Changes in Glottal Contact Quotient During Resonance Tube Phonation and Phonation With Vibrato

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Summary: Phonating into narrow hard-walled tubes of varying diameters and length as an extension of the vocal tract is considered a semioccluded vocal tract exercise. Semioccluded vocal tract postures have been postulated to have a therapeutic effect during the treatment of the dysphonic patient. They appear to affect at least two components of the voice source (1) glottal flow pulse and (2) vibrational characteristics of the vocal folds. Vibrato also has been described as a possible therapeutic tool and may decrease phonatory hyperfunction. The aim of this study was to determine the influence of resonance tubes and phonation with vibrato on the closed quotient. Thirty-six adult classical singers were recruited for this study. Subjects were asked to produce four phonatory tasks at comfortable pitch and loudness: sustained vowel [a:] without vibrato, sustained vowel [a:] with vibrato, sustained phonation into a straw without vibrato, and sustained phonation into a straw with vibrato. Computer analysis of the contact quotient (CQ) was performed for each type of phonation in every participant. An increase in CQ variability was observed during tube phonation when compared with vowel phonation. Although there was a decrease in the mean CQ values when comparing vowel phonation without vibrato with the other three phonatory tasks, the difference was not statistically significant. Intrasubject analysis demonstrated a decrease in the CQ during tube and vibrato phonation in most of the participants. Although a causal relationship is not proven, this finding suggests that the use of straws and vibrato during phonation may have potential therapeutic value in the treatment of patients with hyperfunctional voice disorders.

Key Words: Contact quotient–EGG–Semioccluded vocal tract–Resonance tube–Vibrato.

INTRODUCTION

Glottal contact quotient (CQ) is a quantitative measure obtained by electroglottography (EGG). It is defined as the ratio of the duration of the contact phase to the entire glottal cycle period.[1] When the vocal folds impact stress increases (greater collisions between the vocal folds during vibration), they stay together longer during the vibratory cycle and the CQ increases.[2] The CQ also reflects the mode of phonation, being higher in more hyperfunctional voices.[3]

Resonance tube phonation is often felt to be therapeutic and used by speech-language pathologists for vocal warm-ups or rehabilitation exercises. Resonant tubes are placed between the patient's lips and either air or water. In either case, the tube acts as an artificial lengthening of the vocal tract. The name "resonance tube" comes from the strong sensation of vibrations that are felt in the lips and facial tissues during phonation into these tubes.[4]

Tube phonation belongs to a wider category of vocal exercises called semioccluded vocal tract exercises. Lip occlusive exercises, such as lip trills, tongue trills, lip buzz, and raspberries are also included in this group. Several physiological and technical benefits have been attributed to techniques involving either semiocclusion of the lips or an artificial lengthening of the vocal tract. One such benefit is an increase in vocal tract impedance, specifically resulting in changes in the inertive reactance (inertia of the air column into the vocal tract)[5,6] that may favorably impact vocal fold vibration.[5–9] Other potential benefits include decrease in phonation threshold pressure[6,9]; increased skewing of the glottal flow waveform (faster cessation of the flow) leading to strengthening of the higher harmonics[9]; more resonant voice quality and easier voice production[10]; decreased transglottal pressure[11]; and a decrease in laryngeal muscle activity.[11] Several studies have reported a change in CQ when semiocclusion is compared with traditional vowel phonation.[12–19] A change in CQ might reflect a therapeutic effect of these techniques if the force of vocal fold adduction is truly reduced. Unfortunately, most of these CQ studies have small sample sizes.

One clinical report suggested that vibrato may also have a therapeutic effect on patients with vocal hyperfunction.[20] To date, however, no study has investigated the effect of vibrato on the CQ. The present study was designed to reassess whether there are any measurable changes in glottal contact quotient during the production of phonation into resonance tubes and investigate if vibrato affects CQ (with and without resonance tube phonation).

METHODS

Participants

This study was reviewed and approved by the St. John Hospital institutional review board. Informed consent was obtained from 36 adult classical singers (23 women and 13 men). The age range of this subject set was 19–62 years with an average of 39.45 (35 years for females and 43 for males). Twelve singers were sopranos, 11 mezzo-sopranos, one alto, five tenors, five baritones, and two basses. Inclusion criteria for this study

Accepted for publication January 24, 2013.
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Journal of Voice, Vol. 27, No. 3, pp. 305-311
0892-1997/$36.00

http://dx.doi.org/10.1016/j.jvoice.2013.01.017

included (1) no history of vocal pathology in the past year and (2) at least 5 years of classical singing training. Although 40 singers were recruited, four singers did not meet the inclusion criteria. The average length of voice training of our subjects was 9.2 years, with a range of 5–20 years. Participants were recruited from three different professional choirs and one department of music at an undergraduate institution. All were asked to undergo both flexible laryngoscopy and rigid videostroboscopy to confirm the absence of laryngeal pathology.

