A Preliminary Study for a Slantwise-Placed Electroglottography

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Summary: Objective. Slantwise-placed electroglottography (EGG) was proposed for synchronous use with an ultrasound machine in a previous work. The objective was to confirm the feasibility of this slant EGG, differentiate it from conventional EGG, and give suggestions for its applications.

Study Design and Methods. A synchronized system composed of an EGG device, a high-speed video, a sound level meter, and a headset was established. The same phonation conditions were acquired by training subjects to reach the target phonation frequency and intensity. Electrode position was designed, and vocal fold vibration parameters were measured from EGG waveforms recorded in each electrode position.

Results. Comparison showed that the characteristic points identified in slant EGG waveforms were consistent with the vibration phase shown by high-speed video images. Phonation frequency measured from slant EGG was highly accurate. EGG amplitude nonlinearly decreased with the increase of electrode distance. Compared with conventional EGG parameters, velocity ratio and glottal closed quotient measured from slant EGG were accurate when electrodes were placed symmetrically and the electrode distance was within a proper length.

Conclusions. Slant EGG was proved feasible and can be considered as a useful tool to obtain comprehensive information in investigating the *in vivo* vocal fold dynamics when synchronized with other detecting equipment.

Key Words: Slant EGG–High-speed video–Electrode position–Vocal fold vibration parameter.

INTRODUCTION

Electroglottography (EGG), which is a well-known noninvasive observation technique of laryngeal activity, has been widely used by both clinicians and researchers since its conception by Fabre in 1957.[1,2] A small high-frequency current, with a frequency between 300 kHz and 5 MHz usually, is passed between two electrodes that are placed externally on each side of the thyroid cartilage at larynx level.[3] EGG signal is based on the monitored conductance between vocal folds. A good correlation exists between this signal and the glottal contact area in case of nonpathologic voice phonation. Therefore, for a normal voice, it enables one to evaluate indirectly the amplitude of vocal fold contact during successive vibratory cycles and the main phase of this contact.[4]

EGG waveform models have been developed, and the relationship between vocal fold vibration and EGG waveform have been explored.[5–8] The instants at which glottis opens, glottis closed, and glottal area maximizes have been examined and clearified.[9] A few researchers have given excellent overview of the clinical applications of EGG device, the interpretation and misinterpretations of EGG signals, and the problems and pitfalls of EGG.[1,10–13] Researchers have combined EGG with other measurement techniques to obtain comprehensive knowledge regarding vocal fold vibration. Anastaplo et al[14] detected the onset of glottal opening along the superior surface of vocal folds through synchronizing EGG with videostroboscopy. Saito et al[15] analyzed irregular vibratory patterns of vocal folds via combining EGG with high-speed imaging and acoustic analysis, the clinical applicability of EGG in analyzing pathologic voice was demonstrated. Qin et al[16] improved the accuracy and reliability in extracting the mechanical parameters of vocal fold vibration by synchronizing EGG with a high-speed video.

Over the past decades, medical ultrasound has been applied to assess the biomechanical properties of vocal folds because it is a noninvasive method to easily perform and minimally disturb voice production.[17] Ultrasound transducer is placed on the neck surface of subject at larynx level during ultrasonic data acquisition. Therefore, EGG can not be synchronized with ultrasound in a conventional way, because of the position conflict between ultrasound transducer and EGG electrodes. In our previous study, we established a synchronized system composed of a high–frame rate ultrasound and a modified EGG to image the vibrations of vocal fold body layer and record EGG signals simultaneously. The electrodes of EGG were placed slantwise on the neck skin of subjects to leave sufficient space for ultrasound transducer. This modified EGG was called slant EGG. The slant EGG successfully overcame the position conflict, provided simultaneous phase information of vocal fold vibration for ultrasonic sampling, and helped to enhance the measuring accuracy of vibration amplitude. This synchronized slant EGG is a useful and effective tool to obtain comprehensive information in investigation of *in vivo* vocal fold dynamics.[18]

Titze[19] studied how the electric field pattern changed when EGG electrodes were not placed symmetrically through a simulated experiment setup. In our previous work, we conducted a very brief validation for the slant EGG on *in vivo* vocal folds.[18] However, EGG electrodes were placed slantwise at one given position in both simulation and *in vivo* experiment. The effect of EGG electrode position on EGG signal remains unknown. The difference between slant EGG and conventional EGG has

Accepted for publication July 8, 2014.
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Journal of Voice, Vol. 29, No. 1, pp. 129.e19-129.e27
0892-1997/$36.00

http://dx.doi.org/10.1016/j.jvoice.2014.07.002

not been clarified. Moreover, whether the vocal fold vibration parameters measured in slant EGG are accurate or not needed to be compared with those measured in conventional EGG. Therefore, this slant EGG has not been validated thoroughly, and its feasibility and applicability in providing information of vocal fold vibration still need further investigations.

