Does Cervical Muscular Contraction Affect the Measurement for Electroglottographic Perturbation Parameters?

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Summary: Objectives. The purpose was to assess whether cervical muscular contraction during phonation influences the period and amplitude perturbation quotients (PPQ and APQ, respectively) of electroglottographic (EGG) signals, and whether high-pass filtering can attenuate these effects.
Study Design. Prospective.
Methods. We included 19 nondysphonic speakers and 21 patients with muscle tension dysphonia. During the recording of acoustic and EGG signals, each participant was instructed to naturally phonate sustained vowels /i:/ and /a:/ (NP tasks), and additionally, each nondysphonic participant was asked to phonate the same vowels in a nondysphonic voice quality while contracting the cervical muscles (muscular contracted phonation [MCP] tasks). To confirm the contraction, surface and needle electromyography (EMG) was performed. The EGG signals were high-pass filtered at different cutoff frequencies from 0 to 90 Hz and were subsequently analyzed for the PPQ and APQ.
Results. Compared with the NP tasks, the MCP tasks enhanced the cervical EMG activities ranging from 0 to more than 1000 Hz, but conferred only low-frequency noise to the EGG signals under 50 Hz and increased the values for EGG-APQ, but not EGG-PPQ. These EGG-APQ values exhibited gradual decreases after high-pass filtering with an increase in the cutoff frequency ranging from 0 to 50 Hz in both groups, followed by plateaus during the MCP tasks in the nondysphonic group.
Conclusions. The present results demonstrate that cervical muscular contraction seriously affects the EGG-APQ values for unfiltered EGG signals independent of the EMG activities and that appropriate high-pass filtering over 50 Hz can attenuate these effects.
Key Words: Cervical muscle–Electroglottography–Electromyography–Perturbation analysis–Muscle tension dysphonia.

INTRODUCTION

Methods for the computed analysis of acoustic (Ac) signals have been developed for the objective estimation of various vocal characteristics. In particular, the period and amplitude perturbation quotients (PPQ and APQ) are representative measures used to quantitate cycle-to-cycle irregularities for the period and amplitude, respectively, of Ac signals in pathologic voices.[1,2] Indeed, these measurements have been used for estimating the severity of pathologic voices and assessing the outcomes of diverse therapeutic approaches.[3–5] However, recent studies have pointed out the insufficient reliability of these measurements, particularly for in the discrimination between normal and pathologic voices.[6–8]

Electroglottography (EGG) is a technique used to record impedance changes across the larynx and to analyze the vibratory characteristics of the vocal folds.[9] The waveforms of EGG signals consist of a continuum of a simple waveforms reflected in repeated contacts and dissociations between the vocal folds. A number of previous studies have reported superior reliability of the perturbation measures of EGG signals to those of Ac signals in the estimation of the severity of a pathologic voice.[10–14] In particular, our recent study[14] has ascertained the superiority of the EGG-PPQ/EGG-APQ to the Ac-PPQ/Ac-APQ for discriminating between normal and mildly rough voices using a receiver operating characteristics analysis. In addition, we proposed several hypotheses concerning the reasons for the superiority of EGG perturbations as follows: (1) in the algorithm used to calculate the perturbation quotients, a simpler shape of EGG waveforms facilitates the determination of the cycle boundaries, leading to more accurate frequency tracking and cycle-to-cycle variability calculation; (2) EGG signals include a higher amount of low-frequency components or subharmonic energy compared with Ac signals,[15,16] and (3) EGG signals contain abnormalities resulting from other biological phenomena which do not emerge in Ac signals.

In particular, the electrical changes associated with cervical muscular contraction are likely to influence the EGG signals without impacting the Ac signals because the electrodes of the EGG are fitted on the neck surface over the thyroid cartilage, adjacent to the platysma and anterior cervical strap muscles. Indeed, it has been reported that the electromyographic (EMG) activities of the anterior cervical muscles are detected during phonation in muscle tension dysphonia (MTD) patients.[17–22] Therefore, it can be hypothesized that the surface EMG activities derived from cervical muscles affect the EGG signals during phonation.

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The platysma muscle is a thin and broad muscle like a sheet existing just under the cervical skin and can be voluntarily contracted by depressing the inferior lip. In contrast, the sternohyoid muscle is a strap-like muscle connecting the sternum and hyoid bone and contracts during maximal jaw opening,[23] low-pitch phonation,[24] and neck flexion.[25] In this study, to assess whether EGG signals are influenced by the contraction of these muscles, we investigated the effects of phonatory tasks accompanied by voluntary contraction of these cervical muscles on the measurements obtained for the EGG-PPQ/EGG-APQ in nondysphonic speakers. Furthermore, to verify the hypothesis that action potentials from these muscles contaminate the EGG signals, the surface and needle EMG activities were recorded, and subsequently, the frequency distributions were compared with those of the EGG signals. In addition, because the procedure used to analyze the EGG signals generally requires a high-pass filtering (HPF) technique,[26,27] we assessed the cutoff frequency of HPF suitable for attenuating the effects of the cervical muscular contraction on the calculation of the EGG perturbations.

