Transoral Approach to Laser Thyroarytenoid Myoneurectomy for Treatment of Adductor Spasmodic Dysphonia: Short-Term Results

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Objectives: The surgical technique for the resection of the recurrent laryngeal nerve for adductor spasmodic dysphonia (ASD) has high late failure rates. During the past decade, botulinum toxin has emerged as the treatment of choice for ASD. Although effective, it also has significant disadvantages, including a temporary effect and an unpredictable dose-response relationship. In this study we investigated the effectiveness of a new transoral approach to laser thyroarytenoid myoneurectomy for treatment of ASD.

Methods: Fourteen patients with ASD underwent transoral laser myoneurectomy of bilateral thyroarytenoid muscles. Under general anesthesia, an operating microscope and a carbon dioxide laser were used to perform myectomy of the mid-posterior belly of bilateral thyroarytenoid muscles together with neurectomy of the terminal nerve fibers among the deep muscle bundles. Care was taken not to damage the vocalis ligaments, arytenoid cartilages, and lateral cricoarytenoid muscles. Preoperative and postoperative videolaryngostroboscopy and vocal assessments were studied.

Results: The 13 patients who completed more than 6 months follow-up were enrolled in this study. Moderate and marked vocal improvement was achieved in 92.3% of the patients (12 of 13) after laser surgery during an average follow-up period of 17 months (range, 6 to 31 months). No vocal fold atrophy or paralysis was observed in any patient. None of the patients had a recurrence during the follow-up period.

Conclusions: Transoral laser myoneurectomy of bilateral thyroarytenoid muscles is a relatively simple, effective, and valuable technique for the treatment of ASD. The durability of outcome achieved with this procedure is encouraging.

Key Words: adductor spasmodic dysphonia, recurrent laryngeal nerve, thyroarytenoid muscle, transoral laser myoneurectomy, ventricular fold hyperfunction.

INTRODUCTION

Spasmodic dysphonia most often presents as the adductor type. Adductor spasmodic dysphonia (ASD) is a focal form of adult-onset laryngeal dystonia, and is related to excessive adduction or adductor spasm of the vocal folds.1 It is characterized by a strain-strangled voice pattern that is husky, often with tremors and involuntary pitch breaks in voicing. The voice quality often deteriorates further during stressful speaking situations. This can have a negative impact on the patient's quality of life and may lead to social isolation. As a type of dystonia, spasmodic dysphonia has been considered a chronic neurologic disorder of central motor processing causing action-induced muscular spasms of the larynx. However, its exact cause remains unknown.

Adductor spasmodic dysphonia tends to be resistant to voice therapy. Surgical procedures that have been used to treat this disorder include recurrent laryngeal nerve section and type II thyroplasty.2-5 However, these procedures have the disadvantages of high late failure rates and a tendency to leave the patient with a persistent breathy voice.5,5 Therefore, botulinum toxin (Botox) chemodenervation remains the standard of care for ASD in most tertiary specialty centers.1 Botox injection in the thyroarytenoid muscles provides substantial though variable relief of symptoms with few or no side effects. However, the vocal improvement lasts for a limited time, from several weeks to several months, and then the
effect gradually subsides. Despite efforts to refine both surgical and Botox treatments, symptom relief in ASD with tremor remains suboptimal. None of the available interventions at the nerve and end organ offer a definitive cure. As the outcome after all of these procedures is less than optimal, new approaches to the treatment of ASD that may offer a long-term solution need to be developed.

The ideal treatment for ASD would improve both sound production and voice quality without interference with the sphincter function of the glottis, and would provide long-lasting benefit. In an attempt to achieve this goal, we designed a transoral approach to laser partial resection of ventricular folds followed by myoneurectomy of bilateral thyroarytenoid muscles. This procedure has not been fully addressed in the literature.

PATIENTS AND METHODS

Clinical Data. This study (approved by our Institutional Review Board) included 14 consecutive patients who had the presumptive diagnosis of ASD when referred. Informed consent was obtained from all patients before surgery. Detailed history-taking and physical examinations were performed before operation, including subjective and objective vocal function assessments and videolaryngostroboscopy.

