Historical approaches to the treatment of Adductor-Type Spasmodic Dysphonia (ADSD): Review and tutorial

Erin J. Pearson* and Christine M. Sapienza
Department of Communication Sciences and Disorders, University of Florida, Gainesville, FL, USA

Abstract. Adductor-type spasmodic dysphonia (ADSD) is a voice disorder of uncertain, though likely neurogenic origin. Symptoms of the disorder include mild to profound “strain and strangle” sensations during voiced speech tasks that, in the most severe form, are physically and psychologically debilitating. Over the years, treatment approaches have evolved from behavioral attempts at voice modification, to surgical and, most recently, pharmacological treatments involving partial and temporary paralysis of muscle fibers within the larynx following injection of botulinum toxin or Botox®. The most current research hints at the potential benefits of a multi-faceted approach to symptom management, combining behavioral with pharmacological treatments. The following is intended as a review and tutorial of treatment approaches for ADSD. The tutorial is intended for practicing clinical professionals with an interest in the treatment of neurogenic disorders of voice and speech.

Keywords: Spasmodic dysphonia, ADSD, voice disorder, dystonia

1. History and background on the disorder

Spasmodic dysphonia (SD) is a voice disorder, of neurogenic origin, wherein one or more muscles within the larynx exhibit irregular and uncontrollable spasms, which interfere with the production of a perceptually “normal” voice [3]. According to the National Spasmodic Dysphonia Association, the condition was first described by Traube in 1871 as a “nervous hoarseness” and assigned the label of “spastic dysphonia” [75]. For nearly 100 years following its discovery, SD was viewed as a psychogenic disorder, characteristically observed in anxious individuals and accompanied by repressed hostility over “... the pressures and losses of middle age” [41]. Over the years, SD has been reclassified as a type of focal dystonia affecting laryngeal muscles during speech. Other, non-laryngeal, focal dystonias include torticollis, blepharospasm, oral mandibular dystonia, and writer’s cramp [63]. Common to all the focal dystonias are uncontrollable and abnormal contractions of involved muscles or muscle groups.

SD is further subdivided into two main subtypes. Adductor-type SD (ADSD) is characterized by abrupt, irregular, and uncontrollable approximation or “spasms” of the vocal folds, during otherwise normal phonation, intermittently closing off the glottis and producing the impression of effortful phonation, frequently described within the medical literature as “strained,” “strangled,” “staccato,” or “squeezed” [70,96]. The second subtype, abductor SD (ABSD), is less common (occurring in only around 15% of SD cases), and characterized by uncontrollable and irregular abduction, or opening, of the vocal folds during and following voiceless consonants [63]. Individuals with ABSD may demonstrate phonatory breaks, pitch alterations and irregular periods of excessive “breathiness” during speech.

*Address for correspondence: Erin J. Pearson, M.S., CCC-SLP, Doctoral Student and Speech-Language Pathologist, University of Florida, Department of Communication Sciences and Disorders, P.O. Box 117420, Gainesville, FL 32611-7420, USA. E-mail: ejpear@hotmail.com.
The remainder of this tutorial focuses on theories regarding the causes of adductor spasmodic dysphonia (ADSD) as well as treatment approaches, with special attention paid to the role of behavioral therapies in the long-term management of the disorder. The heterogeneous nature of ADSD calls attention to the importance of treatments that address multiple aspects of the disorder: from physical symptoms, to compensatory behaviors and qualitative variables relating to patient compliance, satisfaction, and quality of life. Apart from the potentially debilitating physical symptoms of this disorder, individuals with ADSD typically exhibit decreased measures of voice-related Quality of Life, as well as increased levels of stress, anxiety, depression, and other psychosocial disturbances which present as secondary manifestations to the voice disorder [7,56,58,60] and typically resolve following successful treatment of the voice symptoms [60,73].

2. Theories and evidence on etiology

Theories as to what “causes” ADSD have evolved from early notions of vocal symptoms that result from psychological disturbance [14], to those which suggested ADSD exists as a result of excessive muscular tension. Later studies proposed that ADSD existed as a disorder of cranial (specifically, vagal) nerve dysfunction yet histologic studies have failed to identify consistent abnormalities within laryngeal nerves of individuals with ADSD compared to normal controls [19,82]. More recently, research has delved into potential contributions of both cortical (supplementary motor area) [43] and subcortical brain structures. Because of the apparent involvement of motor control systems, the basal ganglia and other subcortical structures are commonly implicated as sites of potential dysfunction. These theories are based largely on clinical observation [12,62] and hold that damage to regions of the basal ganglia results in an inability to inhibit unwanted reflex activity that occurs in response to stretching of a primary muscle [72]. In the case of ADSD, this response may occur in response to stretching of the primary muscle of vocal fold movement – the thyroarytenoid. Although dystonia is frequently observed as a correlate to subcortical injury, not all individuals who demonstrate dystonic symptoms demonstrate lesion sites within the subcortex. Frequently, there is no lesion site at all and in contrast to other focal dystonias such as torticollis there does not appear to be a strong genetic or familial component to symptom manifestation.

