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Long-Term Follow-Up Results of Selective Laryngeal Adductor Denervation-Reinnervation Surgery for Adductor Spasmodic Dysphonia

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Selective laryngeal adductor denervation-reinnervation surgery for the treatment of adductor spasmodic dysphonia was reported in 1999 in 21 patients with encouraging results. Here, we report long-term results of this procedure. Surgical outcome was evaluated using patient surveys and perceptual voice assessment. Measured outcomes included Voice Handicap Index (VHI)-10 scores, patient questionnaire, and perceptual evaluation for voice breaks and breathiness. Patient survey was obtained from 83 patients, and perceptual voice evaluation was performed in voice samples from 46 patients. Average follow-up interval was 49 months. Mean VHI-10 scores improved from a mean of 35.6 to 12.7. Eighty-three percent showed significantly improved VHI-10 scores, representing improved physical, social, and emotional well-being. There was a high degree of patient satisfaction, with 91% agreeing that their voice is more fluent after the surgery. Perceptual evaluation of postoperative voice samples revealed voice breaks in 26% (15% mild, 4% moderate, 7% severe) and breathiness in 30% (11% mild, 13% moderate, 6% severe). A majority of patients had stable, long-lasting resolution of spasmodic voice breaks. *Key Words:* Laryngeal denervation, Laryngeal reinnervation, Outcomes study, Spasmodic dysphonia.

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INTRODUCTION

Spasmodic dysphonia (SD) is a voice disorder characterized by involuntary voice breaks during speech. Abductor spasmodic dysphonia (ABSD) and adductor spasmodic dysphonia (ADSD) are the two main types of SD. ADSD is characterized by strained and strangled voice breaks, and ABSD is characterized by breathy voice breaks. Other variations of SD such as mixed dystonia, dystonia with tremor, and concurrent SD with other forms of focal dystonia are also encountered. ADSD is more common (82%) compared with ABSD (17%), and females are more commonly affected (63–79%).[1,2] Abnormal motion of laryngeal muscles during speech can be seen during videolaryngoscopy in SD patients. Laryngeal electromyography (LEMG) shows that pitch and phonatory breaks in SD are coincident with muscle spasms during connected speech.[3,4] On the basis of these findings, SD is classified as a focal dystonia affecting the larynx during speech. Despite a century of discussion in the literature, the etiology of SD remains unknown.[5]

The current standard of therapy for ADSD is chemodenervation of the thyroarytenoid (TA) muscle with botulinum toxin.[6] Using LEMG, some have advocated more selective Botox injections to the lateral cricoarytenoid (LCA) muscle or the interarytenoid (IA) muscle.[7,8] Botox treatment leads to improved fluency, intelligibility, and patient satisfaction.[1,9] However, Botox has several disadvantages. Botox is a temporary treatment with each injection lasting approximately 3 months on average. Therefore, repeated injections are necessary over a lifetime to control the speech symptoms. Botox injection typically results in a period of breathy dysphonia before a symptom free period, which is then followed by a period of symptom recurrence. In addition, the therapeutic window of Botox dose is wide, and a trial and error method of Botox dosing is often necessary because there is currently no way to assess the sensitivity of each patient to Botox. There is also a possibility of developing resistance to Botox.[10] Despite these disadvantages, long-term follow-up of Botox treatment shows, for the most part, continued success but without change in maximum improvement.[11]

Given the limitations of Botox treatment for ADSD, a variety of surgical therapies have been proposed. In 1976, before the Botox era, Dedo[12] described unilateral laryn-

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geal nerve section. Although short-term results were reportedly good, long-term results were less than satisfactory, with an overall 64% failure rate at 3 years.[13] The failure of the procedure has been attributed to persistent symptoms of the contralateral larynx or reinnervation by the proximal recurrent laryngeal nerve (RLN) axons.[14] In 1999, Berke et al.[15] described selective laryngeal adductor denervation-reinnervation (SLAD-R) surgery. Surgical outcomes in 21 patients were reported, and 19 were reported to have "absent to mild" severity of dysphonia postoperatively at a median follow-up period at 36 months. In 2000, Issiki et al.[16] reported the application of midline lateralization thyroplasty (type II thyroplasty) for ADSD. Recently, a 67% to 88% failure rate was reported with this technique.[17]

