Long-term Voice Outcomes After Thyroplasty for Unilateral Vocal Fold Paralysis

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Objectives: To investigate the long-term clinical efficacy and stability of thyroplasty type I for unilateral vocal cord palsy, and to identify the appropriate timing of posttreatment evaluations for determination of long-term voice outcome.

Study Design: Single-institution retrospective study.

Setting: Academic tertiary referral centers in Korea.

Patients: Forty patients with unilateral vocal cord palsy who underwent thyroplasty from January 1, 1996, through December 31, 2006, and were followed up for at least 5 years after the surgical procedure.

Interventions: Thyroplasty type I under local anesthesia.

Main Outcome Measures: Acoustic and aerodynamic analyses of voice were performed on the day before the operation and at preset intervals afterward. Two blinded speech-language pathologists performed the perceptual evaluation.

Results: The GRBAS scale (grade of hoarseness, roughness, breathiness, asthenia, and strain) values showed significant improvement at 6 months after the operation ($P < .05$); these improvements continued up to 1 year and were maintained 5 years after the operation. Acoustic measurements of shimmer and jitter began to show significant improvement at 6 months after the operation, and fundamental frequency and noise harmonic ratios evidenced significant improvement at 1 year ($P < .05$); these improvements were maintained, to a significant extent, at 5 years after the operation. Aerodynamically, the maximum phonation time, glottal flow rate, and peak subglottic pressure improved significantly from before the operation to 6 months and 1 year after the operation, attaining near-normal values at 1 year afterward ($P < .05$).

Conclusions: Thyroplasty type I may provide evidence that voice outcome progressively evolves during the first year after the surgical procedure, and that subsequent vocal improvement presented long-lasting stabilization. To assess the long-term voice quality, it may be enough to perform the voice evaluation at 1 year after the procedure.


Unilateral vocal cord palsy (UVCP) has multiple etiologies, including a neoplasm, trauma, mechanical dysfunction, or central nervous system dysfunction; also, it may be a sequela of extensive thoracic surgical treatment or thyroidectomy. The condition causes temporary or permanent surgical injury to the recurrent laryngeal nerve. Most patients with UVCP report a frustrating change in voice quality, described as hoarseness or breathiness, with or without aspiration, and experience dysphagia caused by persistent glottal insufficiency. The goal of a corrective procedure is to move the edge of the paralyzed vocal fold closer to the midline, to facilitate glottal closure during phonation. This can be achieved either by internal augmentation of the paralyzed vocal fold, via injection of various materials; laryngeal reinnervation; or medialization using an external approach. Because the choice of UVCP management has been based on the duration of paralysis, medialization thyroplasty has been deemed to be the criterion standard of surgical treatment in patients with chronically impaired mobility or permanent paralysis and those who take a long time to recover. The technique of thyroplasty type I was first described in 1915, and was rediscovered and propagated in the 1970s. Since that time, the surgical techniques for thyroplasty type I have been modified, and various types of implantation material have been used. Although the benefits of thyroplasty type I for patients with UVCP have been...
described,\textsuperscript{3-13} little is known about long-term functional outcomes. Several studies have presented long-term results, but patient numbers were small, mean follow-up times varied, and the voice outcomes were evaluated at different times.\textsuperscript{9,10,14-16} Moreover, the appropriate timing of posttreatment evaluations has not been standardized in the determination of long-term voice outcome. Additional acoustic changes, including improvements resulting from further adaptation to improved glottal mechanisms or functional deterioration caused by muscle atrophy, may occur over time. Because assessments of the longitudinal outcomes of patients treated using this technique are needed, we investigated the long-term clinical efficacy and stability of thyroplasty type I, and assessed the appropriate timing of postsurgical vocal evaluations for determination of long-term voice outcome in patients with UVCP.