Surgical Procedure. All 14 patients underwent transoral laser partial resection of the ventricular folds, followed by myoneurectomy of bilateral thyroarytenoid muscles. Under general anesthesia, a direct laryngoscope was inserted to expose the true vocal folds and ventricular folds (Fig 1A). An operating microscope and a carbon dioxide laser (10 W, continuous mode, and slightly defocused) were used to perform partial resection of the ventricular fold to expose the entire true vocal fold (Fig 1B). Then the middle and posterior thirds of bilateral thyroarytenoid muscles were vaporized or resected (Fig
Fig 2. A) Diagram demonstrates that left ventricular fold and middle belly of thyroarytenoid muscle are partially resected by laser. Terminal fibers of recurrent laryngeal nerve among muscle bundles are also vaporized. B) Terminal neurovascular bundle (arrow) among deep muscle bundles was visualized during laser surgery. Laser vaporization of nerve fibers usually elicited strong twitching of muscle.

1C,D). Care was taken not to damage the vocalis ligaments, arytenoid cartilages, or lateral cricoarytenoid muscles (Figs 1D and 2A). During laser surgery on the deep muscle bundles, terminal nerve fibers were frequently found among the muscle bundles. The nerve fibers, if any, were vaporized as well (Fig 2B, arrow). Laser vaporization of the nerve fibers usually elicited a strong twitching of the muscles. In some cases, bleeding from the small vessels occurred, which could be readily stopped by cauterization. Fibrin glue or suture material was not applied to the surgical wound in any patient. The procedure was usually accomplished within 1 hour. The patients were requested to maintain voice rest for several days to 1 week after the operation.

Vocal Function Studies. Vocal function studies and videolaryngostroboscopy were performed as previously described.7-9 The patients were assessed 1 or 2 weeks after operation and again approximately 1, 3, 6, 12, 18, and 24 months after operation. All data were prospectively recorded in a database, including associated symptoms, surgical procedures, complications, vocal function test results, and surgical outcomes. The vocal assessments involved perceptual judgment of voice quality, acoustic analysis, and aerodynamic measurements. All of the assessments occurred a minimum of 6 months after operation.

Acoustic and aerodynamic parameters were applied to recordings of each subject producing sustained vowel productions in a soundproof room. Acoustic variables including mean fundamental frequency, noise-to-harmonics ratio, jitter, and shimmer were measured by use of a Computerized Speech Laboratory (core model CSL 4300B, KayPENTAX, Lincoln Park, New Jersey). The aerodynamic parameters of mean airflow rate and maximal phonation time were measured with the circumferentially vented pneumotachograph mask and differential transducers of the Aerophone system (Aerophone II, model 6800, KayPENTAX).

Perceptual assessments were determined by consensus of a speech pathologist and a senior laryngologist who listened to the recorded speech samples. Judgments of voice quality and ability to communicate were made on the basis of overall grade (G), roughness (R), breathiness (B), interruption or break (I), strain (S), and tremor (T). Clinical severity before and after surgery was evaluated with a 5-point ordinal scale on which "0" indicated normal, "1" mild dysfunction, "2" moderate dysfunction, "3" severe dysfunction, and "4" profound dysfunction. Clinical subjective judgment of the improvement of voice quality and communication after surgery was assessed by a patient self-rating scale. The findings were classified into categories of normal, markedly improved, moderately improved, slightly improved, not changed, and worse.

Laryngostroboscopy was performed with a KayPENTAX Stroboscopy Unit (model 8100). Video and audio data were loaded onto the computer disk (RLS 9100B, KayPENTAX) to facilitate duplicate evaluation by 2 judges experienced in laryngostroboscopy. The mucosal wave patterns, wave amplitude, periodicity, glottal and supraglottal closures, and presence of tremors during phonation were assessed. Each parameter of specific laryngeal movement disturbance was rated on a 5-point scale, with
0 as normal appearance and 3 as the most severe dysfunction.

Statistical analysis used the SPSS for Windows package (SPSS Inc, Chicago, Illinois). Simple descriptive statistics (means and standard deviations) were calculated for each variable. Statistical analyses used the paired t-test and the Wilcoxon signed rank test for paired measurement of ordinal variables.

RESULTS

From September 2003 through February 2006, a total of 14 patients with ASD underwent transoral laser myoneurectomy of bilateral thyroarytenoid muscles. One of the 14 patients was excluded from the study because she was followed up for less than 6 months. The data of 13 patients are summarized in Table 1. There were 2 men and 11 women. Their ages ranged between 33 and 69 years, with a mean age of 51 years. The average duration of dysphonia was 41 months (6 months to 13 years). The postoperative follow-up ranged from 6 to 31 months. One patient (case 12) who had no symptomatic improvement after surgery took Artane, an antiparkinsonism drug prescribed by a neurologist.