To solve these problems, we established a synchronized system composed of an EGG device, a high-speed video, a sound level meter, and a headset, which could simultaneously record EGG signal, vocal fold upper surface vibration images, phonation intensity signal, and speech audio signal. Consistent phonations were achieved by controlling the experiment conditions strictly. Phonation frequency and intensity were kept within a standard range by training subjects to match their phonation frequency and intensity with the target ones. Slant EGG signal and vocal fold vibration image sequence were recorded synchronously to validate the reliability of phase information provided by slant EGG. Two groups of EGG electrode arrangement were designed. Phonation frequency, EGG amplitude, closing-opening velocity ratio, and glottal closed quotient (CQ) were measured from EGG waveforms recorded in each electrode position of these two groups. The parameters measured from slant EGG waveforms were compared with those measured from conventional EGG waveforms, and the parameter accuracy was discussed. Based on results, the feasibility of slant EGG was demonstrated, and suggestions for slant EGG used in different application situations were given in this article.

METHODS

Components of experiment system

A synchronized system was established to simultaneously record EGG signal, vocal fold upper surface vibration images, phonation intensity signal, and speech audio signal. The schematic is shown in Figure 1. This synchronized system was composed of an EGG device, a high-speed video, a sound level meter, a headset, an external trigger, and a personal computer. EGG device (model EG2-PC, Glottal Enterprises, New York, NY) could record signal at a sampling rate of 50 kHz. The high-speed video that included a high-speed digital camera (model 9700, Kay Electronic, Chicago, IL) and an endoscope (model 9106) was used to image the upper surface vibration of vocal folds at 2000 frames/s. The sound level meter (HT-8352, HCJYET, Guangzhou, GD) was used to show the real-time phonation intensity, according to which subjects made self-adjusting to meet the target phonation intensity (65 dB). The headset was composed of a headphone and a microphone. A standard audio (vowel /a:/ with a constant frequency of 100 Hz) generated by speech synthesis method was sent to subjects via the headphone. Subjects attempted to match their phonation frequency to the frequency of the given audio. The microphone was used to record speech audio signals. EGG signal, high-speed video images, phonation intensity signal, and speech audio signal were all displayed on PC screen in real time during subject's phonation. After a stable and requested phonation was obtained, the trigger was pressed to start PC recording. EGG signal, high-speed video images, phonation intensity signal, and speech audio signal were recorded simultaneously. The recording process lasted for approximately 8 seconds, which included several hundreds of vocal fold vibration cycles.

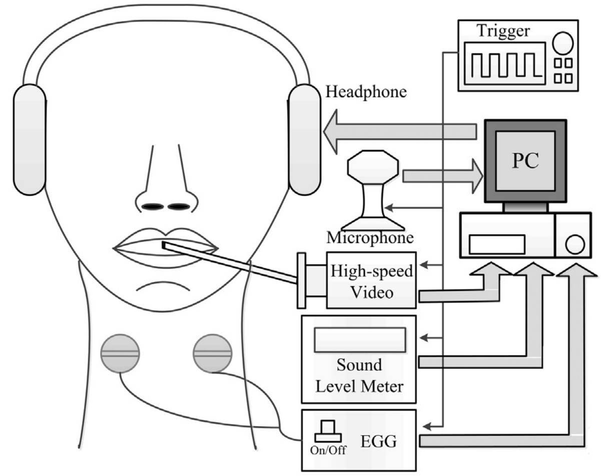

FIGURE 1. Schematic of experiment system.

All experiments were performed in a soundproof room. The sound level meter was fixed on the experiment platform. Chair for subjects was also fixed on the floor, and subjects were asked to try their best to not move their bodies during the whole experiment process. Thus the relative distance between sound level meter and subjects was settled. Five male subjects with healthy voice, who were aged 22 to 27 years (average, 24.5 years old), participated in the experiments.

Training

As the positions of EGG electrodes needed to be changed, subjects held the electrodes by their selves during the whole experiment. Asking subjects to use their hands to hold electrodes on the neck was found to increase the likelihood that the electrodes would stay in position during laryngeal movements and result in better EGG signals.[13]

Subjects were asked to pronounce the vowel /a:/ in chest register and attempt to match their phonation frequency to the frequency (100 Hz) of the standard audio heard through the headphone. Meanwhile, subjects adjusted their phonation intensity slightly until the reading on sound level meter met the target intensity (65 dB). This process was repeated several times until subject could achieve both frequency and intensity requirements at the same time.

Insignificant difference remained between subjects' experimental frequency/intensity and the target frequency/intensity. However, well training could limit these differences to less than 5%, which was acceptable. We could believe that subject's speeches were recorded under the same phonation conditions (normal chest register, 100 Hz, 65 dB).

EXPERIMENTS

We designed two groups of arrangement for the placed position of EGG electrodes, namely, arbitrary arrangement and