The Laryngoscope
Lippincott Williams & Wilkins, Inc.

Medialization Laryngoplasty With Strap Muscle Transposition for Vocal Fold Atrophy with or without Sulcus Vocalis

Chih-Ying Su, MD; Shang-Shyue Tsai, PhD; Jeng-Fen Chiu, PhD; Chu-An Cheng

Objective: **Vocal fold atrophy with or without sulcus vocalis may result in a spindle-shaped glottal incompetence (SGI). Because of varying drawbacks with all existing materials (e.g., Silastic block, Teflon, fat, etc.) used for medialization or augmentation of the atrophic vocal folds, there is a need to supplant these materials with a more stable, autologous tissue to correct the SGI.** ***Study Design:*** **Thirty-two patients with vocal fold atrophy underwent medialization laryngoplasty with strap muscle transposition.** ***Methods:*** **Under local or general anesthesia, the thyroid lamina on the more affected side was vertically incised 5 mm off the midline. The inner perichondrium was carefully elevated from the overlying thyroid ala. Care was taken not to enter the laryngeal lumen. After dividing the thyrohyoid and cricothyroid membranes, the lamina was retracted laterally. To accommodate the muscle flap more easily, the caudal edge of the lamina was trimmed using a small burr. A bipedicled strap muscle flap was then transposed into the space between the lamina and the paraglottic soft tissue. The thyroid cartilages were carefully sutured back in place. All patients underwent pre- and postoperative voice evaluations including laryngostroboscopy, perceptual assessment, and acoustic and aerodynamic analyses. Patients who had been followed up for more than 3 months were enrolled in this study.** ***Results:*** **A total of 27 of the 32 patients with complete pre- and postoperative voice function measurements were included in the analysis. Vocal improvement was demonstrated in 26 of these 27 (96%) patients. No dyspnea or other major complications were noted in any patients.** ***Conclusion:*** **The results indicate that medialization laryngoplasty with strap muscle transposition is a prosthesis-free, safe, and effective technique for correcting SGI caused by vocal fold atrophy.** ***Key Words:*** **Vocal fold atrophy, sulcus vocalis, spindle-shaped glottal incompetence, medialization thyroplasty and laryngoplasty, strap muscle transposition.**

Laryngoscope, **114:1106–1112, 2004**

INTRODUCTION

Incompetent glottal closure during phonation is a common laryngeal finding in patients with dysphonia. It may be caused by benign or malignant laryngeal lesions, vocal fold paralysis, or vocal fold defect after laryngeal surgery. In addition, vocal fold atrophy with or without sulcus vocalis is another disorder that gives rise to a spindle-shaped glottal incompetence (SGI) during phonation.[1–4] The presenting symptoms of vocal fold atrophy with SGI include breathy, husky, and weak voice and difficulty or fatigability during phonation. Vocal fold atrophy has generally been regarded as being incurable.[2] Nevertheless, surgical treatment modalities for this disease, including various techniques of vocal fold injection and thyroplasty, have been attempted with varying degrees of success.[2,4–8] The most common substances used for injection techniques are alloplastics (Teflon) or biologic implants such as autogenous fat and collagen. The most widely used technique used for vocal fold medialization is type I thyroplasty with Silastic implant through a thyroid cartilage window. All of the above methods have their limitations and potential complications. Autogenous fat or collagen requires a surgical procedure to harvest the material, and autogenous collagen requires off-site processing of the patient's skin.[5,6] In addition, the drawback of these two materials includes an unpredictable degree of resorption over time.[4–6] As for the Teflon injection, the complications include misplacement of the injection, granuloma formation, and permanent vocal fold stiffening.[7–10] Long-term phonatory results reveal that local migration of Teflon particles into the superficial layers of the vocal fold may result in loss of mucosal wave and poor voice quality.

Presented in part at the 24th Politzer Society Meeting, Amsterdam, The Netherlands, August 31 to September 4, 2003.

From the Departments of Otolaryngology (C.-Y.S.) and Speech Center (C.-A.C.), Chang Gung University, Chang Gung Memorial Hospital, Kaohsiung Medical Center, Kaoshiung, Taiwan; the Department of Health Care Administration, I-Shou University (S.-S.T.), Kaohsiung, Taiwan; and the Department of Medical Technology, Foo Yin Institute of Technology (J.-F.C.), Kaohsiung, Taiwan.

Supported in part by grants National Science Council. ROC. (NSC92-2314-B-182-093) and Chang Gung Memorial Hospital, NMRPD2116.

Editor's Note: This Manuscript was accepted for publication December 18, 2003.

