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Surgery or Botulinum Toxin for Adductor Spasmodic Dysphonia: A Comparative Study

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Objectives: Currently, botulinum toxin (Botox) injection is the standard of treatment for adductor spasmodic dysphonia (ADSD). We sought to compare the outcome of selective laryngeal adductor denervation-reinnervation (SLAD-R) surgery for ADSD to that of Botox injections.

Methods: Patient-oriented measures (VHI-10) and objective single-blinded gradings of digital voice recordings were utilized as outcome measures. The surgical cohort, recruited by retrospective patient selection, consisted of 77 patients with a mean follow-up time of 7.54 ± 2.55 years (range, 2.2 to 14.2 years). The injection cohort, recruited prospectively, included 28 patients with a mean follow-up time of 46.37 ± 5.51 days (range, 36 to 54 days).

Results: As measured by the VHI-10, the surgical patients had significantly improved voice handicap outcome scores (mean, 14.4 ± 13.6) as compared to the patients who had Botox injection (mean, 26.5 ± 12.1; p = 0.001). Aside from VHI-10 item 2, the surgical group demonstrated significantly improved voice-related function on each VHI-10 component (p = 0.01). Within the injection subgroup, 88% agreed that Botox successfully treats their ADSD, yet only 63% agreed that Botox improves their speech consistently. Within the surgical subgroup, 82% would recommend this surgery to others, and 78% agreed that their voice was actually better after surgery than after Botox. Objective voice ratings demonstrated similar levels of breathiness and overall voice quality in the treatment subgroups.

Conclusions: When indicated, the SLAD-R surgery for ADSD demonstrates outcomes equal to or superior to those of the current standard of Botox injections.

Key Words: adductor spasmodic dysphonia, botulinum toxin, hyperkinetic dysphonia, laryngeal dystonia, larynx, neurologic voice disorder, surgery, voice.

INTRODUCTION

Adductor spasmodic dysphonia (ADSD) is the most common form of laryngeal dystonia. It causes unwanted voice breaks and significantly diminishes patients' quality of life.[1] Although the exact pathophysiologic mechanism is still under investigation, like other dystonias, ADSD is central in origin.[2] However, unlike other forms of dystonia, ADSD is not responsive to muscle training or laryngeal exercises. Voice therapy as a single treatment modality[3] or in combination with pharmaceutical therapy[4] has shown little to no success. Additionally, no treatment to date has successfully targeted the central level of the disorder. Instead, current treatment strategies block the aberrant signaling. The current standard of therapy for ADSD is botulinum toxin (Botox) injections to the intrinsic laryngeal adductor musculature. Botox works by specifically and permanently inhibiting the presynaptic release of acetylcholine, thus effectively blocking neuromuscular activation. Botox therapy has successfully improved ADSD symptoms and quality of life in numerous studies, including a double-blind trial[5] and a massive institutional case series.[6] Although Botox inhibits muscle spasms, it does not affect the underlying disorder. Thus, when new presynaptic vesicles sprout, bypassing the Botox blockade, the centrally mediated dystonic signaling returns until Botox can be readministered. This cyclic nature of ADSD treatment is an unfortunate reality for the majority of patients. In fact, patients with ADSD spend from 57%[7] to 66%[8] of their voice cycles with a suboptimal voice. The suboptimal voice is a result of either awaiting the full therapeutic effect or experiencing a therapeutic decline. Although Botox has been described as the best available therapy,[8] investigators continue to seek improvements in the treatment of ADSD.

Although several surgical interventions are currently proposed for ADSD, such as myoplasty[9] or thyroplasty,[10] only one targets the disordered neu-

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romuscular signaling. First described in 1999, the selective laryngeal adductor denervation-reinnervation (SLAD-R) procedure demonstrated encouraging voice outcomes in a pilot study.[11] The SLAD-R creates its "selective denervation" by opening a window in the thyroid cartilage so that the adductor branch of the recurrent laryngeal nerve (RLN) can be selectively severed, leaving the posterior branch intact. The unaltered abductor muscle can therefore continue normal function; however, the dystonic adductor signaling is disrupted. In order to prevent RLN regrowth, as had been seen previously with RLN section,[12] the adductor branch is reinnervated via a direct anastomosis with a branch of the ansa cervicalis. Reinnervation occurs after an estimated 3 to 6 months, and serves to maintain muscle tone and bulk while preventing RLN regrowth. A long-term follow-up study demonstrated consistency of SLAD-R voice outcomes.[13] Although this study demonstrated the durability of the voice improvement, the efficacy of SLAD-R in comparison to the current standard of Botox therapy is unknown. In this study, we sought to determine whether SLAD-R surgery produces lasting outcomes comparable to, or superior to, those of Botox injections. On the basis of our earlier studies, we hypothesized that SLAD-R patients would demonstrate subjective and objective outcomes superior to those of injection patients.

