR. A single objective measure of perturbation that reliably measures both mild and severe dysphonia and accurately reflects the degree of perceived roughness would clarify the problem of interpretation of acoustical data.

In addition, this study evaluated the effectiveness of surgery for patients who had traditional indications versus those with nontraditional indications for laryngeal framework surgery. No statistically significant effects of traditional versus nontraditional indication on any of the objective measures of speech were obtained. Therefore, arytenoid adduction and thyroplasty were equally effective in patients with nontraditional indications as those patients with traditional indications for surgery. Based on these conclusions, we recommend expanding the indications for arytenoid adduction and type I thyroplasty to include patients with presbylarynx, sulcus vocalis, and unilateral slowing of the traveling wave of the vocal fold without apparent vocal fold paresis. Studies including larger groups of these patients are needed.

This study further evaluated the effectiveness of arytenoid adduction and type I thyroplasty in patients who had received previous vocal fold surgery (e.g., vocal fold stripping or laser laryngoscopy) as the etiology for glottal insufficiency. No improvements in shimmer or jitter measures were detected in patients who had undergone previous vocal fold surgery. However, the remainder of the patients demonstrated a statistically significant improvement in jitter and shimmer from the pre- to postoperative condition. This study identifies those patients who have undergone previous vocal fold surgery with removal of vocal fold tissue as the most difficult group of patients to treat using type I thyroplasty or arytenoid adduction. These patients suffer from glottal insufficiency due to a loss of the lamina propria, resulting in an abnormality of the mucosal wave of the vocal fold. The most effective means of restoring normal glottic function in these patients remains to be determined.

CONCLUSIONS

In this study, an analysis of acoustic and aerodynamic measures in the pre- and postoperative settings was used to evaluate the efficacy of arytenoid adduction and type I thyroplasty for the treatment of glottal insufficiency. Either operation was equally effective in reducing glottal airflow in the treatment of glottal insufficiency. In assessing operative indications for these procedures, the data support the use of type I thyroplasty and arytenoid adduction in patients with nontraditional operative indications, including presbylarynx and sulcus vocalis. However, patients with a previous laryngeal surgery showed no statistically significant improvement in objective measures of voice and aerodynamics.

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