Studies using a variety of methods, including magnetic resonance imaging (MRI), have been unable to identify associations between ADSD symptoms and damage to any particular brain structure or region [6,30,33,87]. In a post mortem examination of an individual with a two-year history of ADSD (in addition to a number of other dystonic symptoms), Yamamoto and Yamashita [104] observed targeted degeneration of thalamic nuclei and select regions of the cerebellum, with no observable changes detected within the basal ganglia. Other studies have pointed toward potential disruption of basal ganglia inputs to brainstem interneurons [94]. In response to (and in spite of) these inconclusive findings, the search for neurogenic correlates to ADSD symptoms continues, in recent years under the assistance of functional imaging technology.

Building upon past observations of cortical dysfunction (via electroencephalography and cortical perfusion studies) carried out by Devous et al. [30] Hirano et al. [43] utilized Positron Emission Tomography (PET) in the examination of an individual with ADSD and found reduced activity within the supplemental motor area (SMA) during vocalization. The significance of this finding rests in the establishment of a heretofore unrealized locus of dysfunction within the efferent pathway from cortical motor areas to the basal ganglia and thalamus as well as secondary activation of auditory association areas within the temporal cortex, believed to function as an auditory feedback mechanism in the presence of speech dysfunction. Though preliminary (and somewhat limited – the authors acknowledged the challenges associated with functional imaging of the basal ganglia and other subcortical structures), the results add strength to theoretic models of disruption of neural networks involving both cortex and subcortex. The findings also point to the importance of functional, as well as anatomic, imaging of neural pathways as means of outlining potential areas of dysfunction in individuals with ADSD.

Future advances in the study of neuropathology in ADSD may well depend on the application of new functional imaging techniques such as fMRI to the observation of motor pathways during vocalization. The current literature, though limited, seems to suggest that fMRI serves as a viable means of examining both superficial and deep neural structures [18,21,79,105] and produces superior spatial resolution compared to other functional imaging tools. Current theory centers on ADSD as a disorder of motor circuitry rather than a
byproduct of damage to any one cortical or subcortical area in particular. Future treatment approaches may well integrate these findings with treatment approaches that directly influence neurotransmitter function throughout this network as a higher-order means of symptom resolution.

3. Treatment options

3.1. Surgical treatments for ADSD

3.1.1. Sectioning or removal of the recurrent laryngeal nerve

Surgical approaches to the treatment of ADSD were spearheaded by Dedo [25] who proposed removing a section of the recurrent laryngeal nerve (RLN) innervating one of the vocal folds, in effect paralyzing the vocal fold innervated by the nerve and preventing the spasmodic closure of the vocal folds during voicing tasks. At the time, Dedo’s protocol was viewed by many as a bold approach to treatment of a disorder that was still considered by many to be the outward manifestation of inner and psychological disturbances. In the years following Dedo’s publication, other researchers set forth less “drastic” versions of this procedure which included selective section of only those fibers responsible for vocal fold closure [20] and “crushing” (as opposed to severing) of the recurrent laryngeal nerve [11]. The latter procedure produced results similar to that of the RLN resection, however the primary voice symptoms returned upon nerve regeneration, approximately three to six months later [28,29].

In the years following Dedo’s original publication, questions began to arise as to the long-term effects of RLN resection. One of the first longitudinal studies to examine the effects of the procedure over time tracked 22 patients following RLN resection. Of those observed, five (22%) experienced return of symptoms anywhere from four months to nearly two years postsurgery [59]. Aronson and DeSanto [4] observed a greater failure rate, with 39% of 37 total patients experiencing return of symptoms up to one and a half years following surgery. Both observed, five (22%) experienced return of symptoms anywhere from four months to nearly two years postsurgery [59]. Aronson and DeSanto [4] observed a greater failure rate, with 39% of 37 total patients experiencing return of symptoms up to one and a half years following surgery. Other researchers have estimated failure rates from as low as 6% [52] and 19% [36] to as high as 64% up to three years post-surgery [5]. One explanation for this return of symptoms involves “overcompensation” of the non-paralyzed vocal fold, which, during laryngoscopic examination of most patients, appeared to cross midline in order to contact the paralyzed fold. Other observed forms of overcompensation included a “sphincteric” action of the false vocal folds and (occasionally) the inferior pharyngeal constrictor muscles [5].

Another possible explanation for symptom return is neural regrowth or “sprouting.” A study by Wilson et al. [100] found one patient’s return of spasmodic symptoms to be accompanied by complete regeneration of the RLN at 13 months post-surgery. Neural regrowth was suspected in another study where patients demonstrating symptom return experienced complete elimination of symptoms following repeat removal of the recurrent laryngeal nerve [88] and has also been supported by observations of equal electrical muscular activity within both paralyzed and non-paralyzed vocal folds following RLN resection [36,64,91]. This regrowth occurs, not only between proximal and distal nerve stumps, but also between the distal stump and any other nearby nerve branch. Although reinnervation may not result in the return of movement (reanimation) to the affected muscle, it may enable return of muscle tone to the area, thereby providing the opportunity for symptom (spasm) return [78]. Efforts to counteract neural sprouting include the procedure of nerve avulsion or “tearing away” of exposed nerve stumps [78]. A follow-up study of 18 individuals who had undergone the avulsion procedure revealed an 89% success rate at three years post-surgery (compared to Aronson and DeSanto’s three year success rate of 36%), indicating that a more extensive [97] or repeat [36] removal of the RLN was successful in preventing neural sprouting and reinnervation of the paralyzed vocal fold.