METHODS

This study was approved by the Institutional Review Board of the University of California–Los Angeles (UCLA Medical-IRB protocol 09-07-0290-01).

SLAD-R Surgical Technique. The surgical protocol for SLAD-R has been previously described in detail.[11,13] Over the past 16 years, the extent of the lateral cricoarytenoid (LCA) myotomy has lessened. The limited LCA myotomy, especially in men, has been noted to reduce the severity of postoperative dysphagia and breathy dysphonia. As the female voice can better tolerate a posterior glottal gap,[14] a more substantial LCA myotomy may be performed in women. This glottal gap is not frequently found in men. A large LCA myotomy has therefore left men with substantial postoperative breathy dysphonia. On the other hand, an overly cautious myotomy may lead to ADSD recurrence. After SLAD-R, patients typically spend 1 or 2 nights in the hospital until the Penrose drain is removed and adequate oral intake is achieved.

Surgical Subgroup Recruitment. Patients who underwent the SLAD-R procedure between January 1, 1995, and December 31, 2007, were included in the initial recruitment. All SLAD-R procedures were performed at UCLA, and all were performed by the senior author (G.S.B.). The patient list was generated from billing codes. Within the inclusion time period, 157 patients from 34 states were identified. A recruitment package was sent to each patient's last known billing address, along with a written survey and a voice recording script. Ultimately, 42 patients were lost to follow-up and 4 patients died. When necessary, medical charts were also searched for patient emergency contacts to identify updated contact information. Of the 111 patients with verified contact information, 77 surgical patients (69.4%) participated in the study.

Injection Subgroup Recruitment. Patients with ADSD who presented for botulinum toxin type A (Botox, Allergan Inc, Irvine, California) injections were approached for voluntary participation. The senior author administered every injection included in the present study. Only patients with at least 2 prior successful injections, as determined by the senior author as having achieved improved postinjection voice symptoms, were asked to participate. The patients were given written research information, and only after the injection was participation agreement or refusal obtained. The injections were performed via the point-touch technique, which has been described previously.[15] The injection date was documented, and injection patient participation was confined to no earlier than 5 weeks after injection and no later than 8 weeks after injection. The strict time constraint was placed to ensure the capture of the optimal Botox therapeutic plateau.[7,8] With 77 patients included in the surgical arm, an a priori power calculation was used to determine the ideal number of injection patients to recruit. A test of difference between 2 independent means was utilized to estimate the Voice Handicap Index–10 (VHI-10) outcome. In order to identify a medium-size effect with an alpha level of 0.05, a power of 0.80, and an allocation ratio N2/N1 of 0.5, 38 injection patients were estimated for recruitment. Through 3 months, 30 injection patients were recruited, but 2 withdrew during the study. An interval data analysis was performed with the remaining 28 injection patients, which identified significant ($p < 0.05$) mean treatment outcome differences with a large effect size ($d = 0.95$). Post hoc analysis of the VHI-10 results demonstrated a power level of more than 0.99, so with 28 patients, recruitment was closed.

Written Surveys. The VHI-10 was utilized as the main patient-oriented outcome measure. The VHI-10 is a validated patient-based measure of functional deficits that arise from voice disorders, and has been

suggested as a more useful measure of voice-related treatment than biological or physiological measures.[16] Additionally, the VHI-10 has been specifically identified as a reliable measure with ADSD patients.[17]

Supplementary questions were included along with the VHI-10. These included demographic data, questions regarding additional medical conditions, and subjective questions regarding the status of the voice and related symptoms following treatment. The list of subjective questions is detailed below.

Voice Recordings and Rating. The surgical and injection subgroups underwent identical voice recording protocols. All patients were called from the same landline telephone within a dedicated room. A DS-40 digital voice recorder (Olympus, Center Valley, Pennsylvania) was connected directly to the telephone handset by microphone adapter. The DS-40 uses a sampling frequency of 44.1 kHz and has an overall frequency response of 50 to 16,000 Hz, although the telephone lines remove frequencies below approximately 300 Hz and above 3,400 Hz. The patients were called and asked to read from a previously mailed telephone script. They first sustained the vowel /*a*/ for a minimum of 5 seconds. The patients were next prompted for a sample of spontaneous speech in response to the request "Tell me about your voice before you began treatment." After at least 10 seconds of spontaneous speech, the patients were asked to read 5 sentences designed to elicit voice breaks. The single most commonly dysphonic sentence was "We mow our lawn all year," which was therefore chosen for inclusion in perceptual tests. The voice recordings were then edited by a single author (A.H.M.) on Sound Forge v10 (Middleton, Wisconsin). The recordings were reduced to 10 seconds: 2 seconds of sustained vowel, 5 seconds of spontaneous speech (with references to either Botox or surgery deleted), and 3 seconds of the standardized sentence.