Videolaryngostroboscopic Findings. Before operation, the most frequent abnormal laryngostroboscopic findings of the 13 patients were mucosal waves with aperiodic and rigid vibration patterns, excessive arytenoid adduction, ventricular fold hyperfunction, anterior-posterior compression of the glottis, and tremors with phonation (Table 1). The dysfunctions and their patterns varied greatly. After operation, the abnormalities of the parameters were improved in 12 patients, but unchanged in 1. None of the patients developed significant vocal fold atrophy, bowing, or paralysis after laser surgery. Postoperative assessment of the vibratory patterns of each vocal fold revealed a significant trend toward increased vibration waves.

Perceptual Assessment and Subjective Ratings. The patients perceived an overall voice improvement after surgery (Tables 1 and 2). The assessment was nonparametric, because it was based on the ranks of the observations. The nonparametric test that is analogous to the paired t-test is the Wilcoxon signed rank test. There was a significant decrease (improvement) in the scales of grade, roughness, strain, interruption or break, and tremor after operation \((p < .05)\), but no significant change in the scale of breathiness. Self-ratings and independent ratings of the outcome of the surgery indicated that marked and moderate improvement was obtained in 92% of the patients (12 of 13). There was no recurrence noted during follow-up ranging from 6 to 31 months. One patient (case 12) who had no symptomatic improvement after surgery took Artane, an antiparkinsonism drug prescribed by a neurologist.
in another hospital. She obtained symptom relief during medication. Unfortunately, a deterioration of vocal symptoms was noted when she ceased taking the medicine because of the side effect of general weakness.

Acoustic and Aerodynamic Analyses. The results of acoustic and aerodynamic analyses are summarized in Table 3. There was a statistically significant decrement (improvement) in the mean jitter and maximal phonation time from the preoperative to the postoperative performance (p < .05). No significant differences were noted on parameters of mean fundamental frequency, shimmer, noise-to-harmonics ratio, or mean airflow rate.

DISCUSSION

Most ASD patients suffer from uncontrolled vocal spasms during phonation. The spasms produce a constrained voice quality with intermittent breaks or interruptions of voicing.1 In addition, the voice pattern may also be tremulous. Botox chemodenervation weakens neuromuscular contraction by interfering with release of acetylcholine at the motor end plates (neuromuscular junctions), resulting in a temporary paresis or paralysis of the vocal folds.10 This reduces the effect of adductor spasms on voice production. In an animal study by Genack et al,11 an external approach to partial unilateral thyroarytenoid myectomy through a thyroplasty cartilage window was used to assess the surgical effects on laryngeal function. They found that thyroarytenoid muscle action potential amplitudes were reduced on the side of the myectomy. Histologically, the excised muscle was replaced with fibroareolar tissue without evidence of muscle regeneration. However, preservation of glottal competence with good true vocal fold adduction was observed. In a retrospective, unblinded study by Koufman et al,12 an external approach to myectomies of the thyroarytenoid and lateral cricoarytenoid muscles was performed on 5 ASD patients. (One of the procedures was performed endoscopically.) Their preliminary results showed improved voice fluency in all patients. By using a direct laryngoscope and a carbon dioxide laser, Dedo and Izdebski13 performed a vocal fold thinning procedure to release the recurrent spasticity after unilateral section of the recurrent laryngeal nerve. In 1990, Woo14 described a new thyroplasty approach to laser-assisted thyroarytenoid myectomy; in recent literature, partial immobility of one vocal fold was also obtained by transoral radiofrequency coagulation. Similar to the above techniques, the transoral laser myoneurectomy procedure used in this study also intervenes on the end organ (ventricular folds, thyroarytenoid muscles, terminal nerve fibers, and neuromuscular junctions; Figs 1 and 2). After laser vaporization, the wound over the thyroarytenoid muscle heals and is replaced with fibrous or fibroareolar tissue. This is postulated to result in a significant decrease in the numbers of the thyroarytenoid muscle fibers and the motor unit end plates after laser surgery. To create an effect similar to that of the external myectomy method, laser myoneurectomy is also designed to weaken the contraction of the thyroarytenoid muscle and thereby reduce the excessive adduction and spasm of the vocal folds (Fig 3). Because muscle regeneration is not evident after myectomy, a long-lasting benefit of laser myoneurectomy on symptom relief of ASD is expected.