The voice breaks of ADSD can be understood biomechanically as a mismatch between laryngeal resistance and subglottic pressure, leading to cessation of airflow. Sudden strong adduction of the vocal folds in ADSD dramatically increases laryngeal resistance that requires matching high subglottic pressure levels for uninterrupted phonation. The lung-thorax system is simply not able to generate the increased subglottic pressure required to overcome the laryngeal resistance, and phonatory break ensues until relaxation of the vocal folds leads to decreased resistance and resumption of airflow. The SLAD-R procedure was initially performed in a canine model to test this paradigm and assess its safety and effect on laryngeal biomechanics.[18] The animal experiments showed that bilateral TA denervation leads to the inability to develop high levels of subglottic pressure despite maximal RLN stimulation, but the geometry of glottal vibration is maintained. In the same study, reinnervation of the distal stump of the adductor branch by the ansa cervicalis nerve lead to reinnervation and maintenance of vocal fold bulk. That scientific experience was then translated into clinical practice to treat ADSD patients.

Selective adductor denervation severs the anterior (adductor) RLN nerve branch that relays the abnormal neural signals to two of the three adductory muscles of the larynx, the TA and LCA muscles. The procedure does not affect the third adductor of the larynx, the IA muscle, which receives innervation from a nerve branch that divides more proximally from the RLN. In this procedure, the adductor branch of the RLN is divided at its insertion to the TA and LCA muscles, and the proximal stump is exteriorized from the larynx to prevent regeneration of axons back into the larynx. The ansa cervicalis nerve is then anastomosed to the distal TA nerve stump to maintain muscle tone and bulk and also to presumably prevent regeneration of RLN axons to the neuromuscular endplates of the TA and LCA muscles. LCA myotomy is also performed (as discussed below).

It is imperative that any surgical procedure for SD be reproducible and stand the test of time. Some have recently begun adopting selective adductor denervation reinnervation surgery in their practice and reported their experiences. Allegretto et al.[19] reported success in five of six patients with an average follow-up time of 20 months. Here, we report long-term results of the SLAD-R operation at a single tertiary care center over a 7 year period. This report constitutes the largest series of patients who have undergone SLAD-R surgery for ADSD.

METHODS

This is a retrospective surgical outcomes analysis. The Medical Institutional Review Board of the University of California, Los Angeles, approved the study. The study consisted of written patient survey and perceptual voice analysis.

Patients

A patient list was generated from operative logs. All patients with ADSD who underwent SLAD-R surgery between the years 1996 and 2003 were included in the study. One hundred thirty-six patients (42 males, 95 females) had the operation during this period. The majority of patients came from outside the state of California. Twenty-five were lost to follow-up. These 25 patients had no recent contact with us, could not be reached at their last given telephone number, and mail sent to their last address was returned undeliverable by the post office. The remaining 111 patients (32 males, 79 females) were successfully contacted, and surveys were sent. Eighty-three patients (23 males, 60 females) returned the survey for a response rate of 75%.

Adequate preoperative recordings were present in 46 patients (11 males, 35 females), and new postoperative recordings were then made from these patients. Average patient follow-up was 49 (median 52) months. The other patients either had no preoperative voice recording, or the recordings were degraded or recorded in a way that could not be used for the study.

Surgical Technique

The surgical procedure has been described in detail previously.[15] The patient is laid supine in the operating room table and intubated with an electromyography endotracheal tube (Medtronic Xomed Nerve Integrity Monitor System, Jacksonville, FL). A transverse cervical incision is made at the level of the lower border of the thyroid ala. The ansa cervicalis nerve is identified bilaterally using anatomic landmarks described previously.[20] The thyroid ala is then exposed bilaterally to the posterior edge, and an inferiorly based laryngotomy window is made in the posteroinferior portion of the thyroid lamina. The posterior vertical cut is made anterior to the inferior cornu, leaving at least a 3 mm posterior strut. The anterior vertical cut is made just at the anterior border of the inferior thyroid tubercle, and the superior horizontal cut is made halfway between the superior and inferior borders of the thyroid lamina. The cartilage flap is retracted inferiorly to expose the intralaryngeal musculature. The inner perichondrium is excised and the intralaryngeal musculature gently dissected with a hemostat. The anterior (adductor) branch of the RLN is identified, followed distally, and verified using a nerve stimulator.