**METHODS**

We retrospectively reviewed the medical records of 128 patients who underwent thyroplasty type I for UVCP in the Department of Otolaryngology at a tertiary care medical center from January 1, 1992, through December 31, 2006. The waiting period for the operation was at least 1 year, especially in UVCP due to idiopathic cause. Thyroplasty type I was performed by a single experienced surgeon. All patients underwent head and neck examinations, and voice quality was assessed via perceptual and acoustic analysis and aerodynamic measurements. The timing of the operation depended on the etiologies of UVCP and/or the electromyographic findings. Voice evaluation was performed on the day before surgical treatment, then at 6 months and 1 year of the postoperative period, and was repeated every year thereafter, at least up to 5 years after the operation. Inclusion criteria included (1) a follow-up period after the operation of at least 5 years; (2) availability of data on voice evaluation and of videostroboscopy performed on the day before the operation and at 6 months, 1 year, and 5 years after treatment; and (3) the absence of additional treatment at the perioperative period, such as injection laryngoplasty or voice therapy, for glottal incompetence. Of the 128 patients, 78 lacked the required follow-up period of 5 years to meet study parameters and were excluded in the present study. Of the remaining 30 patients, 7 with incomplete data of voice evaluation were also excluded. In addition, 3 patients underwent injection laryngoplasty before the operation and were excluded. Thus, the final remaining 40 were selected for analysis in this study. The study protocol was approved by our institutional review board.

**SURGICAL TECHNIQUE**

All patients were placed under local anesthesia and in the supine position. A wedge-shaped implant was carved by an experienced surgeon (S.Y.N.) from a sterile silastic block to fit the size of the window, as described elsewhere.\textsuperscript{7} The implant, to be inserted in the window before the operation, was then soaked in an antibiotic solution. The superior margin of the window lay in the midline between the thyroid notch and the inferior margin of the thyroid cartilage, and the inferior margin of the window was located 3 mm above and parallel to the inferior margin of the thyroid cartilage. The anterior vertical line was located 7 mm from the median line of the thyroid cartilage for men, and 5 mm distant for women. The intended window size was 6 mm x 13 mm. After choosing the window location, the thyroid cartilage was removed. The inner perichondrium was elevated from the medial surface of the thyroid cartilage using a series of elevators, radiating outward from the window. By means of a flexible fiberscope, the extent of incomplete closure of the glottis and the phonation difference before and after block insertion were checked, and stable fixation of the block in the appropriate location was confirmed. Minor changes in block positioning or sizing were allowed in order to optimize phonation time.

**VOICE ASSESSMENT**

**Perceptual Analysis**

Perceptual evaluation of voice on digitized voice recordings was performed independently by 2 blinded speech-language pathologists. Each patient read a long sentence from “San-Chak” (A Walk), recorded using a multidimensional voice program (model 4300B; Kay Elemetrics Corporation) in a quiet room, at a constant mouth-to-microphone distance of 3 inches. The GRBAS scale (grade of hoarseness, roughness, breathiness, asthenia, and strain) was used to evaluate all recordings.\textsuperscript{7} By means of a 4-point scoring system, ranging from 0 (normal) to 3 (severe impairment), 5 voice parameters were assessed: grade of hoarseness, roughness, breathiness, asthenia, and strain.

**Acoustic Analysis**

Acoustic voice signal data were assessed in terms of fundamental frequency, jitter (cycle-to-cycle variation in pitch), shimmer (cycle-to-cycle variation in amplitude), and noise-to-harmonic ratio, using a multidimensional voice program (model 4300B; Kay Elemetrics Corporation). Voice phonation was measured 3 times during sustained phonation of “a” sounds, each for 2 to 3 seconds, at the pitch and sound level with which each patient was most comfortable. Calculations were performed on data derived from 3 consistent trials. The 500-millisecond interval with the lowest jitter score and the most stable phonation was used to calculate each parameter.

**Aerodynamic Study**

An Aerophone II Voice Function Analyzer (Kay Elemetrics Corporation) was used to collect the basic monosyllabic “a” sound, with lips sealed around an oral tube and with nasal clips in place. By means of the longest prolongation of “a” after maximal inspiration, uttered at a spontaneous comfortable pitch and loudness level, maximum phonation time (MPT) and mean glottal flow rate were measured for each patient. Voice phonation measured during a sustained “ipipi” sound was used to calculate mean peak subglottic pressure.