Send Correspondence to Professor Chih-Ying Su, Department of Otolaryngology, Chang Gung Memorial Hospital, No.123, Ta-Pei Road, Niao-Sung Hsiang, Kaoshiung Hsien, Taiwan. E-mail: usgniy@adm.cgmh.org.tw

Because of the problems associated with Teflon paste, its use for vocal fold atrophy has fallen into disfavor.[7,11,12] With respect to the Silastic blocks used in type I thyroplasty, they are firm and nowhere near the consistency of the surrounding tissue.[8] Clinically, extrusion or migration of the implant is always a risk.[13,14] Although the technique is theoretically reversible, foreign body reaction and fibrosis of the surrounding tissue may permanently affect vocal function even after implant removal.[15] By using type I thyroplasty, Netterville et al.[16] found that the degree of improvement of voice quality was not as consistent in patients presenting with bilateral bowing. Because of varying drawbacks with all existing materials used for medialization or augmentation of the vocal folds, there is a need to supplant these materials with a more stable, autologous tissue.

Laryngoplasty using a bipedicled strap muscle flap has been described in an animal experimental study.[17] The bipedicled strap muscle flap has also been used to reconstruct the laryngeal defect after vertical partial laryngectomy for cancer of the larynx in humans.[18] Kojima et al.[19] reported three cases of bowed vocal fold treated with superior-based omohyoid muscle transposition. Su et al.[20] recently developed a new paramedian approach to arytenoid adduction in combination with bipedicled strap muscle transposition to treat glottal incompetence, particularly in patients with unilateral vocal fold paralysis. The effectiveness of transposition of the strap muscle to correct SGI caused by vocal fold atrophy is lacking.

PATIENTS AND METHODS

Patients

From 2000 through 2002, 32 consecutive patients with SGI caused by vocal fold atrophy underwent medialization laryngoplasty with strap muscle transposition. Patients who had glottal incompetence caused by vocal fold paralysis, laryngeal trauma, previous laryngeal surgery, or laryngeal elevated lesions were excluded from the study. Pre- and postoperative clinical examinations were carried out. All cases were entered into a prospective database, which were used to document the age of onset, associated symptoms, surgical procedures, complications, and outcome of the procedure.

Methods

In most patients, the surgical procedures were performed with local anesthesia and light sedation. Two percent lidocaine hydrochloride containing 1:80,000 epinephrine was used for local infiltration. Approximately 15 mL of the solution was used to provide local anesthesia over the operation field, with minimal pain or discomfort. With the patient supine and with the neck extended, a horizontal skin crease incision was made over the upper level of the thyroid lamina on the more affected side, from the midline of the neck to the anterior border of the sternocleidomastoid muscle. Superior and inferior flaps were developed in the subplatysmal plane. The strap muscles were split in the midline and reflected laterally to expose the thyroid cartilage, leaving the outer perichondrium intact. The thyroid lamina was parasagittally incised approximately 5 mm off the midline, using a sharp surgical knife or an oscillating saw. Care was taken not to cut too deeply beyond the inner perichondrium or enter the laryngeal lumen (Fig. 1A). The inner perichondrium was then thoroughly freed from the overlying thyroid ala. After the thyrohyoid and cricothyroid membranes were divided, the thyroid lamina was retracted laterally. To accommodate the muscle flap more easily, the caudal edge of the thyroid lamina was trimmed a little using a small burr. Then, the sternohyoid muscle or sternohyoid-omohyoid muscle was carefully mobilized along its lateral border, with care being taken to interfere as little as possible with its nerve and blood supply. The whole muscle flap, with its top and bottom attachments intact, was then transposed into the space between the thyroid lamina and the paraglottic soft tissue (Fig. 1B). The thyroid cartilage cut was then carefully sutured back in place with 2–0 Prolene or 0.4 mm stainless wires. The wound was copiously irrigated with normal saline. After hemostasis was obtained, the wound was closed in multiple layers with absorbable sutures.

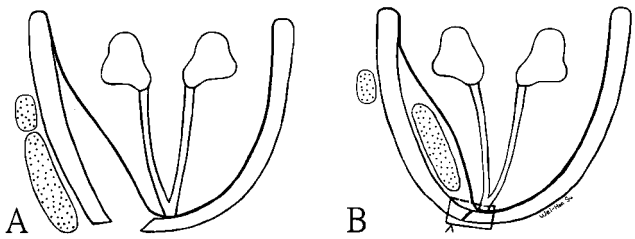

Fig. 1. Medialization laryngoplasty with sternohyoid muscle transposition for vocal fold atrophy.

Vocal Function Evaluation

Pre- and postoperative videolaryngostroboscopy and vocal function studies were carried out as previously described.[20] Vocal function studies consisted of perceptual judgment of voice quality and objective measures of mean fundamental frequency, jitter, shimmer, noise-to-harmonic ratio, maximal phonation time, and mean airflow rate. The patients were examined 1 or 2 weeks preoperatively and followed up 1, 3, 6, 12, and 24 months postoperatively. The laryngostroboscopic examination, acoustic recordings, aerodynamic analysis, and perceptual judgment performed from 6 months or more after surgery were used to assess the surgical outcome. For patients who completed less than 6 months follow-up, recordings from 3 months after surgery were used for analysis because the voice had usually stabilized by 3 months after surgery.