Dedo and associates emphasized the importance of voice therapy in conjunction with surgery for “maximum rehabilitation” [27,29]. The objective of postoperative voice therapy was to eliminate excessive use of low vocal pitches and vocal hyperfunction [28]. Almost all patients were noted to exhibit some form of “aberrant voice quality” or “phoniatric complications” following surgery including any number of the following symptoms: low intensity (“soft”) voice, monotone, aperiodicity, breathiness, vocal tremor, or vocal fry [27,29]. Failure to minimize hyperfunction through postoperative voice therapy was set forth as one of three possible explanations for relatively high (up to 64%) recurrence of symptoms [28]. The other two explanations included inappropriate diagnosis and surgery on individuals with extremely severe adductor symptoms.

3.1.2. Companion surgical procedures

For those patients with persistent reduction in vocal quality following RLN resection, a number of com-
Companion surgical procedures are available. Teflon injections into the paralyzed fold were introduced for patients with persistent breathlessness and reduced vocal intensity in an effort to “bulk” the tissue [29]. This procedure is generally effective in bulking the vocal folds, thereby narrowing the glottal gap and reducing airflow through the glottis during phonation thus decreasing the perception of a “breathy” voice. Vocal fold bulking remains a popular companion procedure and has evolved to utilize a variety of injectable materials including gelfoam [89], vinyl alcohol [81], collagen [84], silicone [44], and fat [42]. Conversely, vocal fold thinning is used for those patients who experienced a return of “vocal fold spasticity” following RLN resection [29]. During this procedure, a carbon dioxide (CO\textsubscript{2}) laser beam excises a 2 millimeter wide and 4 to 5 millimeter deep strip of tissue from the body of the paralyzed vocal fold [29]. The remaining tissue is then rejoined and allowed to heal, producing a “thinner” vocal fold and enhanced glottal gap, theoretically lessening the likelihood of a return of vocal spasms.

Since the introduction of the RLN resection technique, Dedo has remained a strong advocate of the procedure, occasionally speaking out regarding apparent resistance within the medical community to fully embrace RLN resection as a “permanent” cure for vocal spasticity associated with ADSD [26]. Although early publications [28] presented the procedure not as a “cure” for ADSD, but as a means of communicative enhancement, later publications by the author asserted that RLN resection was indeed as close to a “cure” as could be hoped for in a disorder of supposed neurological underpinnings [26]. Dedo cites numerous advantages to the procedure including low risk of side effects or complications, high long-term success rate of 83% (in contrast to considerably lower success rates found by Aronson and DeSanto in 1983), and relatively permanent elimination of symptoms [26]. In spite of this, RLN resection was never fully embraced as a curative therapy for ADSD and fell even further out of favor following a flagship publication introducing the use of botulinum toxin type A (Botox\textsuperscript{TM}) injections for management of ADSD [71]. Through 1991, Dedo and associates continued to advocate for the use of RLN resection, citing the temporary nature of the symptom relief obtained from injections, as well as the then-experimental nature of the injections and unknown risk of side effects [26]. Even following the introduction and widespread acceptance of Botox\textsuperscript{TM}, some authors promoted use of RLN resection for individuals for whom injections were unfeasible or ineffective [78,97].

3.1.3. Other surgical approaches

Another alternative surgical therapy for ADSD includes midline lateralization (type II) thyroplasty, as described by Isshiki and associates [46–51]. Isshiki based this and other laryngeal framework procedures as means of modifying laryngeal mechanics. This functional approach to laryngeal surgery includes procedures for vocal fold medialization, lateralization, relaxation, and tensing applied to a number of voice disorders [49]. In the case of ADSD, the mechanical “problem” is excessive closure of the glottis. Surgery for this condition was therefore designed to lessen the degree of vocal closure possible by increasing the lateral space between the left and right vocal folds. This was achieved through widening of the glottal space by first slicing the thyroid cartilage, from top to bottom, at the midline anterior commissure and separating the left and right halves of the thyroid cartilage. The two sides of the thyroid cartilage are then fixed at this “wider” position through use of silicone shims, which can be up- or down-sized at any point in the future in order to modify the distance between vocal folds [48]. Advantages to the procedure over RLN resection include the ability to modify or reverse the glottal widening through future surgeries, preservation of neural and muscular function, and low risk of complications such as neural sprouting. For individuals desiring a more “permanent” approach to symptom relief, the one-time procedure may be preferable to Botox\textsuperscript{TM} injections, which must be repeated [49–51]. This procedure, in conjunction with post-surgical behavioral shaping, was found to be successful in elimination of vocal symptoms up to one year post-surgery in a single case study involving a woman diagnosed with ADSD [51].

In addition to midline lateralization surgery for ADSD, retrusion (posterior relocation) of the anterior commissure has been used to achieve vocal fold slackening. The technique was performed on 16 patients with ADSD, all of whom experienced complete relief of vocal symptoms immediately following the procedure, followed shortly by symptom return and then, for nine of the patients, gradual and persistent elimination of vocal symptoms [95]. Notably, several subjects who underwent the retrusion procedure experienced a lowering of their habitual speaking pitches.