**STATISTICAL ANALYSIS**

Preoperative and postoperative measurements were compared by 1-way analysis of variance, the Wilcoxon signed rank test, or the Kruskal-Wallis test, as appropriate. Results are given as mean (SD), and P<.05 was considered statistically significant. All statistical analyses were performed using SPSS software, version 14.0 (SPSS, Inc).

**RESULTS**

Forty patients were included in this study. There were 18 men and 22 women, with a median (range) age of 52.2 (22-74) years. The mean (range) time from the onset of UVCP to the thyroplasty type I procedure was 15 (3-23) years.
months. All patients underwent thyroplasty type 1 alone. The mean (range) follow-up time for all patients was 8.7 (6.3–13.2) years. Etiologic factors causing UVCP are summarized in Table 1. No patient experienced any significant early or delayed adverse event. No patients underwent additional management for glottal insufficiency after the operation.

The mean (SD) perceptual overall grade of hoarseness was 2.03 (0.51) before the operation, decreasing to 1.15 (0.82) at 6 months, 0.48 (0.77) at 1 year, and 0.38 (0.47) at 5 years after the operation. The differences between the perceptual grade of hoarseness before and 6 months after the operation, and between 6 months and 1 year, were significant, but the difference between 1 year and 5 years was not. No patient had documented any complaints for their voice after 5 years. The Figure shows the mean scores over time for each GRBAS scale.

Six months after the operation, both mean (SD) shimmer (4.90% [2.48%] vs 8.01% [5.16%]; P < .05) and mean (SD) jitter (1.84% [1.48%] vs 4.66% [2.53%]; P < .05) showed significant improvement compared with presurgical levels. These values also showed significant improvement between 6 months and 1 year after the operation, and these improvements were maintained for 5 years after the operation (Table 2). However, there was no significant difference in either fundamental frequency or noise-to-harmonic ratio between before the operation and 6 months afterward. By 1 year after the operation, both mean (SD) fundamental frequency (186.34 [57.60] Hz vs 207.49 [109.32] Hz; P < .05) and mean (SD) noise-to-harmonic ratio (0.11 [0.08] vs 0.23 [0.19]; P < .05) showed significant improvements compared with presurgical values; these improvements were also maintained for 5 years (Table 2).

Aerodynamic analysis showed that the mean (SD) MPT was 6.84 (2.19) seconds before the operation, 10.81 (3.26) seconds at 6 months, 12.34 (5.60) seconds at 1 year, and 14.14 (7.54) seconds at 5 years after the operation, with all postoperative MPTs being significantly better than the preoperative MPT value (P < .01). The difference between the MPT of 6 months and that of 1 year was significant, but the difference between 1 year and 5 years was not. Mean (SD) flow rate improved from 361.41 (132.53) mL/s before the operation to 249.27 (82.48) mL/s at 6 months after treatment (P < .05), and mean (SD) subglottic pressure improved from 8.16 (2.74) cm H2O before the operation to 3.97 (1.76) cm H2O at 6 months after treatment (P < .05), with both improvements being maintained for 5 years after surgical treatment (P < .01) (Table 3).

**Table 1. Etiology of UVCP in Included Patients**

<table>
<thead>
<tr>
<th>Etiology</th>
<th>Patients, No. (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Surgical cause</td>
<td>18 (45)</td>
</tr>
<tr>
<td>Thoracomedialstinal surgery</td>
<td>2 (5)</td>
</tr>
<tr>
<td>Cardiovascular surgery</td>
<td>3 (8)</td>
</tr>
<tr>
<td>Thyroid or parathyroid surgery</td>
<td>1 (3)</td>
</tr>
<tr>
<td>Skull base surgery</td>
<td>4 (10)</td>
</tr>
<tr>
<td>Nonsurgical causes</td>
<td></td>
</tr>
<tr>
<td>Thoracomedialstinal malignancy</td>
<td>2 (5)</td>
</tr>
<tr>
<td>Postintubation paralysis</td>
<td>2 (5)</td>
</tr>
<tr>
<td>Idiopathic causes*</td>
<td>10 (25)</td>
</tr>
</tbody>
</table>

Abbreviation: UVCP, unilateral vocal cord palsy.
*Idiopathic UVCP is a diagnosis of exclusion when no identifiable cause can be determined.

