Aerodynamic Patterns in Patients With Voice Disorders: A Retrospective Study

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Summary: Objective. A recently published retrospective chart review of aerodynamic profiles of women with primary muscle tension dysphonia by Gillespie et al (2013) identified various relationships between mean airflow rate (MFR) and estimated subglottal pressure (est-Psub). The current retrospective study expanded the diagnostic categories to include all voice disorders referred for voice therapy. Three research questions were proposed: (1) Are there differences in the MFR and the est-Psub compared with the normal control group? (2) Within the disordered population, are there different variations in the pairing of MFR and est-Psub? (3) If these variations exist, are they diagnosis specific?

Methods. A retrospective chart review of patients seen for acoustic and aerodynamic voice assessment at the Emory Voice Center between January 1, 2013 and December 31, 2014, were examined for aerodynamic measures of est-Psub and MFR; of these, 192 met the inclusion criteria. Simple *t* test, two-step cluster analysis, and analysis of variance, as well as Tukey multiple comparisons, were performed using *R* and *SPSS*.

Results. Mean est-Psub was significantly greater in the group with voice disorder than in the control group (P value < 0.001). However, no statistical significance was found when comparing the MFR with the control group (P value <0.59). Nine possible pairings of MFR and est-Psub were found. Sufficient evidence was not found to detect significant differences in these pairings across diagnostic groups.

Conclusion. With regard to the rate and interrelationships of MFR and est-Psub, the findings of this study are similar to those of Gillespie et al, that is, MFR and est-Psub are not determinate of diagnosis.

Key Words: Aerodynamics–Voice disorders–Voice–Subglottal pressure–Mean airflow.

INTRODUCTION

Compensatory muscle tension is a common finding in patients with vocal fold pathologies. Voice patients frequently present with complaints of changes in vocal quality described as breathiness, weakness, or hoarseness; reduced endurance or increased vocal effort often associated with vocal fatigue; shortness of breath or a sense of air deprivation; or a sense of the voice "cutting out." These symptoms are generally accounted for on laryngeal examination during which vocal fold lesions, edema, vocal fold paralysis or paresis, and atrophy are identified, or signs of compensatory or primary muscle tension are observed. Many of the symptoms can be explained by functional limitations resulting from muscle tension. Complaints of vocal fatigue or increased phonatory effort, or difficulty breathing in the absence of visible pathology with no known pulmonary limitations, remain difficult to explain.

Hixon and Hoit[1] describe speech breathing disorders as "an abnormality in the process of supplying the energy source for speech production."(p2) They further define speech breathing disorders as either functional or organic, but state that the term "is restricted to abnormality of the breathing apparatus proper (ie, the pulmonary-chest wall unit)."(p2) Although Hixon and Hoit restricted speech breathing disorders to the movement of the pulmonary-chest wall unit, the symptoms they describe are not dissimilar to those reported in the literature relating to laryngeal behaviors. Stone[2] described a functional patient as presenting with "breath-holding" behaviors. Aronson[3] suggests the existence of a reciprocal relationship between respiratory insufficiencies and laryngeal disorders. He postulates that respiratory disorders can cause laryngeal disorders, but that the reciprocal is also true in that respiratory disorders can be caused by increased or decreased constriction of the glottis.(p349) More recently, Gillespie et al[4] suggested that laryngeal resistance might be "a critical control parameter in voice production."(p650)

Informal observation of patients with a variety of voice disorders reveals that the aerodynamic inefficiency of phonation is more prevalent than previously thought. Research on aerodynamic properties of phonation is limited. A recent literature review of articles on voice assessment[5] reported only 10% of the research articles addressed aerodynamic properties of voice; a majority (60%) of the articles reviewed addressed acoustic analysis, 32% examined measures related to image processing, and 11% examined measures related to electroglottography. These studies generally concluded that aerodynamic measures were robust enough to identify the presence of voice disorders, but were not robust enough to be able to identify the specific disorder. The research on aerodynamic properties of voice production focused on the role of subglottal pressure and airflow in modulation of vocal intensity[6,7]; the effect of specific lesions or muscle tension on airflow,[8,9] ribcage, or chest wall movement[10–16]; or subglottal pressure and airflow during phonation.[8,17–19] Additional studies have focused on the interaction between subglottal pressures and airflow.[8,20–22] A major limitation of all of these studies has been the lack of large-scale normative data, making

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comparisons and conclusions regarding the definition of abnormal behaviors difficult.

A study of 10 women with vocal fold nodules by Sapienza et al[23] report a trend in which patients ceased phonation below the end-expiratory level using a small percentage of volume relative to vital capacity. Studies by Netsell et al,[21] Hillman et al,[20] and Gillespie et al[8] identified various relationships between average airflow and estimated subglottal pressure (est-Psub) on sustained phonation. Netsell et al[21] and Hillman et al[20] evaluated 18 patients (12 females, 6 males) and 15 patients (10 males, 5 females), respectively for airflow and subglottal pressure during production of repeated /pa/. The patient population consisted of patients with nodules and polyps, as well as contact ulcers. Netsell et al included patients with "severed laryngeal nerves and the sequelae of head trauma,"[(p397)] whereas Hillman et al included patients with muscle tension dysphonia (MTD), both primary and secondary. Both studies identified several different variations of the pairings of mean airflow rate (MFR) and est-Psub among the patients studied.

