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Differentiating between adductor and abductor spasmodic dysphonia using airflow interruption

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Abstract

Objective—To measure the laryngeal resistance (R_L), subglottal pressure (P_s), and mean flow rate (MFR) of adductor (ADSD) and abductor (ABSD) spasmodic dysphonia patients using the airflow interrupter.

Methods—The R_L of six ABSD and seven ADSD patients was measured using the airflow interrupter, a noninvasive device designed to measure MFR and P_s via mechanical balloon valve interruption. Subjects performed ten trials at each of two intensity levels, with each trial consisting of a sustained /a/ during which phonation was interrupted for 500 ms. Laryngeal resistance was calculated as subglottal pressure divided by airflow.

Results—Mean R_L for the ADSD and ABSD subtypes at 65 dB were 24.78 cmH₂O/l/s and 14.51 cmH₂O/l/s, respectively ($p = 0.04$). Mean R_L at 70 dB were 40.02 cmH₂O/l/s and 15.84 cmH₂O/l/s ($p = 0.014$). P_s for the ADSD and ABSD subtypes at 65 dB were 10.23 cmH₂O and 8.32 cmH₂O, respectively ($p = 0.582$). At the 70 dB level, P_s were 12.39 cmH₂O and 11.78 cmH₂O ($p = 0.886$). MFR for the ADSD and ABSD subtypes at 65 dB were 435 ml/s and 746 ml/s ($p = 0.205$). Mean MFR at 70 dB were 518 ml/s and 848 ml/s ($p = 0.198$).

Conclusion—Noninvasive measurements of R_L may be useful for differentiating between ADSD and ABSD. This simple objective test which produces a quantitative output could be used to evaluate laryngeal function in patients with spasmodic dysphonia.

Keywords

spasmodic dysphonia; laryngeal resistance; airflow interruption; mean flow rate; subglottal pressure

Introduction

Spasmodic dysphonia (SD) is a voice disorder that causes hyperadduction, hyperabduction, or both of the vocal folds (1). Adductor spasmodic dysphonia (ADSD) is characterized by hyperadduction and represents approximately 85 – 95 % of cases (2,3). Persons with ADSD have a strain-strangle voice quality with pitch breaks and occasional breathiness (4–6). Abductor spasmodic dysphonia (ABSD) results from either hyperactivity of the posterior cricoarytenoid or the failure of the lateral cricoarytenoid or thyroarytenoid muscles to contract. Individuals affected by ABSD exhibit effortful phonation as well as interruption of normal or hoarse voice by whispered or voiceless segments (4,7). Though the disorders have

been characterized both mechanically and acoustically, there is a great deal of variance even among patients with the same subtype (8). A third subtype, mixed SD, exhibits characteristics of both ADSD and ABSD (7,9). Diagnosis and subtype classification is further complicated by muscle tension dysphonia (MTD), another neuromuscular voice disorder presenting with similar symptoms to SD (10). ADSD and ABSD affect different muscles of the larynx. Treatment of these disorders with Botox injections requires locating the correct muscle and delivering Botox to it. While it is true that the classical case of ADSD is easy to distinguish from a classical case of ABSD, it is not always this straight forward. There are ADSD patients who have compensatory episodes of breathiness. These patients generally respond well in Botox injections of the thyroarytenoid (TA) and/or lateral cricoarytenoid (LCA) muscles. There are also others that are truly mixed AD- and ABSD that are more difficult to manage.

Current diagnosis of SD and classification of its sub-types relies heavily upon perceptual evaluation (7,9). However, perceptual analysis is subjective and relies on the impressions of the voice analyst. Though the use of expert analysts improves inter-analyst agreement, analysts frequently disagree when rating symptom severity and importance (11). The absence of a standard test (12) further hinders consistent diagnosis by perceptual evaluation.

Perceptual analysis of voice and laryngoscopy are the primary methods used to differentiate between the ADSD and ABSD sub-types (2). Quantitative acoustic analysis using parameters of tremor and fundamental frequency are employed secondarily (7). Though acoustic parameters can be easily measured, the relationship between acoustic and perceptual measures is not always clear. Watson et al. were unable to distinguish between ADSD and ABSD based on acoustic measures (13). Including acoustic analysis can even complicate or confuse previously made diagnoses. Patients previously diagnosed with one subtype according to perceptual evaluation can present with the acoustic characteristics of the other (14). Laryngoscopy, particularly videostroboscopy, has been used with success to diagnose SD (15). However, videostroboscopy does not provide definitive information on ABSD patients (16) and the procedure is not amenable to all patients (17). Both stroboscopy and flexible laryngoscopy have value when diagnosing SD, although neither is considered optimal. Stroboscopy is useful to detect tremor associated with SD and differentiate SD from tremor when there is uncertainty. Stroboscopy is also more reliable than flexible laryngoscopy in detecting subtle changes, such as abductor spasms, during sustained vowels. The value of flexible laryngoscopy lies in its ability to detect the voice breaks exhibited by SD patients during connected speech.