The open source ALVIN2 software was chosen as the rating platform.[18] ALVIN2 presented edited voice samples in a random and blinded fashion. The monitor displays 5 individual visual analog scales for 5 rating components: overall voice quality, breathiness, roughness, vocal strain, and voice breaks. Raters are allowed to replay the samples without limit, but are not allowed to return to a previously graded response. ALVIN2 presents raters with a visual analog scale and automatically records the distance from left (normal voice) to right (severely deviant) on each scale as a score between 0 (normal voice) and 1,000 (severely deviant).

Three expert voice raters (2 clinical voice scientists and 1 otolaryngologist) completed the ratings for all 96 voice samples. None of the experts had treated any of the study patients, nor had any of the raters heard any of the voices before grading. The raters listened to voice samples in a quiet environment with over-the-ear headphones.

Statistical Analysis. Statistical significance was defined as a p value of less than 0.05. Subgroup demographic differences were compared by use of χ^2 tests, Fisher's exact test, and difference of means testing as appropriate. The VHI-10 scores, as an ordinal variable, were analyzed with nonparametric tests (Mann-Whitney, Kruskal-Wallis), including comparisons of individual VHI-10 components and overall scores. Descriptive statistics alone were used in reviewing the subjective questioning results. Pearson's correlation coefficients measured interrater reliability; r values below 0.50 were treated as nonsignificant, regardless of the associated p value. Spearman's rho was utilized to identify relationships between patient-based and clinical grading outcomes. The p values were corrected for multiple comparisons. Statistical analyses were conducted with SPSS v17.0 (Chicago, Illinois).

RESULTS

The demographic breakdown of the 77 surgical patients and the 28 injection patients are displayed in Table 1. The treatment subgroups demonstrated statistical similarity based on gender, age at treatment, ADSD time course, and additional medical history. However, the surgical group demonstrated a substantially higher percentage of patients who underwent voice therapy before they chose surgical intervention ($p < 0.001$). The mean (±SD) follow-up times were 7.54 ± 2.55 years (range, 2.2 to 14.2 years) for the surgical subgroup and 46.37 ± 5.51 days (range, 36 to 54 days) for the injection subgroup.

Survey Results. The mean (±SD) posttreatment total VHI-10 scores were 26.46 ± 12.09 for the injection group and 14.22 ± 13.60 for the surgical group, indicating significantly ($p < 0.001$) improved patient-oriented voice outcomes for surgery versus injection. Additionally, the surgical subgroup demonstrated significantly improved scores on each VHI-10 component except for VHI-10 item 2 ("People have difficulty understanding me in a noisy room"). Table 2 displays the mean scores for each of the VHI-10 components stratified by treatment subgroup. Additionally, the VHI-10 outcomes in each treatment group were substratified by gender; however, no significant difference was found ($p = 0.52$).

Additional surgical outcome questions utilizing

TABLE 1. DEMOGRAPHIC DATA

	Injection Group (n = 28)	*Surgery Group (n = 77)*	*p*
Female	21 (75.0%)	53 (68.9%)	0.54*
Male	7 (25.0%)	24 (31.1%)	
Average (±SD) age at treatment (y)	53.86 ± 14.1	52.9 ± 13.0	0.74†
Average (±SD) age at onset of adductor spasmodic dysphonia symptoms (y)	37.2 ± 18.3	41.0 ± 14.1	0.32†
Average (±SD) age at diagnosis of adductor spasmodic dysphonia (y)	43.9 ± 16.4	46.0 ± 12.6	0.50†
History of voice therapy	0 (0%)	50 (67.6%)	<0.001‡
Coexisting medical conditions			
Neurologic disorder	6 (21.4%)	12 (15.6%)	0.48*
Laryngeal disorder	1 (3.5%)	5 (6.5%)	0.98‡
Diabetes	0 (0%)	4 (5.2%)	0.57‡
Autoimmune disorder	4 (14.3%)	8 (10.4%)	0.80*
Psychological disorder	4 (14.3%)	5 (6.5%)	0.38*
Gastroesophageal reflux disease	8 (28.6%)	32 (41.6%)	0.23*

*χ^2 test.
†*t*-test.
‡Fisher's exact test.