Removal (myomectomy) of the thyroarytenoid (TA) muscle evolved from successful attempts at symptom control of blepharospasm (uncontrollable contraction of muscles surrounding the eye) through myomectomy of the orbicularis oculi (muscle surrounding the eye) [98]. Removal of the TA is the target
of this procedure since studies have linked hyperactivity of the TA to excessive glottal tightness observed in ADSD [65, 76, 92]. During the procedure, approximately 70% of TA muscle fibers are removed through use of a carbon dioxide laser [102]. Potential advantages to the procedure over Botox™ injections or RLN resection include the potential for permanent symptom relief, ability of the surgeon to modify the extent of the myectomy for each individual patient and low risk of collateral tissue damage, dysphagia or other airway compromise, or post-surgical neural sprouting [102]. Post surgical analysis of electrical potentials within the TA muscles of animals following the procedure revealed intact, yet weakened TA muscles on the surgical side with no evidence of reinnervation or neural sprouting. Potential disadvantages to the procedure included its irreversible nature and the possibility of symptom persistence through the action of other laryngeal adductors besides the TA [38]. In spite of these findings, the procedure remains experimental and no published studies exist which utilize the technique on human subjects.

Selective bilateral denervation of the TA produces a larynx capable of full adduction and abduction (thereby lessening unwanted “breathiness” and risk of airway compromise), yet unable to forcefully hyperadduct to the degree necessary to produce elevated subglottal pressures. This is achieved through severing of the RLN on each side of the larynx (effectively paralyzing the vocal folds). The RLN is then reinnervated, bilaterally, using branches of the Ansa Cervicalis, a grouping of cervical nerves presumably unaffected by spasmodic symptoms. By reinnervating the RLN stump with Ansa Cervicalis, nerve regeneration (resulting in reanimation of the RLN) is prevented and muscular tone retained within the TA [8]. The first study to examine this procedure (in an animal model) found that following denervation, maximum subglottal pressures were 66% lower than those achieved prior to denervation [90]. The rationale behind the procedure was based on past studies, which correlated the “strain and strangle” vocal symptoms of ADSD with excessively high subglottal pressure levels [39, 77, 93]. Though conducted on a canine model, the acoustic signals obtained from the animals that had undergone the denervation procedure demonstrated lower frequency and amplitude perturbations (associated with the perception of “hoarseness”) and altered laryngeal function “in a manner consistent with the alleviation of (ADSD) symptoms” [90]. Two studies which utilized the denervation technique on 27 humans with ADSD (combined) revealed near to total symptom resolution in 90% of subjects with no post-operative airway compromise and minimal disruption in vocal quality [2, 8]. Preservation of glottal closure and sensation assist in minimizing aspiration risk following surgery [8]. Though more complex than other surgical approaches to treatment of ADSD, selective denervation stands as a promising, permanent option for achieving relief of ADSD symptoms.

3.2. Pharmacological therapies for ADSD

Because ADSD is viewed as a neurogenic disorder, though with no known site of dysfunction, pharmacological approaches, like surgical approaches, are viewed as symptomatic, rather than curative, treatments. For the symptom management of ADSD, injection of botulinum toxin type A (Botox™) has emerged as the preeminent and preferred approach due to its high rate of success and low risk of side effects [13]. Historically, Botox™ injections have been used to successfully treat other focal dystonias including blepharospasm and torticollis [16, 53]. Past successes with the treatment of these disorders led researchers to develop protocols for the treatment of ADSD [12, 71].

Published protocols involve the injection of Botox™, either unilaterally or bilaterally, into the TA muscle, the muscle comprising the main mass of the vocal folds and the primary muscle of vocal fold adduction. A recent review of existing literature on Botox™ injections for ADSD [17] concluded that neither the unilateral or bilateral injection technique has been consistently associated with better outcomes in terms of symptom relief and overall vocal function. In spite of this, some evidence exists that suggests the unilateral technique may minimize adverse side effects such as persistent breathiness and hoarseness post-injection [10, 55], produce better functional results in women [61, 68], and increase the likelihood of receiving optimal benefit from the injection (defined as a duration of symptom relief 3 months or longer) [10].

The technique first used for Botox™ injection into the larynx involved a percutaneous injection, guided into location by electromyographic (EMG) signals obtained through use of a teflon-coated hollow needle. The needle, inserted into the space between the thyroid and cricoid cartilages (located through external palpation) is directed upward toward the contralateral TA muscle. By having the patient phonate and observing the resultant EMG signal contact with the TA can be verified [71]. When injected into a muscle, Botox™ effectively denervates that muscle by tem-
porarily blocking the release of acetylcholine at the neuromuscular junction [63]. Over a period of time (typically three months) the affected nerve endings recover, and spasmodic symptoms gradually return. In the case of ADSD, partial denervation of the TA temporarily eliminates the uncontrollable spasmodic bursts responsible for the observed voice symptoms.

