Investigation of the Immediate Effects of Humming on Vocal Fold Vibration Irregularity Using Electroglottography and High-speed Laryngoscopy in Patients With Organic Voice Disorders

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Summary: Objectives. The study aimed to investigate whether humming can immediately improve the regularity of vocal fold vibration on electroglottography (EGG) and laryngeal high-speed digital imaging (HSDI) in patients with organic dysphonia (OD).

Methods. In a series of 49 dysphonic patients who were diagnosed to have benign mass lesions in the vocal folds and an equal number of non-dysphonic speakers, perturbation parameters were calculated on the acoustic (Ac) and EGG signals during natural and humming phonation. In addition, 11 OD patients and as many non-dysphonic speakers underwent simultaneous EGG and HSDI video recording under laryngofiberscopy while performing the two tasks. The perturbation parameters of the EGG signals as well as the glottal area waveforms (GAW), which were extracted from the HSDI movies, were calculated, and the correlations between both perturbation parameters were analyzed.

Results. Humming achieved significant improvements in the EGG perturbation parameters in both groups. More than half of the OD patients showed decreased EGG perturbation parameters to the level of those during natural phonation in the control group. With respect to the GAW analysis, moderate correlations were observed between both period and amplitude perturbation parameters (period: $r = 0.63$, amplitude: $r = 0.41$). Humming decreased both GAW perturbation parameters significantly in the OD and control subjects combined.

Conclusions. These results demonstrate that in OD patients, humming has a potential to improve voice quality by stabilizing the vocal fold oscillation, and suggest that humming can remove the functional component in the vocal disturbance instead of the mechanical effect of the mass lesions.

Key Words: Humming–Perturbation quotient–Electroglottography–High-speed digital imaging–Glottal area waveform.

INTRODUCTION

Voice disorders are generally classified into two categories: organic and non-organic (functional) dysphonia. Organic dysphonia (OD) is defined as an impairment of vocal quality due to actual pathologic changes in the vocal folds.[1] In contrast, functional dysphonia (FD) is characterized by an abnormal voice quality in individuals with normal vocal fold morphology and motility.[1] Because the majority of FD patients show specific abnormal laryngeal postures, perhaps because of the excessive and inappropriate tension in the laryngeal and paralaryngeal musculatures, FD has been referred to as muscle tension dysphonia (MTD).[2,3] Although these two categories have been terminologically demarcated, a number of previous studies[3–9] have described that these two categories of dysphonia frequently coexist in a single dysphonic patient, and that they have a reciprocal cause–effect relationship. For example, vocal functional issues can elicit minor organic pathologies.[4–7] Conversely, certain minor organic abnormalities in the vocal folds can also result in secondary FD/MTD in dysphonic patients.[3,8,9] In such case where these two categories overlap, it remains controversial which of laryngomicrosurgery for resecting vocal fold lesions or voice therapy for removing functional issues should precede as an appropriate therapy plan.[10]

Interestingly, a number of previous studies[11–15] have reported the effectiveness of voice therapy on the voice quality of OD patients, particularly in patients with minor benign pathologies like polyps, nodules, or cysts in the vocal folds. The reason underlying the effectiveness of voice therapy in OD patients could lie in the fact that benign vocal fold lesions result from hyperfunction of the phonatory organ[5] and that voice therapy corrects the abnormal phonatory dynamics, leading to regression and disappearance of these lesions. However, several aforementioned studies[12,14,15] emphasized that a number of OD patients with vocal polyps, nodules, or cysts exhibited improved voice quality without the resolution of the vocal fold lesions, hypothesizing that it is not the regression of vocal fold lesions but the optimization of phonatory dynamics that induces the effectiveness of voice therapy in OD patients.

Of the studies on the effects of voice therapy on OD,[11–15] Yiu and Ho[13] reported that two sessions of voice training using humming for 2 weeks improved the perceptual vocal qualities in female patients with vocal nodules or laryngitis. Humming is a type of vocal training technique used for inducing a resonant

Accepted for publication March 17, 2016.

Conflict of interest: The authors declare no conflicts of interest. The authors alone are responsible for the content and writing of the paper.

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Journal of Voice, Vol. 31, No. 1, pp. 48–56

0892-1997

http://dx.doi.org/10.1016/j.jvoice.2016.03.010

voice.[16–19] In particular, Yiu[19] developed an organized training procedure using humming to accomplish carryover of humming effects to daily speech as follows: (1) producing a hum on a slight upward glide, as though speakers were responding to someone by asking for clarification; (2) producing the hum and opening into a vowel; (3) blending the hum smoothly into a hierarchy of progressively more complex utterances; (4) producing the hum and blending into short daily phrases while practicing loudness control with oral-nasal resonance; (5) fading the use of the hum while maintaining the easy, oral-nasal resonance; (6) using the hum in a reading passage; (7) repeating the reading passage without the hum; and (8) maintaining the easy oral-nasal resonance in a short monologue and conversation. In addition, colleagues of Yiu[20,21] emphasized the importance of motor learning in the process of vocal training.