Videolaryngostoboscopy and recordings were carried out before surgery and over 3 to 24 months after surgery using a Kay Elemetrics stroboscopy unit (Model 8100, Lincoln Park, NJ) coupled with a 70° rigid telescope. Patients who were unable to tolerate examination with a rigid scope were evaluated with an Olympus (Tokyo, Japan) ENT, Type L3, fiberoptic laryngoscope. All patients were asked to sustain the vowel i at a comfortable pitch, loudness, and duration while laryngostroboscopy was being performed. A personal computer (RLS 9100B, Kay Elemetrics) was used to digitize sequential video images of the glottal cycles. The video and audio data were stored in the hard disc of the computer and independently evaluated at a later date by two judges with experience in laryngostroboscopy. The judges were blinded to the identity of the patient, and the patient order was randomized. The presence or absence of the mucosal wave, the wave amplitude, and overall glottal closure were evaluated. The relative size of the glottal gap during phonation was assessed on a 5-point rating scale: no gap during phonation (0), minimal gap or slit (1), small gap extending up to one third of the membranous vocal fold (2), moderate gap extending up to two thirds of the membranous vocal fold (3), and complete SGI with no observable contact between the membranous vocal folds (4).

The acoustic and aerodynamic parameters were measured and analyzed in a sound-proof room using a standardized proto-

col. A senior speech pathologist performed the testing and analysis. In the acoustic analysis, mean fundamental frequency, jitter, shimmer, and noise-to-harmonic ratio were examined for production of the sustained vowel sound a in comfortable phonation. A Computerized Speech Laboratory system (Model 4300B, Kay Elemetrics, Lincoln Park, NJ) under software control (version 5.X) was used for processing and analysis of the data. The very first second of the sample was cut off, and the subsequent seconds were used for the measurements. The sampling rate was 50,000 Hz. The aerodynamic parameter of mean airflow rate and the maximal phonation time were measured with face mask connected to a pneumotachograph-based flow system (Aerophone II, model 6800, Kay Elemetrics). Mean airflow rate was obtained by dividing vital capacity by time in seconds as patients sustained the vowel a at comfortable pitch and loudness level. Mean maximal phonation time was calculated while patients sustained the vowel a as long as possible on one breath.

Perceptual assessment was performed by a speech pathologist and a senior laryngologist who were blinded to the patient's status, and they rated voice quality according to grade, roughness, breathiness, asthenia, and strain (GRBAS).[20,21] These ratings were carried out using data from the patients' sustained i phonation and short talking recorded by the laryngostroboscopic video. The GRBAS parameters were rated on a 5-point scale in which 0 was normal, 1 mild dysphonia, 2 moderate dysphonia, 3 severe dysphonia, and 4 aphonia.[7,20]

Clinical subjective rating of the improvement of voice quality after surgery was based on the patients' reports. The results were grouped into categories of markedly improved, improved, not changed, and worse.

Statistical Analysis

Statistical analysis was performed with the SPSS for Windows package (SPSS Inc, Chicago, IL). Simple descriptive statistics (mean and SD) were obtained for each variable. Statistical analyses were performed with paired t test and Wilcoxon signed-rank test for paired observation of ordinal variables.

RESULTS

A total of 32 patients with vocal fold atrophy underwent medialization laryngoplasty with strap muscle transposition during the study period. Among these, 5 were excluded from the analysis because of follow-up for less than 3 months, leaving a total of 27 patients who were included in the analysis. The data of 27 these patients are summarized in Table I. There were 16 men and 11 women. Ages ranged between 21 and 77 years, with a mean age of 41.5 years. The averaged duration of dysphonia was 21 years. Postoperative follow-up ranged from 3 to 24 (mean 11) months. The laryngostroboscopic diagnosis of vocal fold atrophy with sulcus vocalis was made in 10 cases and without sulcus vocalis in 17 cases.

In the early postoperative period, the glottis at the side of operation appeared markedly edematous, injected, and bulging. The patient's vocal function was usually poor. As the acute inflammatory response resolved, the voice quality greatly improved at 3 to 4 weeks after surgery. Within 3 to 6 months, the voice began to reach its best quality. The pre- and postoperative videolaryngostroboscopic recordings, subjective rating, and perceptual rating were obtained for all 27 patients. Acoustic and aerodynamic results that were adequate for analysis were obtained for 25 patients.

Videolaryngostroboscopic Findings

Preoperatively, the most frequent abnormal laryngostroboscopic findings of the 27 patients were a spindle-shaped glottal gap during vibratory cycles and a decrement of mucosal wave and vibratory amplitude. Glottal closure was significantly improved postoperatively in 26 patients but not changed in 1 patient (Table I) (Fig. 2). Postoperatively, complete or near-complete glottal closure (scored 0–1) during phonation was found in 23 (85%) patients, and partial closure (score 2–3) was noted in 4 (15%) patients. None of the patients had a persistent complete SGI (score 4) after surgery. Postoperative assessment of the vibratory patterns of each vocal fold revealed a significant trend toward increased mucosal wave vibration of the vocal fold. Vocal fold vibration by way of the Bernoulli effect was induced, and the mucosal wave amplitude was increased after surgery in 25 of the 27 patients.