Phonatory tasks

One of the authors (M.A.G.) provided individual demonstrations and verbal descriptions of the required phonatory tasks. Each recording session was accomplished in approximately 15 minutes with the following protocol: Each subject was asked to perform four phonatory tasks at habitual speaking pitch and loudness level: (1) sustained vowel [a:] without vibrato, (2) sustained vowel-like sound into a tube without vibrato, (3) sustained vowel [a:] with vibrato, and (4) sustained vowel-like sound into a tube with vibrato.

The tube phonation tasks were performed with plastic commercial drinking straws of 5 mm inner diameter and 33.8 cm in length. Each participant was instructed to hold the straw with one hand, straight out from the mouth. The straw was maintained a few millimeters in between the rounded lips, so that no air would leak from the mouth, and the free end was kept in the air as an extension of the vocal tract. Participants were aware that nasal air leaking should be prevented during the exercises. They also were asked to feel the perceptible vibratory sensations on the alveolar ridge, face, and head areas.

Participants were required to produce the [a:] vowel and tube phonation tasks with careful control of both pitch and loudness throughout the sequence. Each phonatory task was produced for a minimum of 4 seconds. Loudness was monitored during the sustained vowel /a/ phonation with a sound level meter (model SPL-8810; American Recorder Technologies, Simi Valley, CA) during recordings positioned at 20 cm from the participant's mouth. Because sound pressure level (SPL) values were only used to monitor voice production during examination, SPL calibration was not performed. An electronic keyboard was used to give and control the pitch. This was closely monitored subjectively by the experimenter who is a professional opera singer (M.A.G.).

Loudness level was not controlled with a sound level meter during straw phonation because of the large reduction in radiated acoustic power during phonation into a tube, in contrast with the greater radiated sound production during vowel phonation. Instead, participants were instructed to first produce a vowel [a:] at the same pitch and loudness as the previous vowel [a:] (monitored with the sound level meter) and then to carefully transition to phonating into the tube without changing the perceived effort of voicing and breathing. Participants were taught and allowed to practice this transition for 2 minutes before performing the recordings to ensure that this procedure will be optimally executed.

Loudness and fundamental frequency (F_0) control is relevant because EGG measurements can be affected by subglottic pressure. If these features are not controlled, results could be altered, especially those related to glottal resistance. Therefore, the goal was to minimize the possibility of any change in CQ that might occur due to a change in loudness and F_0. Additionally, because vertical movements of thyroid cartilage may affect the glottal CQ values during the vibrato tasks, participants were asked to produce vibrato phonations with a small extent. This requirement allowed only minimal vertical laryngeal displacement.

Recordings

EGG data were obtained with an Electroglottograph (KayPENTAX, Lincoln Park, NJ), model 6103 connected to a Computerized Speech Lab, model 4150B, which in turn was connected to a desktop computer running a *Real-Time EGG Analysis* software (KayPENTAX), model 5138, version 3.4.1 to monitor the EGG signal, CQ contour, and F_0. Samples were recorded digitally at a sampling rate of 48 kHz with 16 bits/sample quantization. EGG recordings were carried out in a quiet, dedicated voice laboratory.

At the beginning of the examination, participants were asked to sit upright in a comfortable chair. After this, two surface electrodes were attached over the thyroid cartilage by means of a lightweight elastic band. The electrodes were attached with a velcro strip which was wrapped around the participant's neck as tightly as possible to prevent any movement of electrodes throughout the data collection. The elastic band and electrodes were adjusted until the EGG signal was clearly visualized. The quality of the EGG signal was monitored consistently throughout the recordings. Samples were analyzed with *EGG Analysis* software (model 5138; KayPENTAX). Values of the following measures in each phonatory task were determined: CQ mean, CQ standard deviation, F_0 mean, and F_0 standard deviation. CQ was calculated using an algorithm provided by the KayPENTAX *EGG* software that estimates the relative lengths of the closed phase in the glottal cycle at a point that is at 50% of the peak-to-peak amplitude. All measurements were calculated with a window length of 2 seconds selected from the middle part of each sample.

Statistical analysis

Statistical analysis was performed using *Stata* software version 12.1 (StataCorp. 2011; StataCorp LP, College Station, TX). CQ and F_0 differences were assessed by the Kruskal-Wallis one-way analysis of variance and *post hoc* comparisons using the Dunn test correction as a first approach. Differences in CQ among groups were assessed by analysis of covariance (ANCOVA) to include any influence of F_0 to the model as a covariate for CQ values and Tukey test for *post hoc* comparison. Values were expressed as the mean ± standard deviation. A P value <0.05 was considered to be significant. All tests were two sided.

RESULTS

The mean and standard deviation of CQ analysis for the four phases of the experiment for men and women are presented in Table 1 and in Figures 1 and 2. There is a decrease in the mean CQ values when comparing the baseline (sustained vowel /a/) with the other three phonatory tasks across all the participants. However, ANCOVA *post hoc* comparison revealed that none of the differences reached statistical significance. Tube