The adductor branch of the RLN usually runs obliquely from the posteroinferior corner of the laryngotomy window to the TA muscle anterosuperiorly. The TA branch of the RLN is divided before its insertion into the muscle, leaving adequate distal length to allow neural anastomosis. The proximal nerve stump is reflected back, and the nerve branch to the LCA muscle is identified and divided. The proximal adductor branch is exteriorized from the larynx by dissecting posteriorly and suturing to the outer thyroid perichondrium. LCA myotomy is performed before laryngeal reinnervation. Next, the ansa cervicalis nerve is divided, allowing adequate length to perform a tension-free anastomosis. The sternohyoid or sternothyroid branch of the nerve is typically appropriately sized for TA reinnervation.[20] The proximal ansa cervicalis nerve stump is brought underneath the strap muscles into the laryngotomy window, and epineurial anastomosis is performed to the distal TA nerve stump using two to three interrupted 8–0 nylon sutures under loupe magnification.

The LCA nerve branch is not reinnervated because there is inadequate length for neural anastomosis. An approximately 3 × 3 mm piece of cartilage is removed from the posterior border of the laryngotomy cartilage flap to allow entrance of the ansa cervicalis nerve into the larynx before replacement of the cartilage flap to close the window. The flap is then sutured to the thyroid lamina at the outer perichondrium with a 4–0 nonabsorbable suture. The strap muscles are approximated in the midline over a Penrose drain. Patients are discharged when oral intake is adequate.

Patient Survey

A survey was mailed to all patients who could be contacted and gave verbal consent. Postage-paid envelopes were provided to return the survey. The first portion of the survey requested general demographics and history of Botox and voice therapy. Next, the reasons for seeking surgery were asked (Table I). This was followed by Voice Handicap Index (VHI)-10 questions (Table II) and a questionnaire on surgical outcome (Table III). Space was provided to fill in any comments.

The VHI-10 has been recently developed and validated.[21] VHI-10 is based on the longer VHI-30, which is a patient-based self-assessment tool developed by Jacobson et al.[22] and consists of 30 questions covering functional, physical, and emotional aspects of voice disorder. Patients are asked to rate each question on a scale of 0 to 4 (0 = strongly disagree, 4 = strongly agree) for a possible total score of 120. The higher the score, the worse is the voice handicap. A change of 18 points on the VHI-30 has been validated to represent a significant change in the psychosocial function.[22] The VHI-10 is a shortened version of VHI-30, is equally effective while being more tolerable for patients to complete, and its ratio mirrors that of the VHI-30.[21] Therefore, the maximum score in a VHI-10 is 40 points, and a change of 6 points on the VHI-10 would be significant. Patients were given two VHI-10 sections and asked to rate their condition "before surgery" in one section and "after surgery" in the other. The surgical outcomes questionnaire was also rated on a scale of 0 to 4 (0 = strongly disagree and 4 = strongly agree).

Expert Voice Assessment

Four voice experts (3 clinical speech pathologists and an otolaryngologist) who regularly evaluate and treat voice patients were recruited to perform perceptual analysis on the computer voice samples. A stipend was provided to the voice experts for their participation. None of the voice experts were involved in the surgery, and none knew the patients personally. All were listening to the voice samples for the first time. The experts were told that the voice samples came from patients with SD.