Acoustic and Aerodynamic Analyses

The results of acoustic and aerodynamic analyses are summarized in Table II. The preoperative and postoperative mean fundamental frequencies were 199.1 Hz and 197.6 Hz, respectively. There was a statistically significant decrement (improvement) in the mean jitter from the preoperative to the postoperative performance. The mean maximal phonation time increased from 7.96 seconds before surgery to 12.04 seconds after surgery ($P < .001$). The mean airflow rate averaged 0.19 L/sec before surgery and 0.09 L/sec after surgery ($P < .001$). There was a trend toward decreased mean shimmer and noise-to-harmonic ratio after surgery, but this difference did not reach significance.

Perceptual Assessment and Subjective Ratings

Patients perceived an overall voice improvement after surgery (Table III). The assessment was nonparametric because it was based on the ranks of the observations. The nonparametric test that is analogue to the paired t test is the Wilcoxon signed-rank test. There was a significant decrease (improvement) in scales of grading, roughness, breathiness, and strain after operation ($P < .001$). Subjective rating of the effect of the surgery indicated that vocal improvement was obtained in 96% (26/27) of the patients. No deterioration in results was noted during follow-up ranging from 3 to 24 months.

DISCUSSION

Vocal fold atrophy with or without sulcus vocalis often results in various degrees of SGI during phonation. The vocal folds may appear slightly bowed (Fig. 2).[1–3,22] The glottis is usually unable to generate an adequate subglottic pressure to induce full vocal fold vibrations by way of the Bernoulli effect.[23,24] As described by Lindestad and Hertegard,[1] the early onset of symptoms in SGI patients is usually not combined with concurrent diseases, smoking, alcohol consumption, or vocal abuse. This suggests that most cases of SGI, particularly those with sulcus vocalis, may be caused by a congenital disorder or an abnormal development of histologic structure of the vocal fold during childhood or adolescence.

TABLE I.
Summary of 27 Cases of Vocal Fold Atrophy Treated With Strap Muscle Transposition.

Case No.	Sex/Age (y)	Laryngeal Findings	Maximum Phonation Time*		Glottal Gap*		Voice Grading*		Follow-up (mo)
			Preop (sec)	Postop (sec)	Preop (E1/E2)	Postop (E1/E2)	Preop (E1/E2)	Postop (E1/E2)	
1	M/23	r't atrophy	10.0	20.4	2/2	1/1	1/2	0/1	24
2	F/25	bil atrophy	9.0	10.0	4/4	1/1	2/2	0/0	22
3	F/47	bil atrophy	8.3	16.0	2/2	0/1	2/2	0/0	16
4	M/27	bil atrophy	13.4	19.8	2/2	0/0	1/1	0/0	16
5	M/50	bil atrophy with r't sulcus	5.4	10.0	3/2	1/1	1/2	0/1	16
6	M/25	bil atrophy with bil sulcus	12.7	15.3	2/1	1/1	1/1	0/0	14
7	F/40	bil atrophy	7.0	11.3	3/3	0/0	2/2	0/0	14
8	M/38	r't atrophy	11.6	14.0	2/2	0/0	1/1	0/0	13
9	M/62	bil atrophy	6.0	14.0	3/3	1/1	1/1	1/1	12
10	F/30	bil atrophy with bil sulcus	10.8	10.0	3/3	1/1	2/2	0/0	12
11	F/54	r't atrophy	5.0	6.0	1/1	1/0	3/3	1/1	12
12	F/42	bil atrophy with bil sulcus	7.0	6.0	1/1	1/1	3/2	2/1	12
13	M/21	bil atrophy	10.0	11.4	2/2	1/1	1/2	0/0	12
14	F/26	bil atrophy	5.8	9.0	2/2	0/0	1/2	0/0	12
15	M/24	bil atrophy with bil sulcus	4.0	8.6	3/2	2/1	1/2	0/1	12
16	M/28	bil atrophy with bil sulcus	19.0	18.0	1/2	1/1	1/1	0/0	12
17	M/74	l't atrophy	3.2	3.5	3/3	2/2	2/2	1/1	10
18	M/25	bil atrophy with r't sulcus	8.8	9.0	2/2	2/2	1/1	1/1	7
19	M/77	bil atrophy	2.8	5.6	4/4	2/2	3/3	1/0	7
20	F/45	bil atrophy with bil sulcus	5.0	12.0	4/4	1/1	2/2	1/1	6
21	M/52	bil atrophy with r't sulcus	5.0	16.0	3/3	1/1	3/3	2/2	6
22	M/33	bil atrophy	7.8	14.0	2/2	1/1	1/1	0/0	6
23	M/62	bil atrophy	4.8	23.0	2/2	0/0	1/1	0/0	6
24	F/46	bil atrophy	4.5	5.9	2/2	1/1	2/2	1/1	6
25	F/50	bil atrophy	6.8	6.0	2/2	1/1	1/1	1/1	6
26	F/57	r't atrophy	3.9	5.0	2/2	1/1	1/1	1/1	3
27	M/37	bil atrophy with r't sulcus	14.5	25.0	2/2	0/0	1/2	0/0	3