Although the popularity of Botox™ injections for ADSD continues to grow, the published research to date is not easily characterized or summarized. Two fairly recent publications have made efforts to this end. The first of these found that the “average patient” treated for ADSD with Botox™ treatment experienced a 97% improvement in voice, although no outcome variables demonstrated statistically significant improvement [99]. A latter study reviewed existing research literature in an effort to provide both descriptive (method of Botox™ administration and patient characteristics) and quantitative (perceptual, acoustic, and physiologic) measures [17]. In terms of quantitative acoustic measures, Botox™ injections have proved effective in reducing measures associated with vocal fold spasms, including frequency of voice breaks and variation in fundamental frequency while exerting less effect on measures associated with vocal breathiness and roughness including speech or harmonic to noise ratio measures, jitter, and shimmer. Other results reviewed included findings of reduced or altered electrical impulses within muscle units associated with voicing following injection [9,24,64], and improvement in select measures of phonatory airflow and pressures [1,101,106]. Because ADSD is a disorder affecting primarily laryngeal function, measures of airflow during sustained phonation are frequently used to assess functional changes that occur over time. These changes relate to the degree of phonatory “spasmodic” symptoms. Following Botox™ injections to one or both of the TA muscles, vocal fold hyperadduction is lessened, resulting in reduced airflow impedance and subsequent increased rates of airflow during phonatory tasks [1,32,34,69,71,106].

3.2.1. Alternative injection techniques for ADSD

Injection techniques which allow for other means of locating the injection site were developed in an effort to increase the accuracy with which toxin could be administered while eliminating the need for EMG monitoring of injection. These techniques include transoral [35] and transnasal [83] laryngoscopic injections, as well as transtracheal or “point touch” injections [39].

The first of these techniques, the transoral approach, involves indirect visualization of the vocal folds via standard laryngoscopic procedures. The vocal folds are anesthetized through application of a topical cocaine solution. A small amount of dilute Botox™ solution is then injected into two sites along the superior margin of the vocal fold [35]. Precise injection is thought to offset the need for more concentrate doses of toxin. With this technique studies have shown reduction in voice breaks, increased airflow rates during speech, and increased maximum phonation duration. Following injection, most patients expressed a preference for the transoral technique over traditional methods of EMG guided injection [35].

Inagi et al. [45] utilized a transoral approach to Botox™ injection in order to determine which muscle, or combination of muscles, once injected, provides optimum symptom relief. Compared to injection into the TA or lateral cricoarytenoid (LCA) alone, injection into both TA and LCA produced the most favorable results in terms of magnitude of symptom improvement compared to pre-injection, reduced duration of breathiness side-effects, “best” voice, and duration of “best” voice.

The transnasal injection technique uses a flexible nasolaryngoscope with a working channel (a small channel just to the side of the lens which runs the entire length of the scope) that is equipped with a flexible catheter needle. Topical phenylephrine (decongestant) and lidocaine (anesthetic) spray is administered transnasally prior to nasolaryngoscope insertion. Once the scope is placed, a lidocaine solution drip is applied to the surface of the vocal folds via the working channel while the patient phonates so as to avoid airway penetration or aspiration. Injections of Botox™ solution is administered bilaterally, at sites just lateral to the true vocal fold so as to avoid direct puncture or damage to the vocal fold mucosa [83]. In their initial study of 12 patients who received Botox™ injections via the transnasal technique, both benefits and side effects were found to be comparable to previously reported injection techniques. Individual patient needs, equipment availability, and convenience were presented as the primary variables for consideration prior to implementation of the transnasal technique [85].

The transtracheal or “point touch” injection technique refers to the relative ease with which toxin can be injected (cartilage being relatively more dense than muscle, and therefore more difficult to inject into) as means of determining the location of the needle tip within the laryngeal structures [39]. The technique in-
volved insertion of the needle through the surface of the thyroid cartilage halfway between the thyroid notch and inferior edge of the thyroid cartilage. In some patients, especially those with calcification (hardening) of the thyroid cartilage, the needle is passed instead through the cricothyroid membrane at the base of the thyroid cartilage, similar to traditional, percutaneous approaches. Following insertion, the needle is passed through the cartilage and into the TA muscle where the Botox™ is injected. Benefits of the procedure include minimal side effects, reduced measures of vocal acoustic perturbation, reduced measures of airway resistance and preserved vocal fold mobility [39].

A recent review of existing literature on injection techniques, concluded that transnasal and transoral yield similar results in terms of functional benefit to patients and, although transnasal and transoral approaches to injection have demonstrated lower failure rates than percutaneous EMG-guided methods, they may be less well-tolerated by patients [17,37].

The subject of acquired resistance to botulinum toxin is emerging with increasing frequency within the medical literature. Although the risk of developing a resistance is considered low, given the small amounts of toxin which are administered for the management of ADSD symptoms, it appears to be a risk nonetheless. Patients who develop an immunoresistance to the A toxin [80,86] may still be able to experience symptom relief through switching in injections of an alternative form of botulinum toxin, botulinum toxin B (known commercially as Myobloc™ or Neurobloc™) [86]. Patients with non-ADSD dystonias (e.g. individuals with cervical dystonia or torticollis) who exhibit resistance to the type A toxin have demonstrated enhanced responsiveness when switched to the B toxin, although this responsiveness may be short-lived [31]. Further study is needed into the utility of botulinum toxin type B treatment of ADSD.

3.3. Alternative therapies for ADSD

A single case study, published in 1991, recalled an earlier focus on cranial nerve (RLN) dysfunction as the basis for ADSD symptoms. Wood [103] reported on symptom treatment, and eventual resolution, through a series of chiropractic manipulations involving “derotation” of the first (atlas) and second (axis) cervical vertebrae. These manipulations were hypothesized to be effective in alleviating the symptoms of ADSD by relieving compression of the vagus nerve at the point where the nerve exits the bony structures of the upper cervical region at the occipital foramen, restoring normal efferent nerve conduction.