We considered using a standardized passage read by patients for expert voice evaluation. However, we have observed that patients are often more dysfluent when speaking spontaneously, and no report to date has been published showing the superiority of a standardized passage over spontaneous speech in the diagnosis of SD. Therefore, subjects were asked to spontaneously "describe your voice problem and how it affects you." The first few sentences of the response for both the pre- and postoperative voice recordings were then edited as needed to remove voiceless pauses, past verb tenses, and references to surgery. A 13 second sound clip was then created for each voice sample consisting of 2 seconds of sustained vowel /a/, a 1 second pause, and 10 seconds of spontaneous speech. Final voice samples were then coded with a random six-digit number for perceptual analysis.

Preoperatively voice recordings were stored on digital audio tape (DAT). Postoperative voices were recorded over a land-based telephone using a microbar digital audio telephone recorder (Digital Voice Recorder, DDR-3000, Diasonic Technology Co. Ltd., Anyang-City, Korea) connected directly to the phone jack. The preoperative recordings were filtered (band-pass filtered between 600 and 1,500 Hz) to imitate the muffled acoustic quality of the telephone to match the quality of postoperative voice samples. Although recording conditions are not identical (preoperative DAT vs. postoperative telephone), the recording modality does not affect assessment of voice breaks. Although use of voice samples recorded over the telephone to assess breathiness has not been validated, the concern being that the high-frequency noise of breathiness would be lost while recording the narrow bandwidth of the telephone signal, we believe that the use of connected speech (as opposed to sustained vowels) provides additional perceptual cues to allow for adequate and accurate perceptual rating of breathiness. There is a possibility that high-frequency noise signals are important for perceptual assessment of breathiness, but this has not been specifically studied to date for connected speech. Several patients had postoperative DAT recordings. One of the expert listeners was later asked, after the blinded perceptual evaluations were completed, to listen to and perform a side by side comparison of DAT voice samples versus telephone-recorded voice samples from the same patient at similar postoperative periods and concluded that the breathiness ratings would likely be identical. Perceptual evaluation of breathiness has been included here, despite the possible limitations of using telephone-recorded voice, because breathiness is a potential complication of the surgery.

A visual "sort and rate" computer program was designed for voice rating. The program allows users to click on a voice sample

TABLE I.
Reasons for Seeking Surgical Intervention.

	No. of Patients	Percent of Patients
Just wanted to cure spasmodic dysphonia for good	74	94
Ups and downs of Botox	56	71
Prolonged voice difficulties after Botox	41	52
Botox stopped working	25	32
Cost of Botox	24	30
Swallowing difficulties after Botox	13	16
Botox never worked	13	16
Difficulty with traveling to obtain Botox	12	15

TABLE II.
Voice Handicap Index-10 Scores (Mean Score).

	Presurgery	Postsurgery
My voice makes it difficult for people to hear me	3.42	1.47
People have difficulty understanding me in a noisy room	3.61	1.88
My voice difficulties restrict personal and social life	3.72	1.03
I feel left out of conversations because of my voice	3.53	1.04
My voice problem causes me to lose income	2.63	1.01
I feel as though I have to strain to produce voice	3.86	1.29
The clarity of my voice is unpredictable	3.66	1.27
My voice problem upsets me	3.76	1.32
My voice makes me feel handicapped	3.63	1.10
People ask, "What's wrong with your voice?"	3.78	1.28
Mean total	35.61	12.68
Range total	24–40	0–40
Standard deviation of total	3.91	12.72
Total mean score improvement	-	22.93

Ratings: 0 = strongly disagree; 1 = disagree; 2 = undecided; 3 = agree; 4 = strongly agree.

to hear it from a bin that contained randomly arranged pre- and postoperative voice samples. After listening, the rater then drags the voice sample icon and drops it on a rating box. At the top of this box, going from the left to right, and each placed to represent approximately 25% of the box area, were labels "severely abnormal," "moderately abnormal," "mildly abnormal," and "normal." The area under the "normal" label was further highlighted by a separate box so all sound clips considered "normal" could be placed anywhere within it (the rightmost 25% width of the entire rating box). The other labels were to be used as guides, and the expert listeners were asked to drop the sound icon anywhere along this linear spectrum within the rating box. The pixel distance from the left to right of the box was used to develop the severity score. The rightmost pixel on the box was considered 100% on the severity scale. The pixel distance was then converted to a severity scale as follows: 0% to 25% = severe problem, 26% to 50% = moderate problem, 51% to 75% = mild problem, 76% to 100% = normal.