VHI-10 scoring options (0 = strongly disagree; 1 = disagree; 2 = undecided; 3 = agree; 4 = strongly agree) were submitted to the surgical subgroup (Table 3). With a mean score of 3.44, the surgical group would recommend the SLAD-R procedure to others with ADSD, with 5 patients (6.5%) dissenting. The surgical patients noted improved fluency (mean score, 3.41) and a better voice quality than they had experienced after Botox injection (mean score, 3.38). However, 23 surgical patients (31.1%) did respond that they still experienced some level of postoperative dysphagia. The average time to optimal swallow function was 17.36 ± 30.71 weeks after operation. The surgical patients also noted continued voice improvement until an average of 37.61 ± 57.12 weeks after operation.

Matching subjective questions were submitted to the injection patients. Opinions varied as to whether injections consistently achieved similar levels of voice improvement after each treatment (mean score, 2.63). However, the injection group did feel that the Botox treated their ADSD symptoms successfully (mean score, 3.33), and most did not experience any spasms with the Botox in place (mean score, 1.57). Although many patients experienced temporary dysphagia lasting an average of 1.44 ± 1.21 weeks, the injection group as a whole was not experiencing substantial swallowing difficulties at the time of the survey (mean score, 1.00). The injection patients required an average of 4.14 ± 5.76 weeks for maximal voice improvement after injection.

Voice Rating Results. The posttreatment voice recordings were presented to the raters in a randomized blinded fashion. The inter-rater reliability was computed for each of the 5 grading criteria. Only

TABLE 2. VOICE HANDICAP INDEX–10 RESULTS

		Injection Group (n = 24)	*Surgery Group (n = 74)*	*p*
VHI 1	My voice makes it difficult for people to hear me	2.54 ± 1.56	1.53 ± 1.48	0.008
VHI 2	People have difficulty understanding me in a noisy room	2.67 ± 1.40	2.00 ± 1.62	0.100
VHI 3	My voice difficulties restrict personal and social life	2.79 ± 1.44	1.35 ± 1.55	<0.001
VHI 4	I feel left out of conversations because of my voice	2.30 ± 1.40	1.25 ± 1.45	0.004
VHI 5	My voice problem causes me to lose income	2.17 ± 1.67	0.95 ± 1.35	0.002
VHI 6	I feel as though I have to strain to produce voice	2.74 ± 1.45	1.40 ± 1.54	0.001
VHI 7	The clarity of my voice is unpredictable	2.92 ± 1.25	1.64 ± 1.58	0.001
VHI 8	My voice problem upsets me	3.04 ± 1.37	1.50 ± 1.56	<0.001
VHI 9	My voice makes me feel handicapped	2.83 ± 1.40	1.27 ± 1.53	<0.001
VHI 10	People ask, "What's wrong with your voice?"	2.75 ± 1.42	1.46 ± 1.62	0.001
VHI-10 Total		26.46 ± 12.09	14.22 ± 13.60	<0.001

Table displays mean (±SD) VHI-10 score for each component (0 = strongly disagree; 1 = disagree; 2 = undecided; 3 = agree; 4 = strongly agree). Associated p values were calculated via Mann-Whitney nonparametric analysis. As demonstrated, surgical subgroup had significantly better total VHI-10 score, as well as better scores on each component, except for item 2.

TABLE 3. SUBJECTIVE VOICE QUESTIONNAIRE RESULTS

	Injection Group (n=24)	*Surgery Group (n=74)*	*p*
My speech is more fluent after the (surgery/injection)	3.13 ± 1.01	3.41 ± 1.11	0.05
I am not embarrassed speaking in public	2.59 ± 1.30	3.00 ± 1.36	0.13
My speech is understandable	3.29 ± 0.96	3.45 ± 0.92	0.29
Botox (treated/treats) my spasmodic dysphonia successfully	3.33 ± 0.70	1.66 ± 1.32	<0.01
I have NOT had any spasmodic dysphonia symptoms since the (surgery/injection)	2.08 ± 1.44	2.77 ± 1.41	0.03
I have NOT experienced breathing difficulties since the (surgery/injection)	3.30 ± 1.19	3.22 ± 1.28	0.97
I have NOT experienced any new swallowing problems since the (surgery/injection)	2.88 ± 1.30	2.65 ± 1.49	0.59
The breathiness of my voice following (surgery/injection) has improved over time	2.95 ± 1.05	3.32 ± 1.16	0.02
I still have vocal spasms when I speak	1.57 ± 1.36	1.17 ± 1.48	0.12
I still have swallowing difficulties since the (surgery/injection)	1.00 ± 1.29	1.38 ± 1.57	0.05
I would recommend this operation to others with spasmodic dysphonia		3.45 ± 1.11	
I would be interested in alternatives to Botox injections	3.08 ± 1.02		
I need Botox treatments after the surgery for spasmodic dysphonia		0.53 ± 1.14	
I need Botox treatments more frequently now	1.39 ± 0.89		
My speech is better following the surgery than following Botox		3.39 ± 1.12	
My speech improves to the same level after each injection	2.63 ± 1.17		
Time until maximal speech improvement (wk)	4.14 ± 5.76	37.61 ± 57.12	
Time until maximal swallow function (wk)	1.44 ± 1.21	17.36 ± 30.71	