Glottal gap: 0 = complete closure; 1 = minimal gap; 2 = small gap; 3 = moderate gap; 4 = complete gap.
Voice grading: 0 = normal; 1 = mild dysphonia; 2 = moderate dysphonia; 3 = severe dysphonia; 4 = aphonia.
*Statistically significant.
Preop = preoperative; Postop = postoperative; E1 = evaluator 1; E2 = evaluater 2; bil = bilateral; r't = right; l't = left.

Thyroplasty and injection laryngoplasty are widely used treatments for vocal fold medialization or augmentation. Isshiki et al.[2,25] were the first to use type I thyroplasty for dysphonia caused by vocal fold atrophy. They found that better results were obtained for ease of phonation rather than for voice quality and that those cases with a sulcus were more difficult to treat. Several follow-up studies indicate that reversion of the voice can occur in some patients who received type I thyroplasty.[26,27] This may be partly caused by atrophy of the intralaryngeal soft tissue and muscles caused by constant pressure from the Silastic implant.[26] Chan and Titze[28] reported that the viscoelastic properties of the biomaterials are significantly different from those of the soft tissue of the endolarynx, and thus they may interfere with normal vibration of the vocal folds and alter voice quality. To overcome some of the limitations of various implantation materials, a more versatile surgical option and more stable autologous tissue with predictable, long-lasting characteristics in the larynx are needed.

Poor voice quality is usually problematic in patients with early laryngeal cancer who undergo a cordectomy or partial laryngectomy. The bipedicled strap muscle flap together with the outer perichondrium of the thyroid cartilage has been used to fill the soft tissue defect after vertical partial laryngectomy.[18] The goal of this technique is to provide adequate long-term bulk to approximate the contralateral normal vocal fold. In the current study, we found that this technique was a suitable treatment for SGI caused by vocal fold atrophy. Similar to the role of the Silastic implant in type I thyroplasty, the transposed strap muscle can push the paraglottic tissue and effectively medialize the bowed vocal fold (Figs. 1 and 2). This technique also preserves the structures and the viscoelastic properties of the vocal fold to allow normal vibration. The comparative consistency and compatibility of the strap muscle implant with the paraglottic soft tissue suggest that it may result in a better prognosis than techniques using foreign materials in medialization laryngoplasty.