Statistical Evaluations

Perceptual evaluation was repeated a second time, after more than a month had elapsed from the first rating session, by all expert listeners on the entire set of voice samples to allow adequate assessment of interrater and intrarater reliability. The average measure intraclass correlation (ICC) was calculated for interrater reliability. Pearson's correlation coefficient (r) was calculated for intrarater reliability and to assess the relationship between VHI-10 scores and perceptual voice evaluation scores. SPSS version 13.0 for Windows was used for all statistical calculations (Chicago, IL).

RESULTS

Patients

One hundred thirty-six patients (42 males, 95 females) with ADSD underwent surgery during the study

TABLE III.
Patient Response to Questionaire.

Statements	Percent Strongly Agree	Percent Agree	Percent Undecided	Percent Disagree	Percent Strongly Disagree
My speech is better after the surgery than after Botox	69	13	8	8	3
I would recommend this operation to others with spasmodic dysphonia	64	19	12	1	4
My speech is more fluent after surgery	64	27	5	1	2
My speech is understandable	60	28	5	4	2
Breathiness of my voice after surgery has improved over time	60	20	6	3	11
I have NOT experienced breathing difficulties since surgery	56	19	5	15	6
I am not embarrassed speaking in public	52	21	15	6	6
I have NOT had any spasmodic dysphonia symptoms since surgery	40	27	12	11	10
I still have swallowing difficulties since surgery	12	20	7	20	41
I still have vocal spasms when I speak	10	7	10	19	54
Botox treated my spasmodic dysphonia successfully	9	26	10	31	23
I need Botox treatments after surgery for spasmodic dysphonia	1	4	5	20	70

period (1996–2003). One hundred eleven patients (32 males, 79 females) were successfully contacted for participation in the study, and 83 (23 males, 60 females) returned the written survey. Average age of onset of SD symptoms for this group was 39.5 years, and average age at diagnosis was 44.3 years. The mean and median age at surgery was 51 (range 29–75) years. Ninety-six percent had been treated with Botox, and 67% had received and failed voice therapy before the surgical procedure. Patients had an average of 16 Botox injections before surgery. Their reasons for seeking surgery are listed in Table I.

VHI-10 Scores

Mean follow-up time for the survey group was 49 (median 52) months. The mean VHI score decreased by 22.9 points postoperatively (Table II). Improvement was seen in every question of the VHI-10. The distribution of VHI-10 scores is illustrated in Figure 1. Preoperative VHI-10 scores were between 20 to 40 in every patient. Postoperative VHI-10 scores were less than 10 in 57% and less than 20 in 74%. Although a change of 6 points in the VHI-10 is probably significant, we used a more rigid criterion because the improvement after surgery was so dramatic. We considered less than 1 SD change (13.5 points) in improvement below the mean change (22.9 points) as failure of the operation. In other words, the VHI-10 score must decrease by at least 9.4 points postoperatively for that patient to have benefited from the operation. With use of this criterion, 14 patients (17%; 6 males, 8 females) had less than optimal surgical outcome in the self-administered VHI-10 questionnaire.

Response to Questionnaire

Patients' opinions regarding the outcome of the procedure also generally reflected the outcome of the VHI-10 scores. Ninety-one percent of the patients agreed or strongly agreed that their speech was more fluent after surgery, and 83% agreed or strongly agreed that they would recommend the operation to others with SD. Responses to questions are listed in Table III.

Twelve patients operated on in the early part of the study period did not undergo LCA myotomy. When data from this subgroup were analyzed, no difference were found compared with the rest of the group. VHI-10 scores decreased from a mean of 36.64 preoperatively to 14.27 postoperatively. Response to "I would recommend this surgery to others with spasmodic dysphonia" was rated "agree" by 1 (9%) patient and "strongly agree" by the remaining 11 (91%) patients.