Table displays mean (±SD) subjective score for each subjective questionnaire item (0 = strongly disagree; 1 = disagree; 2 = undecided; 3 = agree; 4 = strongly agree). Questions were tailored to patient treatment groups. Certain questions could not be asked of both groups, and responses are subdivided by treatment group. Associated p values were calculated by nonparametric rank sum analysis. Statistical analysis was not applied to select measures, given differences of administered subjective questionnaires.

overall voice quality and breathiness were rated reliably (overall voice quality: Pearson's r = 0.58, 0.63, 0.62, p < 0.001; roughness: r = 0.51, 0.34, 0.35, p < 0.001; breathiness: r = 0.78, 0.64, 0.76, p < 0.001; vocal strain: r = 0.33, 0.26, 0.18, p = 0.01; voice breaks: r = 0.25, 0.37, 0.35, p = 0.01). The mean scores for both categories were similar between the two treatment groups for both overall voice quality (injection group, 379 ± 199; surgical group, 342 ± 213; p = 0.44) and breathiness (injection group, 185 ± 184; surgical group, 169 ± 232; p = 0.73; Fig 1). Additionally, the scores for voice quality and breathiness were significantly correlated (Pearson's r = 0.55; p < 0.001), suggesting a connection between these two grading criteria. Neither voice quality (p = 0.99) nor breathiness (p = 0.42) grading was affected by patient gender.

Finally, we investigated the correlation between the VHI-10 scores and the ratings of voice quality. The total VHI-10 scores and the breathiness scores were poorly correlated (Spearman's rho = 0.14; p = 0.21). However, the total VHI-10 scores demonstrated a modest correlation with the overall voice quality scores (Spearman's rho = 0.48; p < 0.001; Fig 2).

DISCUSSION

Adductor spasmodic dysphonia is an incurable condition for which effective symptomatic treatments are available. The most widely available treatment is Botox injections administered to the laryngeal adductor musculature. Botulinum toxin consistently improves voice and quality of life in patients with ADSD.[19] However, there are numerous issues that can hamper the utilization of Botox. First, the

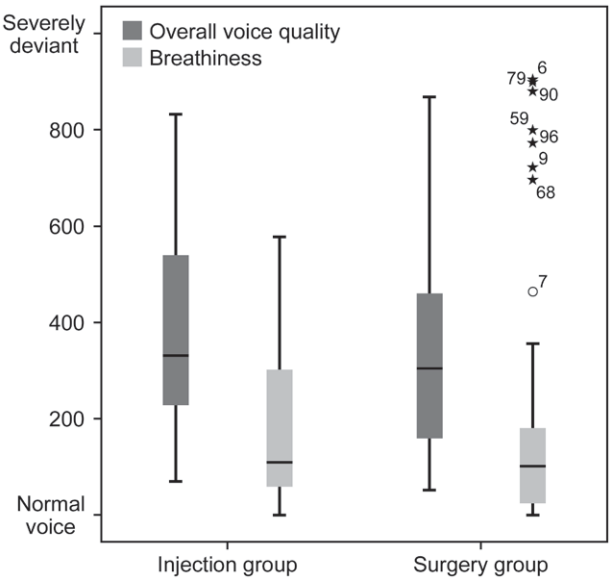

Fig 1. Averaged voice rating scores (y-axis) are displayed stratified by treatment subgroup. Neither ratings for overall voice quality nor ratings for breathiness were significantly different between patients with surgery and patients with botulinum toxin injection. Median values and quartile ranges are seen to be quantitatively equivalent.