The above-mentioned study raises several interesting observations, especially when compared to other reported therapies for ADSD, which hold as their focus the “correction” of RLN dysfunction. Wood’s hypothesis that adductory symptoms were brought about as a result of impaired efferent (motor) signal conduction within the RLN and that symptom relief was to be achieved by removing this compression (presumably allowing for restored efferent function) stands in direct contrast to other, RLN-focused, studies. The studies upon which the author bases his hypothesis reported symptom relief through complete removal (via resection) of the RLN. Other studies involving laryngeal nerve crush (an intentional impairment of all nerve conduction achieved by “crushing” portions of the nerve thereby blocking conduction) have also reported symptom improvement, though temporary in nature with symptom return following natural repair, over time, of the nerve’s conductive properties. Given the findings from the RLN resection and crush studies, it would be expected any decompression or normalization of the RLN to exacerbate, rather than alleviate, spasmodic symptoms.

No information regarding the subject’s prior attempts at treatments were presented, other than that he had undergone “various therapies,” all of which had failed to provide symptom relief [103]. Interestingly, the subject demonstrated no neurological signs beyond those described as “strain and strangle” speech.

Citing ADSD as characteristic of “a general imbalance in energy regulation” or “Chi,” several studies have investigated the utility of acupuncture in the treatment of ADSD [23,57]. The first of these consisted of a case-comparison between two individuals diagnosed as demonstrating ADSD, one of which was treated with Botox™ injections into the TA muscle, bilaterally. The other patient, after having refused Botox™ treatment, was treated via acupuncture one time per week for two months. Dependant variables within this study were acoustic measures of voice including fundamental frequency (F0), standard deviation of F0, jitter, shimmer, and noise to harmonic ratio. Additional dependent variables were duration measures including MPT (maximum phonation time), phrase grouping (number of words per breath), speech rate (words read per minute), and sentence duration. The subjects’ performance on each of these variables was measured pre-treatment and at a single point post treatment. Both subjects demonstrated “improvement” (reduction
of acoustic measures, increase in durational measures) following their respective treatments. No statistical analyses were performed on the data, and the authors stopped short of setting forth acupuncture as a successful treatment for ADSD, citing the need for continued study [23].

A more recent study examined the effects of a standardized acupuncture treatment on various acoustic ($F_0$, intonation stimulability, vocal intensity), temporal (tremor frequency, diadochokinetic rate, syllable rate), and qualitative (Voice Handicap Index, Unified Spasmodic Dysphonia Rating Scale, CSL Motor Speech Profile) voice variables. Following baseline data collection, 10 subjects undergoing no other treatment for ADSD were enrolled in a standardized eight-session course of acupuncture therapy along the Lung/Large Intestine Distinct Meridian, including electrical stimulation for six of the eight sessions. Following acupuncture, significant improvement in vocal tremor, periodicity, lowest $F_0$, vocal intensity, and average total score of the Voice Handicap Index [57] occurred. Results from the Unified Spasmodic Dysphonia Rating Scale, a perceptual measure used by clinicians to assess a number of voice and speech characteristics, revealed no significant improvements in perceptual judgments of voice quality during a reading sample from pre- to post-treatment. Experimenters who utilized the Scale were blinded to patient identity as well as to whether the recording occurred prior to, or following, acupuncture treatment. Seven of the 10 subjects reported improvements in voicing, though only four stated that they would be willing to continue the treatment in the future. Though mixed, these results suggested the need for continued research of alternative therapies for ADSD. The authors concluded with a discussion of the importance of patient perception in the assessment of treatment outcomes for ADSD as initially noted by Lundy et al. [66].

### 3.4. Behavioral therapies for ADSD

Behavioral therapies for ADSD seek to improve voicing through systematic changes in the way an individual uses his or her voice. Prior to the emergence of surgical or pharmacological treatments, these therapies were the preliminary means through which symptoms of ADSD were addressed. In many cases, behaviorally-driven voice therapy approaches were discredited and subsequently discarded out of frustration when conventional means of vocal rehabilitation failed to offer long-lasting relief to the seemingly impossible-to-treat patient with ADSD. In spite of this history, behavioral therapies have found a niche within the overall picture of clinical management, emerging as a low-risk and (comparatively) low-cost means of assuring optimal treatment outcomes. Medical management of ADSD continues to evolve, along with the realization that, at the present time, there is no definitive cure with treatment as a patient- and symptom-specific venture. Existing, as well as new, information suggests that behavioral therapies may play a role in the management of ADSD.

Behavioral treatment approaches for ADSD grew out of frequently observed and well-documented improvement in vocal symptoms achieved through use of specific, volitional voicing behaviors such as whispered or breathy voice, non-communicative vocalizations (coughing or throat clearing), singing, humming, or pitch alterations [15].

One such maneuver involves the use of inspiratory speech or “inverse phonation” and is based on the theory that the inspiratory process (involving abduction of the vocal folds along with activation of inspiratory muscles directly counter the actions of spasm-prone adductory muscles active during normal, expiratory speech, producing a “gentler” approximation of the vocal folds [40,70]. Though isolated cases document the success of this technique, it has demonstrated only limited clinical utility over the years due to difficulties in habituating inspiratory speech to everyday communication tasks.