**Figure.** Results of perceptual voice analysis. The GRBAS scale (grade of hoarseness, roughness, breathiness, asthenia, and strain) was used for serial follow-up.

Thyroplasty type I is the most widely used laryngeal framework surgical procedure and has become the criterion standard for management of patients with permanent UVCP. Although this technique has shown both satisfactory subjective results and successful objective results, most previous studies had relatively small patient numbers and short follow-up periods, and almost all of them demonstrated immediate restoration and short-term stability of thyroplasty results within several months. Moreover, many earlier works did not assess the effects of aging over time; these include vocal fold atrophy, decreased pulmonary support, and a general deterioration in health. Our study cohort was followed up for a mean of 8.7 years after surgical treatment and evaluated in terms of voice outcome up to 5 years after the operation. Voice quality was significantly improved after the operation, like many previous studies. Our study documented a relatively longer postoperative follow-up, featuring evaluation at preset times, than can be noted in any previous work. Of course, postoperative improvement was an expected finding, but quantitatively defining the extent to which voice parameters near normalized may enable the otolaryngologist to prepare the patients for what vocal gains can be reasonably anticipated and what limitations may remain after thyroplasty.

The surgical indications for thyroplasty type I also have gradually expanded. Increasing numbers of elderly individuals with presbylaryngis and patients with cancer-related UVCP are now treated with thyroplasty type I, which has been shown to improve voice quality and ease of phonation in such patients. In this respect, it is necessary to know the long-term stability of thyroplasty and the appropriate timing of postsurgical vocal evaluations for determination of long-term voice outcome. In this study, we hypothesized that the patients may present a diminution...
in benefit after several months or years because of atrophy of the thyroarytenoid muscle from continued denervation. However, we found significant improvements in perceptual analysis during the first year after surgical treatment, with no significant change beyond that time for up to 5 years. All acoustic and aerodynamic parameters also showed significant improvements at 6 months or 1 year after the operation compared with presurgical values, resulting in attainment of near-normal values by 1 year. Although there were slight fluctuations between 1 and 5 years after the operation, no further serial improvements or decline were evident, and the values never returned to the preoperative status. On the basis of early restoration, it is reasonable to evaluate the voice quality at an earlier time (eg, at 1 or 3 months). However, our results imply that, if patients do not complain of voice quality, it may be enough to evaluate the voice outcomes at 1 year after thyroplasty in the aspect of long-lasting stability. We recommend that voice measures be performed at 1 year after surgical treatment to evaluate long-term voice quality. This notion is also supported by the data of several other studies, which showed that voice quality after thyroplasty type I continued to improve in some patients for up to 1 year after the operation.

In this study, most objective and subjective parameters presented not only long-term stability but also late improvements between 6 months and 1 year after surgical treatment. Of those parameters that were not fully restored within 6 months of surgical treatment, many showed continued improvement or even near normalization at 1 year. The reason for these improvements is complex and unclear. Improved vocal cord adduction resulted initially in an increase in habitual voice intensity, most likely from continuation of increased breath support patterns necessary to compensate for inadequate glottis closure. After thyroplasty, long-term results allowed for a self-adjustment or the relearning of more natural breath support patterns consistent with improved vocal cord adduction and glottis closure, thereby allowing for reduced vocal effort and a corresponding decrease in overall habitual voice intensity. Furthermore, the renewed ability to maintain adequate subglottic air pressure allowed for a more natural use and ease in communication. These may contribute to vocal improvement and long-term stability. Our findings suggest that the return to maximally improved or near-normal voice may require many months to complete. Such information could be clinically useful in counseling patients who may be anxious about residual rough quality, lack of projection, or instability of voice in the first postoperative weeks.