Gillespie et al,[8] in a large retrospective study consisting of 90 women with primary MTD, replicated the Hillman et al[20] study to determine whether it was possible to identify similar aerodynamic pairings in women with primary muscle tension. Five different pairings or clusters out of a possible nine between est-Psub and MFR were identified. The five different pairings were as follows: (1) normal flow, normal est-Psub; (2) high flow, high est-Psub; (3) low flow, normal est-Psub; (4) normal flow, high est-Psub; and (5) high flow, normal est-Psub.

The inclusion of patients with vocal fold nodules and polyps, contact ulcers, vocal fold paralysis, or paresis in the abovementioned studies[21,23] raised the question on whether the relationship between MFR and est-Psub, especially normal est-Psub paired with low or high mean airflow on sustained phonation, is a unique characteristic of MTD, or whether it is related to compensatory behaviors in patients with other types of voice disorders. The current study is an attempt to gain insight into and a better understanding of the nature of these aerodynamic relationships within the population with voice disorder.

The present study presents the results of a retrospective chart review of all patients seen for acoustic and aerodynamic voice assessment between January 1, 2013 and December 31, 2014. Three research questions were proposed:

(1) Are there differences in the mean flow rate and the est-Psub in the disordered group compared with the normal control group?
(2) Within the disordered sample, are there different pairings of mean flow rate and est-Psub similar to those identified by Gillespie et al[8] and Hillman et al?[20]
(3) If similar pairings are found in the general disordered sample, are they diagnosis specific?

METHODS

This study was approved by the Emory University institutional review board.

A retrospective chart review of patients seen for acoustic and aerodynamic voice assessment between January 1, 2013 and December 31, 2014, were examined for aerodynamic measures of est-Psub and MFR on sustained phonation. Inclusion criteria consisted of individuals 19 years of age or older with a primary diagnosis of dysphonia referred for voice therapy by an laryngologist. Patients with significant comorbidities such as autoimmune disorders, malignancies, and major pulmonary or respiratory disorders were excluded. Of the patients referred for voice evaluation, 192 (133 females and 59 males) met the criteria for inclusion in this study. Patients ranged in age from 19 to 86 years, with a mean age of 53 years.

The control group reported in this study is the same control group used by Hillman et al[20] and Gillespie et al[8], and developed by Holmberg et al.[17] The Holmberg et al data were collected on 25 normal males ranging in age from 17 to 30 years (mean age: 22 years), and 20 normal females ranging in age from 18 to 36 years (mean age: 24 years). All were speakers of American English. "Normal" was defined as a nonsmoker with no history of speech, voice, or hearing problems and no formal training in singing. This control group was used to facilitate comparison of our results with those of the Gillespie et al[8] study.

The assessment protocol for aerodynamic measures uses the Pentax *Phonatory Aerodynamic System* 6600 (*PAS*, Pentax Medical Montvale, New Jersey). The mean airflow during sustained phonation was measured using the comfortable sustained phonation protocol, and the est-Psub was made using the vocal efficiency protocol for the *PAS*. In both protocols, the airflow mask was placed securely over the nose and mouth. During acquisition of mean airflow on sustained phonation, the patient was asked to sustain an /a/ at a comfortable pitch and loudness for about 5–10 seconds. The same mask was used for the est-Psub. A small pressure tube was inserted into the mask. The patient was asked to place the tube on top of the tongue and say /pa/ five times at a rate of 1.5 repetitions per second for three repetitions. Beginning and ending tokens were eliminated.

A simple *t* test, two-step cluster analysis, and analysis of variance, as well as Tukey multiple comparisons, were performed using *R* (open-source software) and *SPSS* (IBM, New York, NY) statistical analysis programs.

Mean est-Psub across patients was compared with the control group (mean = 6.3 cm/H_2O, std = 1.4 cm/H_2O) to assess differences by a one-sample *t* test. Mean flow rate across groups was similarly compared with those of the control group (mean = 0.19 L/s, sd = 0.07 L/s) to assess differences by a one-sample *t* test. P value less than 0.025 was considered statistically significant to adjust for type I error by a Bonferroni correction. MFR and est-Psub were each divided into high, normal, and low groups. The high and low groups were 2 standard deviations respectively above and below the mean. The data were then further split into all possible pairings of est-Psub and MFR. A two-step cluster analysis was conducted to identify the variations in aerodynamic clusters, that is, various pairings of est-Psub and MFR. All the pairings of est-Psub and MFR groups were considered, and clusters were empirically determined.

To determine whether there was an effect of diagnosis on either est-Psub or MFR, four groups of commonly associated diagnostic categories were created based on the International Classification of Diseases, Ninth Revision codes (still in use at