Perceptual Evaluation

Fourteen (30%) patients had breathiness postoperatively (Fig. 2). Among these patients, breathiness was rated severe in two (6%) patients, moderate in seven (13%), and mild in five (11%). Seven were male (64% of the males), and seven were female (20% of the females). More male patients were breathy postoperatively than females (χ^2, $P < .05$). Of the 14 breathy patients, 5 patients had improved scores on the VHI-10 (scores decreased by 14–24 points), 8 patients had minimal improvement to worse scores (scores decreased by 6–16 points), and 1 patient had voice recorded but did not return the survey.

Twelve (26%) patients had voice breaks postoperatively (Fig. 3). Among these patients, voice breaks were rated severe in three (7%) patients, moderate in two (4%), and mild in seven (15%). One (8%) was male, and 11 (92%) were female. Interestingly, all patients with severe and moderately severe postoperative voice breaks reported dramatic improvements on their VHI-10, were happy with the surgery results, and would strongly recommend surgery. Closer evaluation revealed that these patients had improved fluency postoperatively, although they still had voice breaks. Among the seven patients rated to have mild voice breaks, three had improved scores on the VHI-10 (VHI-10 score decreased by 15, 18, and 34) and indicated in the questionnaire that they had no spasmodic voice breaks, one patient did not return the survey, and the last three had minimal changes in the VHI-10 score (-5, -3, and 3). One of the latter three also had moderate breathiness postoperatively.

Interrater reliability was very good to excellent. The average measure ICC for breathiness was 0.76 and 0.83 for the preoperative voice samples and 0.90 and 0.92 for the postoperative voice samples at the first and second

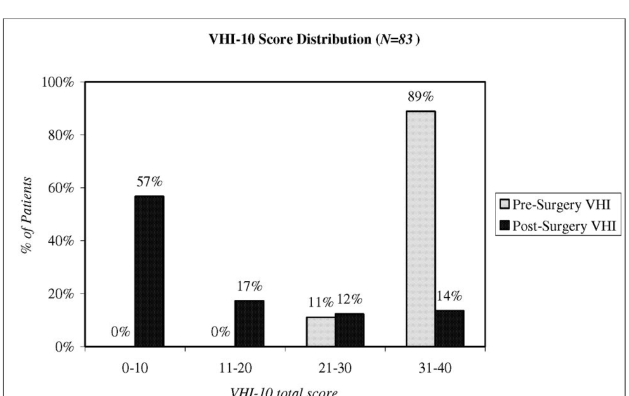

Fig. 1. Total Voice Handicap Index (VHI)-10 score distribution before and after surgery.

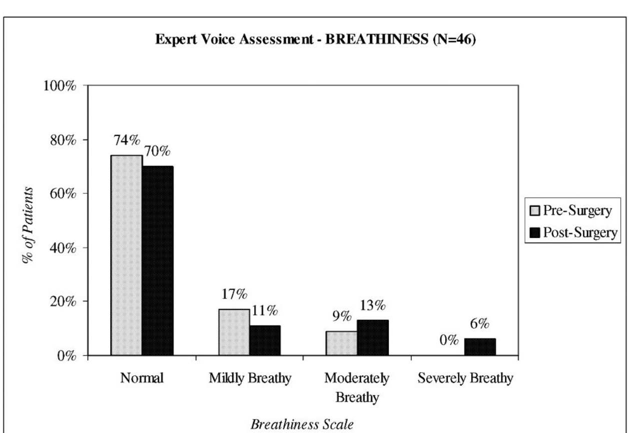

Fig. 2. Expert perceptual voice evaluation for "breathiness" before and after surgery.