However, our research group has previously reported the effectiveness of humming for patients diagnosed with MTD and demonstrated that humming itself immediately improves vocal quality and induces various physiological changes in the larynx in non-dysphonic speakers and patients diagnosed with MTD.[22–25] The effectiveness of humming was shown as follows: (1) voice therapy sessions using humming induced a long-term improvement on the perceptual vocal roughness[22] and the perturbation parameters of acoustic (Ac) and electroglottographic (EGG) signals in MTD patients[23]; (2) humming immediately decreases the perturbation parameters of Ac/EGG signals in both MTD patients and non-dysphonic speakers[25]; (3) humming immediately induces a slight increase in the contact quotient (CQ), a parameter reflecting the degree of vocal fold contact during phonation, in MTD patients[25]; (4) humming immediately decreases the standard deviation of the CQ, implying an improved contact regularity in the vocal fold vibratory cycles[25]; and (5) humming immediately improves the degree of supraglottic compression, one of the characteristic laryngeal features of MTD[2] in both MTD patients and non-dysphonic speakers.[24] Because the EGG signals during phonation reflect the changes in the impedance across the larynx, which are mainly affected by the contact area between the bilateral vocal folds,[26] the perturbation parameters of EGG signals have been considered to depend on the irregularity of contact area in each cycle of vocal fold vibration.[23,27–29] Accordingly, these results demonstrate that humming elicits therapeutic effects on the vocal quality of MTD patients by adjusting vocal fold vibration and releasing the supraglottic compression.

In the present study, we aimed to verify whether humming immediately corrects the vocal disturbance in OD patients with mass lesions in the vocal folds, and if this is the case, to elucidate the mechanisms underlying the immediate effectiveness of humming on voice qualities. First, we assessed the perceived voice quality and the period and amplitude perturbation quotients of the Ac/EGG signals while performing two phonatory tasks: natural and humming phonation in OD patients with benign mass lesions in the vocal folds and non-dysphonic speakers. Second, in different series of OD patients and non-dysphonic speakers, high-speed digital imaging (HSDI) movies of the vocal folds and EGG signals were synchronously recorded, and the HSDI movies were analyzed for the perturbation parameters of glottal area waveforms (GAW). To assess whether humming can improve the regularity of vocal fold vibration, the GAW perturbation parameters were compared between the two tasks for only subjects showing improved EGG perturbation parameters. In addition, the GAW reflects essentially different phenomena from EGG signals: the GAW is dependent on the size of vocal fold dissociation in a superficial view, whereas EGG signals are affected by the impedance across the larynx reflecting the vocal fold contact area. This difference may generate a gap in the perturbation measures between the EGG signals and GAW. Accordingly, in the present study, the correlations between the GAW and EGG perturbation measures were analyzed. Furthermore, to identify factors affecting the improved vocal fold oscillation, the position of the vocal fold mass lesions and the degree of supraglottic compression were compared between the two tasks.

MATERIALS AND METHODS

Participants

The protocol of this study complied with the Declaration of Helsinki, and an institutional review board approval was obtained from the Osaka University Graduate School of Medicine (No. 14432). Only dysphonic patients who visited Osaka University Hospital in the period of December 2010 and January 2014 were recruited for recording of the Ac/EGG signals. The inclusion criteria for the dysphonic patients with organic lesions in the vocal folds were having either polyps, nodules, Reinke's edema, or cysts, and presenting with vocal roughness predominantly relative to breathiness, with more than 1 point in the mean R score on the GRBAS scale assessed by a single laryngologist (M.O.) at the initial assessment. The exclusion criteria were having neurologic abnormalities (paralysis, paresis, spasm, or tremor) or chronic disorders of the upper aerodigestive tract. Non-dysphonic speakers were investigated for having no vocal fold pathologies or abnormal laryngeal postures, such as supraglottic compression and glottal chink, under transnasal fiberlaryngoscopy. All participants were evaluated based on their medical history, which included vocal abuse, smoking, alcohol use, psychoneurotic events, and reflux symptoms. After a conventional otorhinolaryngological observation, each participant was examined via flexible transnasal laryngoscopy (ENT-P4, Olympus, Tokyo, Japan) following the topical administration of 1% lidocaine and 0.02% adrenalin. Forty-nine OD patients with vocal fold mass lesions (OD: 16 males and 33 females; median age: 54 years; range: 20–82 years) and an equal number of non-dysphonic speakers (control: 29 males and 20 females; median age: 37 years; range: 24–71 years) were included for the analysis of Ac/EGG signals in this study. Concerning the kind of vocal fold mass lesions in the OD patients, polypoid masses (Reinke's edema) were observed in 17 patients, polyps in 15 patients, nodules in 11 patients, and cysts in 6 patients.

To analyze the laryngeal HSDI movies and EGG perturbation parameters, 11 OD patients with vocal fold mass lesions, who visited the Osaka University Hospital in the period of April to August 2015, were enrolled (5 males and 6 females; median age: 63 years; range: 33–82 years). The inclusion and exclusion criteria were the same as those stated earlier. Polyps were