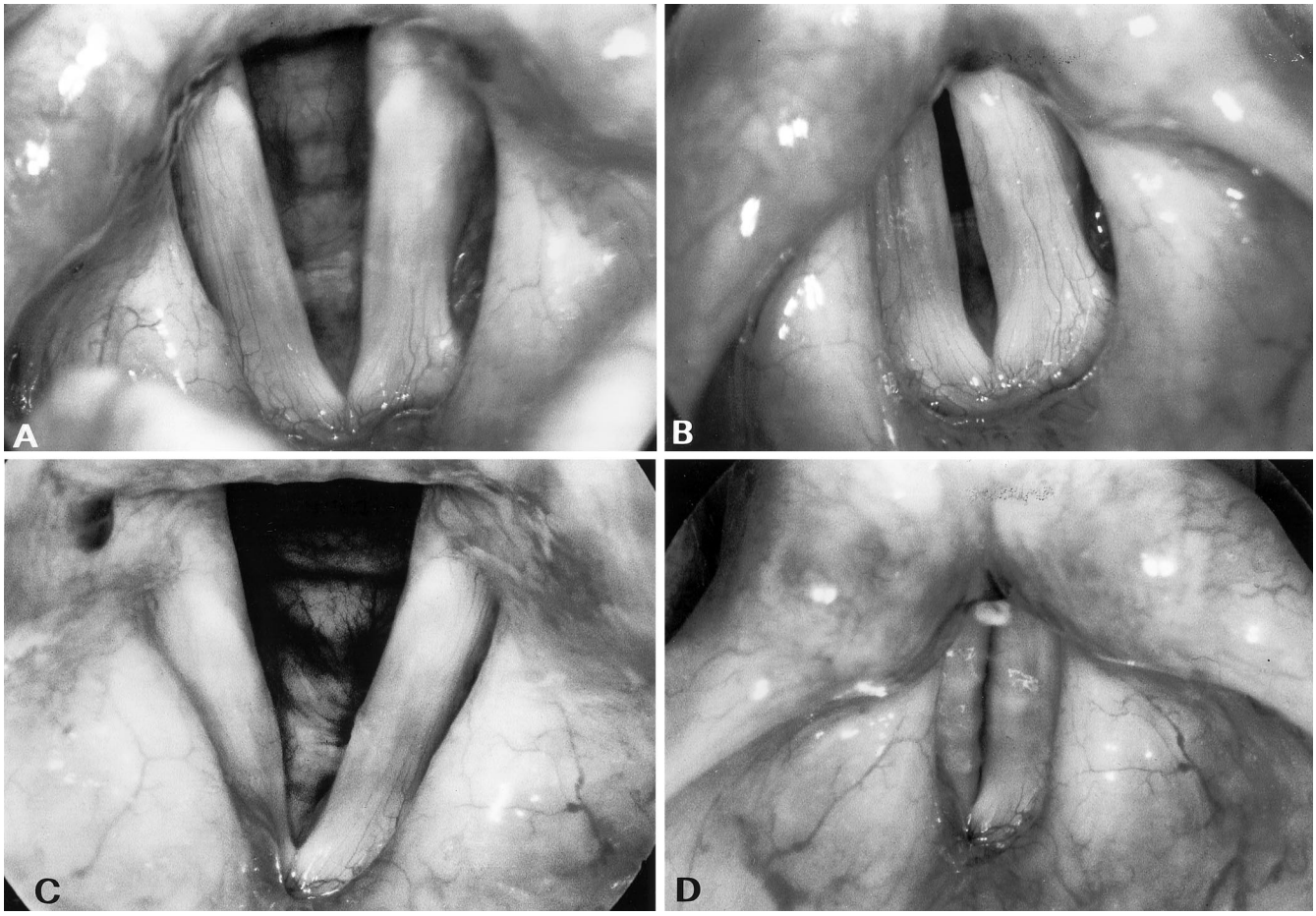

Fig. 2. Laryngoscopic view in a 45-year-old women (case 3) with bilateral fold atrophy before—(**A**) at rest and (**B**) during phonation—and after—(**C**) at rest and (**D**) during phonation—strap muscle transposition. A mild convexity of the treated fold (right side) corresponds well to the opposite bowed fold. Nearly complete glottal closure is noted after surgery (**D**).

As previously described,[20] there are two issues of concern when using strap muscle transposition for medialization laryngoplasty: 1) determination of the most appropriate volume of the muscle flap to harvest, and 2) whether significant atrophy of the muscle flap will occur over time. For vocal fold atrophy patients with mild to moderate SGI, transposition of sternohyoid muscle only is usually sufficient for correcting the glottal gap. For patients with severe SGI, however, transposition of the sternohyoid-omohyoid muscles is recommended. In our experience with this technique, transposition of the whole sternohyoid muscle or sternohyoid-omohyoid muscles may contribute to overcorrection or over-medialization of the vocal fold position without compromising the airway in the early postoperative period (Fig. 1B). This overcorrection is necessary because some atrophy of the transposed

TABLE II.
Comparison of Pre- and Postoperative Measures of Acoustic and Aerodynamic Parameters.

Variables	Patient No.	Preoperative (Mean ± SD)	Postoperative (Mean ± SD)	Time	*P* Value
F0 (Hz)	25	199.12 ± 64.18	197.58 ± 53.19	−0.19	.854
MPT (sec)	25	7.96 ± 3.92	12.04 ± 5.47	4.47	<.001*
JITT (%)	25	2.93 ± 2.25	1.67 ± 0.93	−2.83	.009*
SH (dB)	25	0.51 ± 0.49	0.44 ± 0.19	−0.66	.516
NHR	25	0.18 ± 0.13	0.13 ± 0.03	−1.98	.059
MAR (L/sec)	25	0.19 ± 0.10	0.09 ± 0.05	−5.81	<.001*

*Statistically significant at $P < .05$.
Fo = fundamental frequency; MPT = maximum phonation time; JITT = jitter percent; SH = shimmer; NHR = noise-to-harmonic ratio; MAR = mean airflow rate.

TABLE III.
Nonparametric Analysis of GRBAS Perceptual Assessment Pre- and Postoperatively.

Variable	Patients No.	Two Related Samples Test	Z	*P* Value (two-tailed)
Grading	27	G1-post/G1-pre	−4.59	<.001*
		G2-post/G2-pre	−4.96	<.001*
Roughness	27	R1-post/R1-pre	−4.85	<.001*
		R2-post/R2-pre	−5.07	<.001*
Breathiness	27	B1-post/B1-pre	−4.67	<.001*
		B2-post/B2-pre	−4.11	<.001*
Asthenia	27	A1-post/A1-pre	−1.40	.162
		A2-post/A2-pre	−1.74	.081
Strain	27	S1-post/S1-pre	−4.94	<.001*
		S2-post/S2-pre	−3.88	<.001*

*Statistically significant at $P < 0.05$ (Wilcoxon signed-rank test).
1 = evaluator 1; 2 = evaluator 2; pre = preoperative; post = postoperative.

muscles and resolution of the postoperative laryngeal edema will occur. Use of a split sternohyoid or a monopedicled omohyoid muscle flap[19] is not recommended because it may further interfere with the nerve and blood supply to the muscle flap and then lead to a significant amount of muscle atrophy and fibrosis. By using computed tomography and histologic examination,[20] our previous studies found no significant atrophic change of the transposed strap muscle during long-term follow-up.