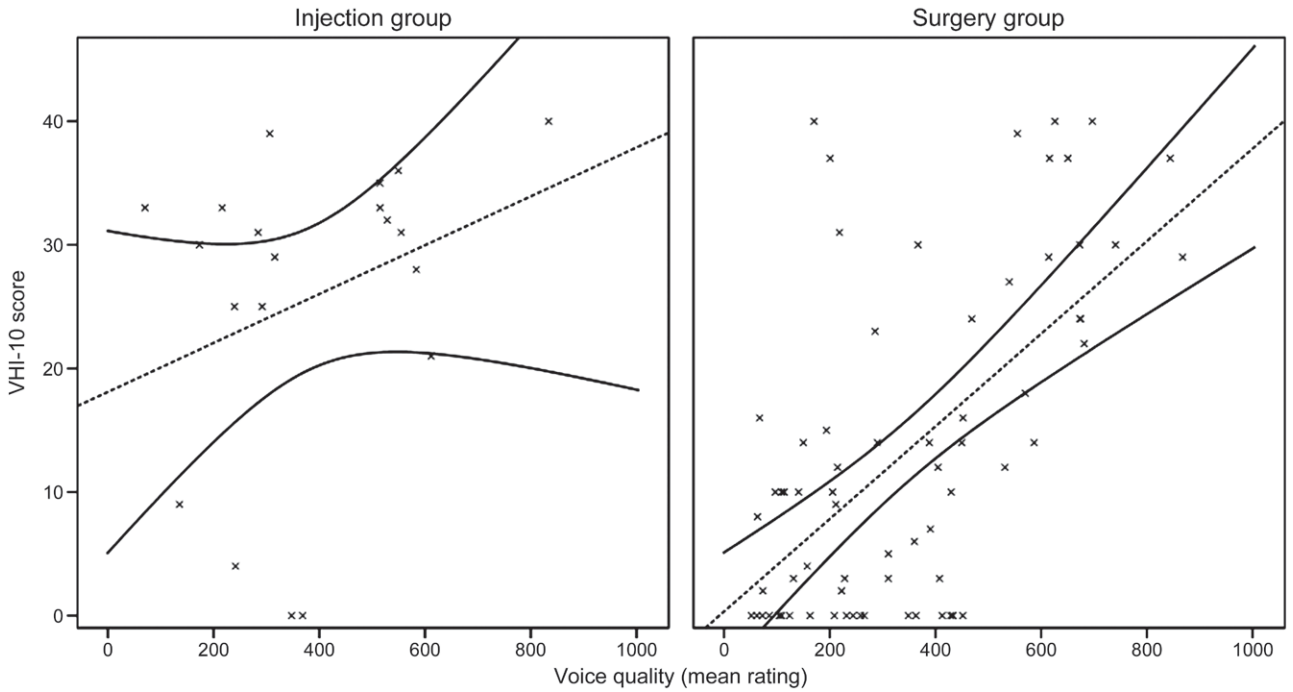

Fig 2. Voice Handicap Index–10 (VHI-10) and overall voice quality rating scores are plotted with estimated linear regression lines (dotted) and 95% confidence interval curves. Scatterplots are stratified by treatment subgroup (injection subgroup, R^2 = 0.094; surgical subgroup, R^2 = 0.376).

optimal dosage is highly variable, and individualized requirements must be discovered by trial and error.[7] Botox-induced neuroblockade takes an average of 2 or 3 days to complete,[20] after which a significantly breathy voice can be expected for up to 10 days.[7] The duration of the improvement in symptoms varies by individual,[7] but on average lasts 3 to 6 months.[6] After the plateau of optimal voice quality, a subsequent period of decline in voice quality can last for up to 33% of the treatment cycle until repeat injection can be performed.[8] The strain of this undulating cycle is consistent with the finding that the patients treated with Botox gave the most negative ratings on the VHI-10 components addressing voice unpredictability and associated emotional strain.

Repeated Botox injections can also become financially burdensome because of the costs of the injectate, office visits, time off from work, and, in some cases, significant travel expenses. It is also our opinion that over many years, precise injections become increasingly more challenging because of scarring of the injection sites. Therefore, some patients become more interested in alternative methods of ADSD treatment. Before surgical intervention, most patients within the present study had tried at least one alternative therapy — most commonly, voice therapy (68% of patients). This trend was especially striking in light of the finding that none of the injection patients had tried voice therapy.

To the end of finding a permanent solution to these problems, the SLAD-R surgery was developed in the 1990s.[11] Although a long-term follow-up study demonstrated more than 4 years of improved voice and quality of life, it was still unknown how well SLAD-R outcomes compared to the outcomes of Botox therapy. Additionally, the durability of effect of the SLAD-R procedure has been questioned.[20] With a mean follow-up of 7.5 years, the present results confirm the long-term efficacy of this procedure. In total, the results reported herein demonstrate, at a minimum, a therapeutic equivalence, as measured by an objective rating, and superiority, as measured by patient-based instruments.