Aerodynamic measurements offer an objective and quantitative alternative to perceptual analysis. Noninvasive measurements of subglottal pressure (P_s) and airflow could be used not only to aid in the diagnosis of SD, but also the classification of its subtypes. Though disagreements between perceptual and acoustic measures may occur when evaluating SD patients, hyperadduction and hyperabduction correspond to predictable changes in P_s and airflow. In this study, indirectly estimated P_s , airflow, and derived laryngeal resistance (R_L) measurements were recorded from both ADSD and ABSD patients to determine if aerodynamic measures could reliably differentiate between the two subtypes.

Materials and Methods

Design

The experimental apparatus (figure 1) was similar to that described in Jiang et al., 1999 (18). A mouthpiece (Series 9063, Hans Rudolph, Inc., Kansas City, MO) was held in the subject's mouth against the labial surface of the teeth. This was used instead of a mask to eliminate variability associated with mask placement. The mouthpiece was connected to a PVC pipe

with a diameter of 1.905 cm and length of 12 cm. The PVC pipe was fitted with a pressure and airflow transducer/Pneumotach amplifier (Series 1110, Hans Rudolph, Inc.). The voltage outputs of the transducer were relayed via baby-N connector cables to a data acquisition system (model DAQCard-6036E, National Instruments, Austin, TX), and the signals were digitized and coordinated with interruption and subject feedback on intensity level (LabVIEW custom-programmed Voice Analyzer data acquisition software program, National Instruments). The researcher actuated an inflatable balloon valve (Series 9340, Hans Rudolph, Inc.) inflated after approximately 1.5 seconds of phonation to interrupt subject expiratory airflow, allowing subglottal pressure and supraglottal pressure to equilibrate. The balloon requires 84 ms to inflate and the interruption lasted 500 ms, during which time pressure could be measured inside the lumen of the PVC pipe. A nose clip (Series 9014, Hans Rudolph, Inc.) was used to prevent airflow through the nasal cavity.

Human Subject Testing

This study was done under the approval of the University of Wisconsin – Madison Institutional Review Board. Thirteen previously diagnosed patients were recruited from the patient population of one author (CNF). All patients were free of pulmonary disorders. Seven ADSD and six ABSD patients participated immediately before receiving their regularly scheduled Botox injections. Subjects were allowed to get accustomed to the system and the interruption. This was followed by two sets of ten trials, each lasting about five seconds. The first set was performed at an intensity level of 65 dB and the second at an intensity level of 70 dB. Variations in sound pressure level of $\pm 2\%$ were allowed from the desired amplitude.

Data Analysis

Supraglottal pressure and airflow data traces were analyzed with a customized LabVIEW 8.0 program. The method presented by Hoffman et al., 2008 (19) was used to estimate P_s . The maximum pressure achieved within the first 150 ms from the moment supraglottal pressure began its increase was recorded as the P_s . When measuring airflow, a novel method of automated analysis using a window of least standard deviation was employed. As mean flow rate (MFR) represents a stable airflow, measuring airflow at the time when it is least variable should approximate MFR. The method measures the section of data lasting 100 ms that has the smallest standard deviation and computes the mean within this window. This value represents the estimated airflow.

To determine if R_L , P_s , and MFR were significantly different between the two subject groups, t-tests were performed. If data were not normal, a Mann-Whitney rank sum test was performed. A significance level of $\alpha = 0.05$ was used.

Results

Mean R_L for the ADSD and ABSD subtypes at 65 dB were 24.78 cmH₂O/l/s and 14.51 cmH₂O/l/s, respectively ($p = 0.04$). Mean R_L at 70 dB were 40.02 cmH₂O/l/s and 15.84 cmH₂O/l/s ($p = 0.014$) (figure 2). Significant differences in P_s were not found at either the 65 dB level ($p = 0.582$) or 70 dB level ($p = 0.886$) (figure 3). Significant differences were also not found for MFR at either the 65 dB level ($p = 0.205$) or 70 dB level ($p = 0.198$) (figure 4). Summary data can be seen in table 1. Individual subject data are provided in figure 5.

Discussion

The data from this study support the use of aerodynamic parameters to aid clinicians in the classification of SD subtypes. Significant differences between ADSD and ABSD were found for R_L . Conducting additional studies to increase sample size would lead to the estimation of mean values and variances which more closely approximate actual population values. These could then be considered if utilizing aerodynamic assessment when diagnosing new patients.

Because resistance of the larynx cannot be directly measured, P_s and MFR were used to derive R_L . Physiologically, though, R_L is the parameter that is modulated by the musculature of the larynx. As SD affects muscular control, the effects of this disease will be seen most prominently in R_L . The lack of significance in MFR and P_s could be attributed to these parameters proportionally changing. For example, two subjects in the ADSD group had mean R_L of 26.89 and 26.04 cmH₂O/l/s. However, the first subject's MFR and P_s were 270 ml/s and 7.16 cmH₂O, while the second subject's were 51 ml/s and 1.23 cmH₂O. Even though these two subjects had drastically different values for P_s and MFR, their calculated resistances were still typical for their subtype.