The most frequent cause of UVCP in patients who undergo thyroplasty is surgical injury to the recurrent laryngeal nerve and idiopathic paralysis. Similarly, 24 of our 40 patients (60%) experienced iatrogenic surgical injuries. In patients with idiopathic paralysis, or when traumatic or iatrogenic injury to the recurrent laryngeal nerve cannot be completely confirmed, the traditional practice includes waiting 12 months before thyroplasty, to allow time for spontaneous recovery. However, tolerance of longstanding vocal cord immobility has been reported to yield unfavorable voice results. Considering the benefits afforded by and the stability of the outcomes of thyroplasty type I, surgical treatment should be considered actively in patients with iatrogenic permanent injury.

Our study had the limitations inherent to retrospective analyses. First, our study group was relatively nar-

| Table 2. Acoustic Voice Analysis Before and After Thyroplasty Type I |
|---------------------|-----------------|-----------------|-----------------|-----------------|
| Variable            | Preoperative    | 6 Months        | Postoperative    | 5 Years         |
| Fo, Hz              | 207.49 (109.32) | 194.18 (63.26)  | 186.34 (57.60)  | 180.52 (47.54)  |
| Jitter, %           | 4.66 (2.53)    | 1.84 (1.48)     | 1.32 (1.27)     | 0.909 (1.12)    |
| Shimmer, %          | 8.01 (5.16)    | 4.90 (2.48)     | 3.44 (2.01)     | 3.02 (1.46)     |
| NHR                 | 0.23 (0.19)    | 0.19 (0.11)     | 0.11 (0.08)     | 0.10 (0.05)     |

Abbreviations: Fo, fundamental frequency; NHR, noise-to-harmonic ratio.

| Table 3. Aerodynamic Voice Analysis Before and After Thyroplasty Type I |
|---------------------|-----------------|-----------------|-----------------|-----------------|
| Variable            | Preoperative    | 6 Months        | Postoperative    | 5 Years         |
| MPT, s              | 6.84 (2.19)     | 10.81 (3.26)    | 12.34 (3.60)    | 14.14 (2.54)    |
| MFR, mL/s           | 361.41 (132.53) | 249.27 (82.48)  | 193.09 (67.12)  | 187.06 (59.27)  |
| MSP, cm H₂O         | 8.16 (2.74)     | 3.97 (1.76)     | 3.27 (1.45)     | 3.09 (0.98)     |

Abbreviations: MFR, mean flow rate; MPT, maximum phonation time; MSP, mean subglottic pressure.
row. We limited the patients to those with a follow-up period after the surgical procedure of at least 5 years. There was a large drop-out from the study cohort; almost all the patients who dropped out did not return to the clinic for the scheduled follow-up within 1 year after thyroplasty. Second, the choice of implant was not randomized but rather at the discretion of the surgeon. Only silicone blocks, carved by an experienced surgeon, were used as implants, although other materials, including hydroxyapatite, cartilage, Gore-Tex, and titanium, have been used as source block material for use in thyroplasty type 1.\textsuperscript{25-29} There have been reports\textsuperscript{30,31} that compare the vocal outcome of thyroplasty between silicone blocks and other implants, and they presented no significant difference between implant materials. However, although the voice outcomes of our patients after 6 months were comparable with those reported after use of other implant materials, long-term voice results may be affected by implant type. Moreover, many reports\textsuperscript{25-27,30,31} about functional outcome of medialization thyroplasty use different parameters for outcome, which limits the comparison of previous studies with ours, to a certain extent. An additional limitation is the absence of analysis of the glottal gap size; thus, we did not document the magnitude of aerodynamic competence. However, in the present study, we focused principally on acoustic outcomes. Further studies will determine whether thyroplasty using various other materials will ultimately make a difference in achieving the long-term voice outcome and whether vocal gains are perpetuated.

In conclusion, thyroplasty type I may provide evidence that voice outcome progressively evolves during the first years after the surgical procedure and that subsequent vocal improvement presented long-lasting stabilization. To assess the long-term voice quality, it may be enough to perform the voice evaluation at 1 year after the operation. Thyroplasty type I may be a method of choice, affording stable management of improved voice outcomes in patients with permanent UVCV.

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