TABLE 2. COMPARISON OF PREOPERATIVE AND POSTOPERATIVE PERCEPTUAL ASSESSMENTS

<table>
<thead>
<tr>
<th>Parameters</th>
<th>No. of Patients</th>
<th>Two Related Samples Test</th>
<th>Z (2-Tailed)</th>
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<tr>
<td>Grade</td>
<td>14</td>
<td>E1 postop/preop -3.27</td>
<td>.001*</td>
</tr>
<tr>
<td></td>
<td>14</td>
<td>E2 postop/preop -2.85</td>
<td>.004*</td>
</tr>
<tr>
<td>Roughness</td>
<td>14</td>
<td>E1 postop/preop -3.27</td>
<td>.001*</td>
</tr>
<tr>
<td></td>
<td>14</td>
<td>E2 postop/preop -2.23</td>
<td>.026*</td>
</tr>
<tr>
<td>Breathness</td>
<td>14</td>
<td>E1 postop/preop -1.73</td>
<td>.083</td>
</tr>
<tr>
<td></td>
<td>14</td>
<td>E2 postop/preop -1.41</td>
<td>.157</td>
</tr>
<tr>
<td>Strain</td>
<td>14</td>
<td>E1 postop/preop -2.99</td>
<td>.003*</td>
</tr>
<tr>
<td></td>
<td>14</td>
<td>E2 postop/preop -2.71</td>
<td>.007*</td>
</tr>
<tr>
<td>Tremor</td>
<td>14</td>
<td>E1 postop/preop -2.95</td>
<td>.003*</td>
</tr>
<tr>
<td></td>
<td>14</td>
<td>E2 postop/preop -3.08</td>
<td>.002*</td>
</tr>
<tr>
<td>Interruption or break</td>
<td>14</td>
<td>E1 postop/preop -2.97</td>
<td>.003*</td>
</tr>
<tr>
<td></td>
<td>14</td>
<td>E2 postop/preop -2.89</td>
<td>.004*</td>
</tr>
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</table>

*Statistically significant at p < .05 (Wilcoxon signed rank test).

TABLE 3. COMPARISON OF PREOPERATIVE AND POSTOPERATIVE MEASURES OF ACOUSTIC AND AERODYNAMIC PARAMETERS

<table>
<thead>
<tr>
<th>Parameters</th>
<th>No. of Patients</th>
<th>Preoperative (Mean ± SD)</th>
<th>Postoperative (Mean ± SD)</th>
<th>t</th>
<th>p</th>
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<td>Fundamental frequency (Hz)</td>
<td>14</td>
<td>197.51 ± 33.82</td>
<td>194.85 ± 42.16</td>
<td>0.22</td>
<td>.830</td>
</tr>
<tr>
<td>Maximum phonation time (s)</td>
<td>14</td>
<td>14.14 ± 8.49</td>
<td>18.79 ± 7.49</td>
<td>-2.39</td>
<td>.033*</td>
</tr>
<tr>
<td>Jitter (%)</td>
<td>14</td>
<td>2.69 ± 1.89</td>
<td>1.33 ± 1.03</td>
<td>2.40</td>
<td>.032*</td>
</tr>
<tr>
<td>Shimmer (dB)</td>
<td>14</td>
<td>0.53 ± 0.42</td>
<td>0.45 ± 0.40</td>
<td>0.54</td>
<td>.595</td>
</tr>
<tr>
<td>Noise-to-harmonics ratio</td>
<td>14</td>
<td>0.26 ± 0.23</td>
<td>0.17 ± 0.12</td>
<td>1.46</td>
<td>.168</td>
</tr>
<tr>
<td>Mean airflow rate (L/s)</td>
<td>14</td>
<td>0.05 ± 0.05</td>
<td>0.08 ± 0.14</td>
<td>-0.81</td>
<td>.434</td>
</tr>
</tbody>
</table>

*Statistically significant at p < .05.
During a mean of 17 months (range, 6 to 31 months) of follow-up, there was no evidence of recurrence of vocal symptoms in this series. Compared to Botox chemodenervation and external surgical methods, the transoral laser technique has the advantages of time- and cost-effectiveness with low morbidity. It is a relatively simple and effective procedure with a durable outcome.