Like acoustic analysis using parameters such as fundamental frequency or tremor, aerodynamic assessment offers objective numerical results. However, while acoustic analysis can be disparate to other methods of diagnosis (14), the aerodynamic values obtained in this study corresponded to the diagnoses made using videostroboscopy. The muscular activity characteristic of SD has predictable effects on airflow, pressure, and resistance. During hyperadduction, the smaller glottal area increases R_L , causing the pressure drop across the glottis (P_s) to increase while decreasing MFR. Accordingly, hyperabduction is characterized by decreased P_s , increased MFR, and decreased R_L . Typically, ABSD patients would exhibit below normal R_L , below normal P_s , and above normal MFR. ADSD patients would be characterized by above normal R_L , above normal P_s , and below normal MFR. These relative relationships were demonstrated by Finnegan et al. (20) although the only significant difference found was for P_s between ADSD and control subjects. Only one ABSD subject was included in this study as ABSD is far less than prevalent than ADSD, but this subject did behave according to theoretical predictions. Differences in aerodynamic parameters can be attributed to the hyperactivity of laryngeal musculature characteristic of SD. By incorporating aerodynamic measurement into the routine clinical assessment of patients with SD, clinicians can take advantage of these predictable relationships that reflect symptoms and symptom severity.

Though mean R_L was significantly different between ADSD and ABSD, there was some overlap in the ranges for the two subtypes. For example, one ADSD subject had a mean R_L of 15.12 cmH₂O/l/s at 70 dB, slightly below the ABSD overall mean of 15.84 cmH₂O/l/s. This could possibly be attributed to the subject exhibiting only mild symptoms. When expanding study sample size, it may be beneficial to test newly diagnosed patients before receiving their first Botox injection. In this study, the time between injections was variable. Because each patient responds differently to Botox injection and the decision of when to return for treatment is made by the patient, there is also variability in symptom severity. However, any residual functioning toxin would move patients closer to normal ranges for the aerodynamic parameters. This demonstrates the sensitivity of our method to measure the effect of SD on R_L , even when patients are exhibiting decreased symptom severity.

Significant differences were found for R_L between the subtype groups in this study using sustained phonation, but more evident differences may be discovered if measuring parameters during connected speech. To do this, traditional aerodynamic equipment would have to be modified. Changing current methodology to facilitate application to connected

speech will be investigated in future studies. Exploring alternative methods of measuring subglottal pressure which do not completely interrupt phonation, such as incomplete airflow interruption (21), will be the subject of future research.

Quantitative assessment of laryngeal function is not only useful during diagnosis, but can also be used as an easy means of tracking patient progress during treatment and evaluating the efficacy of Botox injections. While videostroboscopy has been a useful addition to the battery of tests commonly used to assess SD, it remains a subjective non-quantitative measure. Though a qualitative test, it can provide information on hyperfunctional muscular activity, which can be correlated with diagnostic voice breaks. Furthermore, it can often help in distinguishing SD from muscle tension dysphonia and tremor. However, in cases where it is difficult to distinguish abductor and adductor components in an SD patient, videostroboscopy is often of limited value. In such instances, a quantitative measurement may aid in patient assessment. Using airflow interruption and videostroboscopy in conjunction with perceptual evaluation and acoustic measures may provide clinicians with a more complete picture of laryngeal function.

Conclusion

The aerodynamic parameters of patients with adductor and abductor spasmodic dysphonia were measured. Measurements corresponded with the muscular dysfunction characteristic of each subtype. Aerodynamic assessment could be employed by clinicians when classifying spasmodic dysphonia subtypes and monitoring patient progress or symptom severity. Applying aerodynamic assessment to connected speech would further enhance its clinical utility.

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Figure 1.
Schematic diagram of the experimental system.

Figure 2.
Box plots displaying laryngeal resistance (R_L) data for each group at 65 and 70 dB.

Figure 3.
Box plots displaying subglottal pressure (P_s) data for each group at 65 and 70 dB.

Figure 4.
Box plots displaying mean flow rate (MFR) data for each group at 65 and 70 dB.

Figure 5. Individual subject laryngeal resistance (R_L) data for the abductor (ABSD) and adductor (ADSD) spasmodic dysphonia patients.

Table 1

Mean values for the adductor (ADSD) and abductor (ABSD) spasmodic dysphonia patients. P_s = subglottal pressure (cmH_2O); MFR = mean flow rate (ml/s); R_L = laryngeal resistance ($\text{cmH}_2\text{O/l/s}$). Significant p-values are denoted with an asterisk.

	65 dB			70 dB		
	ADSD	ABSD	P-value	ADSD	ABSD	P-value
P_s	10.23	8.32	0.582	12.39	11.78	0.886
MFR	435	746	0.205	518	848	0.198
R_L	24.78	14.51	0.04*	40.02	15.84	0.014*