The patient-based outcomes were measured via posttreatment use of the VHI-10. The VHI-10 scores were significantly and substantially lower in the surgical group (mean, 14.22) than in the injection group (mean, 26.46), suggesting improved patient-based voice outcomes following surgery as compared with Botox treatment. Although every effort was made to test the injection patients during their optimal therapeutic window, this subgroup's posttreatment scores were still abnormal. The mean injection VHI-10 score in the present study is elevated over what has been previously reported for VHI-10 scores of patients with ADSD treated with Botox.[7,17] However, the mean surgical VHI-10 score of the present study equals or exceeds previously reported injection VHI-10 scores. It is conceivable that the injection group's elevated VHI-10 score represents their

decreased quality of life throughout their entire cycle, as opposed to the limited time of capture. In fact, additive factors such as emotional and psychological stress play a large role in overall ADSD quality-of-life measurements[8] and should be considered in analyzing strict voice-related outcomes. Because some patients who have undergone SLAD-R may no longer associate themselves with ADSD, the continued stress of the disorder no longer manifests. The poor correlation between the VHI-10 scores and voice quality ratings in the Botox group suggests a personal bias. In other words, some patients with satisfactory objective voice quality ratings scored themselves poorly on the VHI-10.

The ratings of breathiness and overall voice quality did not differ significantly between the two treatment groups, demonstrating that SLAD-R produced voice quality results similar to those of Botox injection, but on a long-term basis. The durable nature of the surgical effects also implies a need for caution. As seen specifically in the breathiness ratings, there were outliers within the surgical treatment group, consistent with occasional poor outcomes that led to worsened dysphonia. Postoperative voice breaks can be successfully managed with postoperative injections. In the current cohort, 7 of 72 surgical patients (9.7%) had received postoperative Botox injections for spasm recurrence. However, of these patients, 3 reported substantial improvement of their fluency after SLAD-R, and all 3 would recommend the surgery to others with ADSD. The remaining 4 of 72 patients (5.6%) have persistent and residual untreated ADSD.

Voice ratings placed 8 of 72 postsurgical voices (11%) as outliers on a breathiness scale. The breathiness ratings for these outliers were positively correlated with the VHI-10 scores (mean, 28.5; $r = 0.49$; $p = 0.03$). However, of these severely breathy patients, 50% would still recommend the surgery to others with ADSD, and 75% feel that their voices are more understandable since the surgery. These observations suggest that patients with relatively poor postsurgical voice outcomes may still consider themselves successfully treated.

Dysphagia is typically a transient postoperative symptom, yet in some cases, dysphagia has been protracted. From the subjective data, 13 of 72 patients (18%) experienced a noticeable decrease in their swallowing function, and 11 of 72 (15%) noted a more significant dysphagia. Yet, as a measure of satisfaction, 11 of 13 patients (85%) with subjectively mild dysphagia and 7 of 11 patients (64%) with subjectively severe dysphagia would still recommend SLAD-R to other ADSD patients. In comparison, 8% of the injection subgroup had noticeable dysphagia, and an additional 8% experienced subjectively significant dysphagia, consistent with previous reports that laryngeal injection of Botox is not devoid of treatment complications.[6,21] Future study with objective swallowing function measures may help elucidate the risk of dysphagia with SLAD-R. Patients with ADSD must weigh the risks and benefits of injections and surgery.

Several limitations of the present study must be mentioned. Most prominently, the pretreatment condition is not included in the present analysis. The magnitude of voice improvement is dependent on the severity of the untreated ADSD,[19] and absolute conclusions cannot be drawn without understanding the pretreatment severity of either subgroup. However, given the length of follow-up and the diffuse geographic composition of the study population, this factor was unavoidable. The use of telephone recordings also limits the conclusions from perceptual analyses. It is possible that the bandpass-filtering of the telephone transmission caused reductions in inter-rater agreement levels, although telephone recordings have been successfully used in previous research.[8,22]

CONCLUSIONS

Patients who underwent SLAD-R surgery for ADSD demonstrated significantly improved patient-based measures of vocal function in comparison to patients who received Botox injections. Additionally, expert listeners' ratings of voice quality did not differ significantly between the groups with surgery and Botox injection. Positive voice outcomes were seen at an average of 7.5 years after surgery, and thus can be considered durable. In conclusion, the SLAD-R surgery should be considered a reasonable therapeutic alternative to Botox injections for patients with ADSD.