In this study, the choice of the side for operation was made according to which of the two vocal folds appeared to be more atrophied or bowed on the laryngostroboscopy. The goal of medialization laryngoplasty with strap muscle transposition is to displace the medial edge of a bowed vocal fold toward the midline to enhance the Bernoulli effect during phonation and therefore facilitate glottal closure (Figs. 1 and 2). For the cases of vocal fold atrophy with bilateral bowing, we found that a unilateral strap muscle transposition is usually enough to close the glottal gap. Long-term follow-up in this series revealed that correction of bilateral bowing by addressing only one vocal fold can lead to a mild convexity of the treated fold, which corresponds well to the concavity of the opposite bowed fold (Fig. 2C). Therefore, a more perfect glottal closure during phonation is achieved (Fig. 2D). In some severe SGI cases, particularly those with sulcus vocalis, a small glottal gap may remain after a unilateral procedure. Nevertheless, improvement of the vocal function in these patients was still obtained in this study. Transposition of bilateral strap muscles for simultaneous medialization of both bowed folds are not recommended because the framework of the thyroid cartilage may become unstable and difficult to suture back into place. Most of our patients were generally satisfied with the dramatic improvement in their voice after a unilateral procedure. Further procedure for the contralateral vocal fold is seldom needed.

Isshiki et al.'s[26] type I thyroplasty and arytenoid adduction should be performed using local anesthesia. This allows precise placement of the implant and adequate adduction of the arytenoid according to the intraoperative adjustment. In the current procedure, however, intraoperative auditory evaluation of the vocal function is usually difficult because transposition of the strap muscle into the larynx may soon result in a remarkable bulging of the treated fold and voice strain. Nevertheless, concern about overcorrection of the vocal fold position and voice strain should be balanced by the fact that some atrophy of the muscle flap and resolution of the laryngeal edema can be expected within weeks after surgery. Because intraoperative vocal adjustment is not necessary, the current procedure can be successfully carried out under either general or local anesthesia. In this study, most of the procedures were carried out under local anesthesia with light sedation

Suture displacement or improper closure of the thyroid ala can occur in the horizontal and vertical planes. This may result in lateralization of the transposed strap muscle and malalignment of the vocal fold level, which may result in a poor vocal function. A poorly calcified thyroid cartilage may be too fragile to withstand the surgical stress, particularly during closure of the thyroid cartilage cut. Therefore, careful and meticulous manipulation during operation is mandatory. To close the thyroid ala more easily and facilitate accommodation of the muscle flap, the caudal edge of the thyroid ala should be trimmed a little using a small burr. In the closure of a poorly calcified thyroid cartilage cut, we usually placed 2–0 Prolene sutures with several 4–0 Vicryl sutures for enhancement. The supplemented 4–0 Vicryl suture can effectively prevent sliding of the cut edges. As for a heavily calcified thyroid cartilage, particularly over the caudal portion, closure with a 0.4 mm stainless steel wire was preferred. By using the above techniques, the cartilage rift was completely closed without leaving a gap in all of our cases. Strap muscle transposition in combination with cricothyroid approximation can be used for some SGI patients with too low pitch problems.

Airway compromise has been reported as an uncommon but life-threatening complications of type I thyroplasty with Silastic implant and arytenoid adduction.[13,14] In our experience, however, airway obstruction was usually not problematic in patients who received strap muscle

transposition for vocal fold atrophy. Although endolaryngeal edema and swelling were inevitable during the early postoperative period, airway compromise was nil, even without steroid administration. Other complications were minimal.

In this study, the results for acoustic and aerodynamic parameters showed that both the voice quality and the ease of phonation were remarkably improved after surgery. The postoperative laryngostroboscopic findings indicated that the transposed strap muscle could effectively push the atrophied vocal fold medially, correct fold bowing, and significantly decrease the glottal gap during phonation. There was postoperative improvement in most of the parameters of vocal function, and voice quality achieved a stable and persistent status at 3 to 24 months after surgery. Satisfactory voice results were obtained in 96% of patients treated with this technique. There was no significant difference in the results whether the atrophy was accompanied sulcus or not.

CONCLUSION

Medialization laryngoplasty with strap muscle transposition is a prosthesis-free, safe, and effective technique for treating dysphonia caused by SGI. The durability of the results with this procedure is encouraging. Our results suggest that the bipedicled strap muscle flap has great potential as an autologous tissue for correcting the SGI caused by vocal fold atrophy with or without sulcus vocalis.

Acknowledgment

The authors thank Wei-Han Su for the medical illustrations.