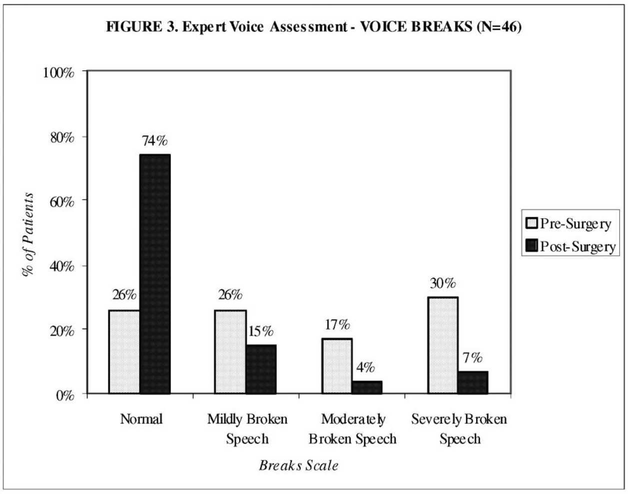

Fig. 3. Expert perceptual voice evaluation for "voice breaks" before and after surgery.

rating sessions, respectively. The average measure ICC for voice breaks was 0.92 and 0.84 for the preoperative voice samples and 0.91 and 0.89 for the postoperative voice samples at the first and second rating sessions, respectively. Intrarater reliability measures ranged between 0.66 and 0.87 (Pearson's r, $P < .001$ for all raters). There was significant correlation between postoperative VHI-10 scores and breathiness (Pearson's r = 0.84, $P < .01$) but not with voice breaks (Pearson's r = 0.10, $P > .05$).

DISCUSSION

The etiology of ADSD remains unknown. Treatment of this condition is therefore directed at the neuromuscular level to eliminate the effects of aberrant neural signals. Although Botox therapy has been effective, it cannot be the ultimate solution for this vocally debilitating condition. This study demonstrates that patients with ADSD have major limitations of psychosocial and emotional function as shown by the preoperative VHI-10 scores. Patients with ADSD want to cure SD for good and avoid the ups and downs of Botox. A permanent cure for SD is needed indeed.

The results from this study are very promising for SLAD-R surgery to effect long-term cure of ADSD symptoms and to improve the functional, social, and emotional quality of life. Patients in general were highly satisfied with the surgical outcome (Table III). Eighty-three percent improved their VHI-10 scores significantly. Eighty-two percent felt the speech outcome after surgery was better after the surgery than after Botox. Eighty-three percent would recommend the surgery to others.

Patients with suboptimal results could be divided into two groups. The first group consisted of patients with recurrence of dystonia, a true failure of the operation. The second group consisted of patients with long–term postoperative breathiness, an undesirable outcome from the operation. Although mild breathiness is often expected after this surgery and well tolerated by the patients, our results indicate that the possibility of moderate to severe postoperative breathiness exists in up to 20% and must be discussed before the operation. Postoperative breathiness correlates with patient dissatisfaction from surgery, as evidenced by significant change in VHI-10 score in patients with recurrence of dystonia alone but lack of improvement in VHI-10 scores in patients with moderate to severe breathiness, even if there was no dysfluency. Therefore, patients were more likely to associate the presence of moderate to severe breathiness as negatively affecting their psychosocial and emotional well-being compared with residual or recurrence of dystonia or mild breathiness. In this series, postoperative breathiness was present in 14 (30%) patients, but only 8 (17%) did not improve on the VHI-10. Those who tended to tolerate breathiness either had mild breathiness or such severe spasmodic symptoms preoperatively that they were willing to accept breathiness over voice breaks.

Long-term postoperative breathiness appears to be related to LCA myotomy, and we now perform limited myotomy. Initially, LCA myotomy was added after several recurrences after TA denervation and reinnervation were treated successfully with LCA myotomy. Although LCA myotomy appears to increase the potential for long-term success, it increases the risk of breathiness because of incomplete posterior commissure closure. Males appear to tolerate posterior glottic gap less well than females. With partial LCA myotomy, there is less risk of moderate to severe breathiness, although we still frequently encounter mild breathiness.