MATERIALS AND METHODS

Participants

The protocol of this study complied with the Declaration of Helsinki. Institutional Review Board approval was obtained for this study (No.13416). Generally, men have more developed cervical muscles and less subcutaneous fat compared with women. Therefore, only male participants were enrolled in the present study. All participants were initially evaluated by their medical history including vocal abuse, smoking, psychoneurotic events, and reflux symptoms and subsequently underwent a routine otolaryngological examination. The inclusion criteria for the nondysphonic group were the male speakers (1) having no complaints about their voice, (2) whose habitual voice was judged to be of nonpathologic quality by two laryngologists, and (3) exhibiting no organic or functional laryngeal abnormalities during an examination by flexible transnasal laryngo-fiberscopy (P-4; Olympus, Tokyo). The inclusion criteria for the MTD group were male patients (1) presenting with vocal roughness predominantly relative to breathiness, (2) whose habitual voice was judged to be more than 1.5 points in the mean R score on the GRBAS scale, as assessed by the two laryngologists, and (3) exhibiting supraglottic compression during phonation without any organic abnormalities of the vocal folds under the observation using flexible transnasal laryngo-fiberscopy. The exclusion criteria for both groups were (1) the presence of chronic disorders in the upper aerodigestive tract, (2) the presence of neurologic disease, and (3) experience with musical or theatrical training. Consequently, 19 male nondysphonic and 21 male MTD participants were enrolled (median age: 35 and 65 years; range: 23–45 and 35–85 years old, respectively).

Phonatory tasks and recording of acoustic and EGG signals

In the recordings for the nondysphonic group, the participants were instructed to perform four phonatory tasks with or without cervical muscle contraction in the following order: (1) natural sustained vowel /i:/ phonation (/i:/ NP task); (2) sustained vowel /i:/ phonation while depressing their inferior lip maximally (/i:/ muscular contracted phonation [MCP] task); (3) natural sustained vowel /a:/ (/a:/ NP task); (4) sustained vowel /a:/ phonation while opening the jaw maximally (/a:/ MCP task). While performing both the NP and MCP tasks, each participant was asked to phonate stably at a habitual pitch and loudness without changing the pitch or vocal quality for 3 seconds. These procedures were repeated up to three times, particularly in cases where an individual was judged not to produce normal voice quality or where the electrode-to-skin contact was loosened due to the cervical muscular contraction. Consequently, all of the participants completed these tasks appropriately. In addition, the MTD participants were asked to perform only the two NP tasks because MTD patients have been reported to have latent contraction of the cervical muscles.[17–22]

Simultaneous Ac and EGG recordings were made in a sound-treated room. A head-worn microphone (SE50; Samson Technologies Corp., Hauppauge, NY) was laterally positioned 2 cm from the lips the participant. The electrodes of the EGG (model 6103; KayPENTAX, Lincoln Park, NJ) were fitted on the neck beside the bilateral lamina of the thyroid cartilage using a Velcro strap. The lines of the microphone and EGG were connected to a linear PCM recorder (H4n; Zoom Corp., Tokyo) for digitalization at a sampling rate of 44.1 kHz and 16 bits per sample quantization. Then, the recorded Ac/EGG signals were stored as stereo sound files on a Windows PC. All of the recorded Ac/EGG signals were divided into Ac and EGG monaural sound files and were subsequently saved as a separate file for each task for all participants.

Recording of EMG signals during phonatory tasks

We conducted a surface EMG study to confirm whether the surface EMG activities were actually augmented in the MCP tasks. In addition, a needle EMG study was performed to confirm whether the contraction of the platysma or sternohyoid muscle was actually induced by the MCP tasks for the vowel /i:/ and /a:/, respectively. Because the needle EMG is associated with some pain and discomfort, only two of the nondysphonic participants were asked to participate in the EMG study, and both of them agreed to our request.

Each participant was seated comfortably on a chair. EMG signals were recorded using a Neuropack S1 (Nihon Kohden, Tokyo) and the bundled EMG software program *QP-963B* (Nihon Kohden). The ground electrode was placed on the skin surface below the right clavicle. In the surface EMG study, the exploring and reference electrodes were placed on the cervical skin surface over the left lamina of the thyroid cartilage and the lower site over the inferior ridge of the lamina of the left thyroid cartilage, respectively. In the needle EMG study, from the midline adjacent to the laryngeal prominence, a needle was inserted into the thin muscle layer of the left platysma over the left lamina of the thyroid cartilage, just beneath the surface of the skin with an average insertional depth of 0.5 cm or was inserted into the left sternohyoid muscle body over the left lamina of the thyroid cartilage by identifying the