BIBLIOGRAPHY

1. Lindestad PA, Hertegard S. Spindle-shaped glottal insufficiency with and without sulcus vocalis: a retrospective study. *Ann Otol Rhinol Laryngol* 1994;103:547–553.
2. Isshiki N, Kojima H, Shoji K, Hirano S. Vocal fold atrophy and its surgical treatment. *Ann Otol Rhinol Laryngol* 1996; 105:182–188.
3. Hirano M, Yoshida T, Tanaka S, Hibi S. Sulcus vocalis: functional aspects. *Ann Otol Rhinol Laryngol* 1990;99: 679–683.
4. Ford CN. Advances and refinements in phonosurgery. *Laryngoscope* 1999;109:1891–1900.
5. Ford CN, Staskowski PA, Bless DM. Autologous collagen vocal fold injection: a preliminary clinical study. *Laryngoscope* 1995;105:944–948.
6. Hsiung MW, Woo P, Minasian A, Mojica JS. Fat augmentation for glottic insufficiency. *Laryngoscope* 2000;110: 1026–1033.
7. Koufman JA, Salem W. Laryngoplasty for vocal cord medialization: an alternative to Teflon. *Laryngoscope* 1986;96: 726–731.
8. Montgomery WW, Blaugrund SM, Varvares MA. Thyroplasty: a new approach. *Ann Otol Rhinol Laryngol* 1993; 102:571–579.
9. Rubin HJ. Misadventures with injectable polytef (Teflon). *Arch Otolaryngol* 1975;101:114–116.
10. Kasperbauer JL, Slavit DH, Maragos NE. Teflon granulomas and overinjection of Teflon: a therapeutic challenge for the otorhinolaryngologist. *Ann Otol Rhinol Laryngol* 1993;102: 748–751.
11. Isshiki N, Tanabe M, Ohkawa M, Kita M. Laryngeal framework surgery for voice disorders. *Auris Nasus Larynx* 1985; 12:217–220.
12. Siavit DH. Phonosurgery in the elderly: a review. *Ear Nose Throat J* 1999;78:505–512.
13. Rosen CA. Complications of phonosurgery: results of a national survey. *Laryngoscope* 1998;108:1697–1703.
14. Abraham MT, Gonen M, Kraus DH. Complications of type I thyroplasty and arytenoid adduction. *Laryngoscope* 2001; 111:1322–1329.
15. Escajadillo JR. Technique for external repositioning of the paralyzed vocal cord with silastic implant. *Ann Otol Rhinol Laryngol* 1988;97:234–238.
16. Netterville JL, Stone RE, Luken ES. Silastic medialization and arytenoid adduction: the Vanderbilt experience: a review of 116 phonosurgical procedures. *Ann Otol Rhinol Laryngol* 1993;102:413–424.
17. Bernstein L, Holt GP. Correction of vocal cord abduction in unilateral recurrent laryngeal nerve paralysis by transposition of the sternohyoid muscle. *Laryngoscope* 1967;77:876–885.
18. Hartig G, Zeitels SM. Optimizing voice in conservation surgery for glottic cancer. *Otolaryngol Head Neck Surg* 1998; 9:214–223.
19. Kojima H, Hirano S, Shoji K, et al. Omohyoid muscle transposition for the treatment of bowed vocal fold. *Ann Otol Rhinol Laryngol* 1996;105:536–540.
20. Su CY, Lui CC, Lin HC, et al. A new paramedian approach to arytenoid adduction and strap muscle transposition for vocal fold medialization. *Laryngoscope* 2002;112:342–350.
21. Hirano M. Psycho-acoustic evaluation of voice. In: Arnold GE, Winckel F, Wyke BD, eds. *Clinical Examination of Voice*. New York: Springer-Verlag, 1981:81–84.
22. Tanaka S, Hirano M, Chijiwa K. Some aspects of vocal fold bowing. *Ann Otol Rhinol Laryngol* 1994;103:357–362.
23. Maragos NE. Type I throplasty: pitfalls of modifying the Isshiki approach. How I do it. *J Voice* 1997;11:470–473.
24. Isshiki N. Mechanical and dynamic aspects of voice production as related to voice therapy and phonosurgery. *Otolaryngo Head Neck Surg* 2000;122:782–793.
25. Isshiki N, Okamura H, Ishikawa T. Thyroplasty type I (lateral compression) for dysphonia due to vocal cord paralysis or atrophy. *Acta Otolaryngol* 1975;80:465–473.
26. Isshiki N, Taira T, Kojima H, Shoji K. Recent modifications in thyroplasty type I. *Ann Otol Rhinol Laryngol* 1989;98: 777–779.
27. Koufman JA. Surgical correction of dysphonia due to bowing of the vocal cords. *Ann Otol Rhinol Laryngol* 1989;98:41–45.
28. Chan RW, Titze IR. Viscosities of implantable biomaterials in vocal fold augmentation surgery. *Laryngoscope* 1998;108: 725–731.