This study is a continuation of the first report on the efficacy of SLAD-R for the treatment of ADSD.[15] In that report, 21 patients were followed for a mean of 3 years, and only 2 of 21 (10%) patients had voice breaks at follow-up voice analysis. This is a longer-term study in a larger series of patients. The results show that the initial improvement in symptom is maintained long-term. When vocal spasms return, they return within 12 months, probably coinciding with the completion of nerve regeneration. The authors cannot recall any instances of recurrence of spasms after more than 24 months of symptom-free period. In this study, 12 (26%) patients were noted to have voice breaks postoperatively. The higher incidence of voice breaks in the study could be caused by the use of multiple expert listeners (some voices considered to be "normal" were considered "mild breaks" by another expert and ultimately categorized as mild breaks). Another reason is that in the earlier study, the expert listener considered voice samples with very mild dystonia within the normal range. In this study, only 5 of the 12 patients with voice breaks had moderate to severe voice breaks postoperatively. These are probably the "true failures" of the operation, and then incidence of failures in this study (11%) is similar to the earlier report (10%).

Thirty-five percent of the patients responded "Botox treated by dysphonia successfully," and five patients continued to require Botox after the surgery for SD (Table III). We looked at these two groups, in addition to other categories, to look for clinical features that explained the outcomes. No specific differences were found among those who felt they had responded to Botox. However, among those who failed surgery and still needed Botox after surgery, their preoperative dystonia symptoms were invari-

TABLE IV.
Demographics of Study Participants versus Nonparticipants.

	Lost to Follow-Up/Nonresponders (%)	Participated (%)	Total Group (%)
n	53 (39.0)	83 (61.0)	136
Females	34 (64.2)	60 (72.3)	94 (69.1)
Males	19 (35.8)	23 (27.7)	42 (30.9)
Mean age at Surgery (yr)	46.4	50.8	50
Median surgery date	7/27/2000	9/10/2000	8/23/2000

ably rated severe. The numbers are too small to perform statistical evaluations. A prospective study is underway to evaluate the preoperative, intraoperative, and postoperative features that could predict the outcome from this surgery.

This report has the inherent disadvantages and limitations of a retrospective study. The majority of our patients were from out of state, and the study included a lengthy time period. Therefore, many patients were lost to follow-up. However, 111 of 136 (81%) patients were successfully contacted, and 83 of the 111 (75%) patients returned the survey. The overall follow-up rate is therefore 61%. Of those who responded, 46 (55%) patients had adequate pre- and postoperative voice samples for perceptual analysis. If those who were lost to follow-up, or did not respond to participate, were less likely to have had success from surgery, then the results presented here would be biased. However, it has been our experience that patients who were not improved postoperatively are more likely to contact us to ask why they are not better, and those who improve go on with their lives and do not contact us again after the initial follow-up. Therefore, this study is more likely to capture the majority of complications and failures because these patients remain in contact longer, and their addresses and telephone numbers accordingly remain current in medical records and therefore are less likely to be lost to follow-up. A demographic analysis of patients who participated in this study compared with nonresponders or those lost to follow-up shows no significant difference (Table IV). Therefore, we believe the data presented here are probably accurate and reflective of the overall population that has undergone SLAD-R surgery.

Further studies are needed to understand the etiology of recurrent voice breaks after denervation reinnervation surgery. Possible mechanisms include failure of reinnervation by the ansa cervicalis nerve, regrowth of RLN axons into the laryngeal adductors, and residual spasmodic dystonia in the IA muscle. This surgery does not treat the IA muscle, and it is possible symptoms return because of IA activity once complete glottic closure is obtained after reinnervation.[23] Further investigations are also needed to understand the biomechanical, acoustic, and motoneuronal changes effected by the surgery. Other investigative approaches such as LEMG, acoustic analysis, and aerodynamic analysis may shed light into these areas. A prospective study is underway to further understand this surgery.

CONCLUSIONS

SLAD-R is an operation on the microanatomy of the larynx (intralaryngeal nerves and muscles) to alter its biomechanics (laryngeal resistance) to treat the symptoms of ADSD. The results indicate it provides long-lasting relief of dystonia symptoms in the majority of patients. The risk of postoperative breathiness is linked to the degree of LCA myotomy and should be discussed with patients. Partial LCA myotomy appears to reduce this risk. Further studies are needed to evaluate the neuromuscular and biomechanical parameters altered by surgery.

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