There are two main issues of concern in performing laser myoneurectomy of the thyroarytenoid muscle: 1) determination of the most appropriate location and volume of the muscle vaporized or resected; and 2) assessment of whether significant vocal fold atrophy, vocal fold paralysis, or glottal incompetence will occur after laser surgery. From an anatomic and neurophysiological perspective, the design of the transoral approach to laser vaporization focusing on the middle and posterior thirds of the thyroarytenoid muscle is feasible and reasonable. The recurrent laryngeal nerve terminates in the thyroarytenoid muscle. The terminal branching pattern is that of the anatomic neural networks surrounding the muscle fascicles and within the muscle (Fig 2). In the thyroarytenoid muscles, these neural networks become dense and complicated, especially in the medial part of the thyroarytenoid (vocalis muscle) at the vocal fold margin. An immunohistochemical study of human true vocal folds by Sheppert et al revealed that the most neuromuscular junctions (74%) were located in the middle third of the thyroarytenoid muscle, followed by the posterior third, and the least (7%) were found in the anterior third. Rossi and Cortesina also reported that approximately 70% to 80% of the fibers in the medial two thirds of the thyroarytenoid muscle had multiple motor end plates. These findings suggest that the medial thyroarytenoid has a much finer neural control that probably offers an increased rate of rise of tension in vocalization. Because neuromus-
cular junctions are most highly concentrated within the mid-posterior belly of the muscle, laser surgery on ASD patients should be targeted to this region (Figs 1 and 2). After laser resection of a significant amount of muscle tissue just lateral to the vocal ligament, fibrous or scar contracture created in healing may serve to pull the free edge of the vocal fold away from the midline, and thereby eliminate the excessive adduction of the vocal folds in voicing. Laser vaporization extending to the anterior portion of the thyroarytenoid muscle is not recommended, because it offers little further benefit on control of vocal spasms and may also increase the risk of anterior glottal incompetence after surgery. We advocated the use of laser myoneurectomy on bilateral thyroarytenoid muscles. It is assumed that laser weakening of a unilateral vocal fold may result in abnormally asymmetric vibrations of the vocal folds. Although most patients had had various degrees of temporary aspiration and husky voice during the initial postoperative period, none of them developed significant vocal fold atrophy (bowing) or glottal incompetence during follow-up. The absence of postoperative vocal fold paralysis in this series may be attributed to the routine preservation of the lateral cricoarytenoid muscle during the procedure (Fig 2B).

Patients with ASD often exhibit glottal and ventricular fold (false vocal fold) hyperadduction or hyperfunction. The ventricular folds are composed of elastic connective tissue containing fat cells and a few muscular fibers derived from the vocalis muscle of the corresponding side. A substantial number of motor end plates are scattered in the ventricular fold. On the basis of the hypothesis that a "ventricular muscle" may contribute to the hyperfunction in these cases, Schonweiler et al treated 8 ASD patients with bilateral injection of botulinum toxin type A into the ventricular folds. They found that ventricular fold hyperfunction had resolved in all patients at 4 weeks after treatment. In the current series, partial laser resection of the ventricular fold (Figs 1 and 2) was also shown to be an effective treatment for the correction of ventricular fold hyperfunction and anterior-posterior glottal compression in voicing (Table 1 and Fig 3).

Because mild endolaryngeal edema and temporary laryngeal dysfunction is an inevitable consequence of laser surgery, transient aspiration and hoarseness were noted in most of our patients. The symptoms and signs gradually subsided, and the patients' voice quality stabilized within 1 to 3 months after surgery.

The postoperative complications were minimal in this series. One of our patients developed hemoptysis immediately after the operation. Revision laryngomicroscopy revealed a small bleeder at the right ventricular wound, which was successfully stopped by cautery. Four of the 13 patients developed granulomas at the wound site in the ventricular area. All of the granulomas gradually disappeared within 3 to 4 months of operation.

Moderate to marked improvement in speech following laser thyroarytenoid myoneurectomy was reported by 92% of patients (12 of 13) in this series. Eight of them obtained a near-normal to normal voice quality after operation. Our results demonstrated that this new transoral approach to laser thyroarytenoid myoneurectomy for the treatment of ASD effectively improved both perceptual assessment and subjective ratings of voice production. The patients' voice quality and glottal configuration achieved a stable and persistent status at 6 to 31 months after surgery.

CONCLUSIONS

Transoral laser myoneurectomy of bilateral thyroarytenoid muscles is a relatively safe, effective, and technically simple surgical procedure for treatment of ASD. It results in a sustained weakening but adequate functioning of the thyroarytenoid muscles. This technique has excellent potential to provide an alternative for management of ASD patients.

Acknowledgments: The authors thank Ben-Hua Wang and Wei-Han Su for production of the Figures, Wei-Wei Su for contributing to this project, and Chu-An Cheng for performing the vocal function tests and voice assessments.

REFERENCES