Manual laryngeal tension reduction (sometimes referred to as “laryngeal massage”) is a procedure aimed at reducing muscular tension within the larynx by manually repositioning the larynx within the throat. As
described by Roy, Ford, and Bless [85] the technique involves targeted, deep pressure applied to the superior border of the thyroid lamina which is then gently coaxed to move both laterally and inferiorly, countering the tendency of tight extrinsic laryngeal muscles to “raise” the resting position of the larynx. Use of manual laryngeal tension reduction has not been shown to exert long-term symptom improvement in individuals with ADSD, but is useful in differentiating ADSD from other laryngeal disorders of hyperfunction, for which it is effective [85]. An example of this would be a patient presenting with dysphonia as a result of excessive laryngeal tension or hyperfunction who, following a session of targeted laryngeal massage, is able to achieve significant improvement in dysphonia symptoms.

Henschen and Burton [41] published a report on progressive relaxation therapy for ADSD utilizing electromyographic (EMG) biofeedback for symptom improvement. The subjects were two individuals who had received no benefit from prior, traditional, voice therapy. The treatment utilized combined visual and auditory feedback to encourage progressive relaxation of muscles surrounding the larynx. Following treatment, there was no noted improvement in muscular tension levels, or patient self-assessment of “tension” following treatment. An additional observation was made surrounding patient compliance to the relaxation therapy, which varied from very low in one patient, to very high in the other. The authors applied these observations to garner further support for ADSD as a disorder of psychogenic origin. A follow-up “personality study” indicated both subjects shared a number of personality characteristics including hostility, an inability to express anger, ambitiousness, a need to conform, immaturity, impulsivity, poor tolerance for frustration, excessive self-control, and reaction against the “pressures” and “losses” of middle age [41].

Traditional voice therapy strategies to decrease vocal hyperfunction in turn decreasing incidence of pitch breaks have been used both in isolation, and in combination with other therapies for ADSD [70]. Sometimes referred to as “direct voice rehabilitation,” these techniques include the identification and habituation of a “natural” speaking pitch level and range, establishing a “forward focus” to the voice, enhancing breath support for speech and carryover of learned behaviors into conversational contexts [22,70]. Though specific therapy activities will vary from clinical setting to clinical setting, these general principles remain the focus of most voice therapy sessions for individuals with ADSD.

Scattered throughout the literature on ADSD exist accounts alternately “revealing” the total success, questionable benefit, or complete failure of behavioral techniques in symptom management. In a 1991 review of treatment options for ADSD, Miller and Woodson stressed the importance of continued research into the role of speech therapy in the management of ADSD in order to optimize treatment success and clinical understanding of ADSD within the era of Botox™ therapy [70]. In spite of this need for continued research, to date there is one published study addressing the role of behavioral (speech) therapy in the combined-modality (voice plus Botox™ therapies) management of ADSD. This study, carried out by Murry and Woodson [74] examined 27 subjects with ADSD who were assigned to either experimental (Botox™ injection with voice therapy) or control (injection only) groups. Behavioral therapy approaches utilized within the study focused on the facilitation of “easy onset” voicing, the use of continuous airflow during phonation, and the reduction of articulatory effort. The data obtained as a result of this study suggests that behavioral treatment approaches may enhance the effectiveness of Botox™ injections by reducing hyperfunctional vocal behaviors such as hard glottal attacks and excessive laryngeal tension [74]. These hyperfunctional behaviors are often compensatory in nature and are developed over time, by individuals with long-standing ADSD, as means of countering vocal spasms, and may persist even after the spasms are eliminated via injection. By assisting the patient in unlearning these behaviors, the patient is better able to achieve easy phonation with reduced effort [70]. In addition to this, those subjects who underwent the combined modality treatment of Botox™ injections plus voice therapy were able to increase the duration of the time period between injections. Subjects who received the combined modality treatment went an average of 7.4 weeks (with a range of 13 to 54 weeks) prior to the next injection whereas the mean time between injections for the injection-only group was 14.9 weeks (with a range of 9 to 26 weeks).

Theory behind the use of combined modality treatment for ADSD is grounded within principles of sensorimotor “retraining.” Theory holds that muscular weakening (such as that which occurs following Botox™ injection) effectively suppresses maladaptive sensorimotor loops, which feed dystonic symptoms [54]. It is during this period of weakening that the patient is most able to acquire (and ideally habituate) new sensorimotor templates. In the case of ADSD, this retraining holds as its focus the production of “easy” and continuous voicing while minimizing extraneous muscular tension.
These results provide a sound, though preliminary, basis for further exploration of a multifaceted approach to the treatment of ADSD. This need was reiterated by Boutsen et al. [17] who, at the conclusion of an exhaustive meta-analysis of all studies to date addressing the effects of Botox™ injections on ADSD, concluded that the “important and frequently overlooked” issue of development of compensatory strategies following injection should stand as a centrally important objective for future studies.

Future investigations into the efficacy of behavioral management for ADSD, whether alone or in combination with other therapies, should implement the basic standards of experimental design presented by MacKenzie et al. [67]. Utilizing a single-blind, randomized controlled trial, the authors were able to document statistically significant results in a combination of objective and subjective outcome measures following six weeks of either behavioral therapy or, as a control, no therapy for generalized dysphonia.