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REFERENCES

1. Bhattacharyya N, Tarsy D. Impact on quality of life of botulinum toxin treatments for spasmodic dysphonia and oromandibular dystonia. Arch Otolaryngol Head Neck Surg 2001; 127:389-92.

2. Ludlow CL, Adler CH, Berke GS, et al. Research priorities in spasmodic dysphonia. Otolaryngol Head Neck Surg 2008;139:495-505.

3. Murry T, Woodson GE. Combined-modality treatment of adductor spasmodic dysphonia with botulinum toxin and voice therapy. J Voice 1995;9:460-5.

4. Silverman EP, Garvan C, Shrivastav R, Sapienza CM. Combined modality treatment of adductor spasmodic dysphonia. J Voice 2011 Feb 2 [Epub ahead of print].

5. Troung DD, Rontal M, Rolnick M, Aronson AE, Mistura K. Double-blind controlled study of botulinum toxin in adductor spasmodic dysphonia. Laryngoscope 1991;101:630-4.

6. Blitzer A, Brin MF, Stewart CF. Botulinum toxin management of spasmodic dysphonia (laryngeal dystonia): a 12-year experience in more than 900 patients. Laryngoscope 1998;108: 1435-41.

7. Novakovic D, Waters HH, D'Elia JB, Blitzer A. Botulinum toxin treatment of adductor spasmodic dysphonia: longitudinal functional outcomes. Laryngoscope 2011;121:606-12.

8. Paniello RC, Barlow J, Serna JS. Longitudinal follow-up of adductor spasmodic dysphonia patients after botulinum toxin injection: quality of life results. Laryngoscope 2008;118:564-8.

9. Shaw GY, Sechtem PR, Rideout B. Posterior cricoarytenoid myoplasty with medialization thyroplasty in the management of refractory abductor spasmodic dysphonia. Ann Otol Rhinol Laryngol 2003;112:303-6.

10. Chan SW, Baxter M, Oates J, Yorston A. Long-term results of type II thyroplasty for adductor spasmodic dysphonia. Laryngoscope 2004;114:1604-8.

11. Berke GS, Blackwell KE, Gerratt BR, Verneil A, Jackson KS, Sercarz JA. Selective laryngeal adductor denervation-reinnervation: a new surgical treatment for adductor spasmodic dysphonia. Ann Otol Rhinol Laryngol 1999;108:227-31.

12. Dedo HH, Behlau MS. Recurrent laryngeal nerve section for spastic dysphonia: 5- to 14-year preliminary results in the first 300 patients. Ann Otol Rhinol Laryngol 1991;100:274-9.

13. Chhetri DK, Mendelsohn AH, Blumin JH, Berke GS. Long-term follow-up results of selective laryngeal adductor denervation-reinnervation surgery for adductor spasmodic dysphonia. Laryngoscope 2006;116:635-42.

14. Södersten M, Hertegård S, Hammarberg B. Glottal closure, transglottal airflow, and voice quality in healthy middle-aged women. J Voice 1995;9:182-97.

15. Green DC, Berke GS, Ward PH, Gerratt BR. Point-touch technique of botulinum toxin injection for the treatment of spasmodic dysphonia. Ann Otol Rhinol Laryngol 1992;101:883-7.

16. Rosen CA, Lee AS, Osborne J, Zullo T, Murry T. Development and validation of the voice handicap index–10. Laryngoscope 2004;114:1549-56.

17. Morzaria S, Damrose EJ. A comparison of the VHI, VHI-10, and V-RQOL for measuring the effect of Botox therapy in adductor spasmodic dysphonia. J Voice 2010 Oct 15 [Epub ahead of print].

18. Hillenbrand JM, Gayvert RT. Open source software for experiment design and control. J Speech Lang Hear Res 2005; 48:45-60.

19. Cannito MP, Woodson GE, Murry T, Bender B. Perceptual analyses of spasmodic dysphonia before and after treatment. Arch Otolaryngol Head Neck Surg 2004;130:1393-9.

20. Blitzer A. Spasmodic dysphonia and botulinum toxin: experience from the largest treatment series. Eur J Neurol 2010;17 (suppl 1):28-30.

21. Venkatesan NN, Johns MM, Hapner ER, DelGaudio JM. Abductor paralysis after Botox injection for adductor spasmodic dysphonia. Laryngoscope 2010;120:1177-80.

22. Chhetri DK, Merati AL, Blumin JH, Sulica L, Damrose EJ, Tsai VW. Reliability of the perceptual evaluation of adductor spasmodic dysphonia. Ann Otol Rhinol Laryngol 2008;117: 159-65.