A phase I clinical trial to examine the effects of combined modality approaches to the management of ADSD is currently underway at the University of Florida and is supported by a grant from the Dystonia Medical Research Foundation and National Spasmodic Dysphonia Association (Christine Sapienza, Ph.D., PI). Study objectives include determining the effects of combined modality (pharmacologic plus behavioral) management of ADSD compared with standard (pharmacologic only) management protocols on Quality of Life measures, as well as selected acoustic indices of vocal function. Subjects enrolled at each of the study’s three recruitment sites (Gainesville, Orlando, and Miami) are randomly assigned to receive either standard (Botox™ only), combined modality (Botox™ plus behavioral voice therapy targeting hyperfunctional vocal behaviors resulting from habitual compensatory strategies), or sham (Botox™ plus placebo voice therapy designed to preserve patient expectations and patient-clinician interactions with no direct targeting of vocal behaviors) therapies. Results obtained from this study should enhance understanding of physiologic mechanisms which underlie ADSD symptoms, as well as the manner in which these symptoms are best managed.

An additional research priority is the determination of the etiology of ADSD. In light of continued failure to identify a lesion site responsible for ADSD symptoms, future investigations will employ technologies to examine brain physiology (that is, the way in which various areas of the nervous system are activated) as a potential means of uncovering the neurological underpinnings of the disorder. Increasing emergence of cases involving “Botox™ resistance” within individuals receiving only small doses for management of ADSD stands as an additional area of research priority, as are continued efforts to achieve consensus as to optimal procedures of toxin administration. Finally, continued refinement of surgical procedures may yet produce a true “cure” for ADSD, enabling permanent resolution to a heretofore chronic condition.

References


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<table>
<thead>
<tr>
<th>Treatment approach</th>
<th>Treatment</th>
<th>Advantages</th>
<th>Disadvantages</th>
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<tbody>
<tr>
<td>Pharmacological</td>
<td>Botulinum toxin type A (Botox™)</td>
<td>Readily available; the current “gold standard” approach for symptom management; temporary nature allows for dosage adjustments; less invasive than surgical options.</td>
<td>Not a permanent “cure” – must be repeated at regular intervals; small risk of acquired immunoresistance; potential for adverse side-effects incl. overly “breathy” voice and airway compromise.</td>
<td>Miller et al. (1987) Whurr et al. (1998) Blitzer et al. (1998) Benninger et al. (2001)</td>
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<tr>
<td>Pharmacological</td>
<td>Botulinum toxin type B (Myobloc™ or NeuroBloc™)</td>
<td>May provide a viable alternative for individuals with an acquired resistance to botulin toxin type A.</td>
<td>Limited availability; limited history of use with ADSD.</td>
<td>Sataloff et al. (2002)</td>
</tr>
<tr>
<td>Surgical</td>
<td>Laryngeal nerve crush</td>
<td>A “temporary” means of assessing effects of full RLN resection; non-drug treatment option.</td>
<td>Invasive – carries surgical risks; temporary – symptom return upon nerve regeneration; expensive</td>
<td>Billar et al. (1989)</td>
</tr>
<tr>
<td>Surgical</td>
<td>Laryngeal framework approaches</td>
<td>A “permanent” treatment option; Does not target nerve function</td>
<td>Invasive – carries surgical risks; limited availability.</td>
<td></td>
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<tr>
<td>Surgical</td>
<td>Selective laryngeal adductor denervation-reinnervation</td>
<td>A “permanent” treatment, assuming reinnervation is successful in preventing RLN reanimation; enhanced airway protection because laryngeal adduction is preserved</td>
<td>Invasive – carries surgical risks; still a fairly “new” procedure with limited history of use in humans; expensive</td>
<td></td>
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<tr>
<td>Behavioral</td>
<td>Voice therapy</td>
<td>Inexpensive when compared to other treatments for ADSD; no side-effects; no contraindications; non-invasive; may enhance and/or prolong effects of pharmacological interventions.</td>
<td>Not effective against primary (spasmodic) symptoms of the disorder; requires high levels of patient compliance; specific behaviors must be maintained/practiced over time.</td>
<td>Murry and Woodson (1995) Miller and Woodson (1991)</td>
</tr>
<tr>
<td>Other</td>
<td>Acupuncture</td>
<td>Less invasive than surgical or pharmacological options; few known side-effects or contraindications.</td>
<td>Experimental; no standardized treatment protocol; limited documentation within medical literature.</td>
<td>Crevier-Buchman et al. (1997) Lee et al. (2003)</td>
</tr>
<tr>
<td>Other</td>
<td>Progressive Relaxation</td>
<td>Noninvasive; inexpensive; may be useful as a companion procedure to inhibit compensatory hyperfunction which occurs secondary to the primary symptoms.</td>
<td>Not effective against primary (spasmodic) symptoms of the disorder.</td>
<td>Henschen and Burton (1978)</td>
</tr>
<tr>
<td>Other</td>
<td>Chiropractic manipulation</td>
<td>Noninvasive; relatively inexpensive compared to more standard treatments.</td>
<td>Very limited documentation within medical literature; no documentation of use within groups of patients; theory behind use stands in opposition to current neurophysiologic theory regarding ADSD.</td>
<td>Wood (1991)</td>
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