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Short Communication

EXPERIMENTAL DEVICE FOR DETECTING LARYNGEAL MOVEMENT DURING SWALLOWING

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Abstract

It has been reported that swallowing is a rhythmic movement, in which the onset of the oro-pharyngeal stage of swallowing starts from the mylohyoid muscle, followed by movement of the oral and pharyngeal muscles, and reaching the superior esophageal sphincter muscle. This is defined as the oro-pharyngeal stage of swallowing. It has also been reported that along with this movement, the larynx elevates in an antero-superior direction. To investigate the swallowing movement, it would be useful to be able to detect the start of swallowing movements from the body surface. Such a device was designed in this study to investigate the relationships between the onset of laryngeal movement and the EGM initiation of the anterior digastric muscle. Although experimental conditions must be further examined, we were able to record the reproducible movement and the position of larynx using our device provides another tool for studying the swallowing movement.

Key words: Swallowing—Pharyngeal swallowing—Anterior digastric muscle—Swallowing reflex

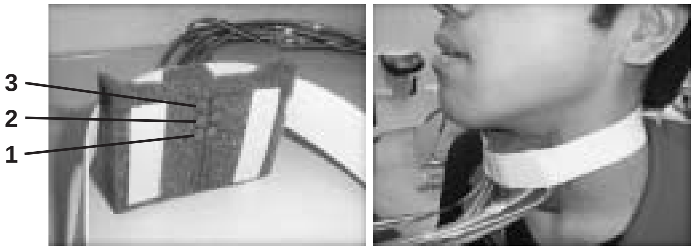

Fig. 1 The detector consisted of two sets of three pressure sensors, 6 mm in diameter and aligned equidistantly at a distance of 8 mm.

INTRODUCTION

Movement of the oral and pharyngeal organs during swallowing has been studied by X-ray television-movie methods[1,2,5]. These reports have shown that swallowing is a rhythmic movement in which the muscular contraction starts from the mylohyoid muscle, followed by contractions of the oral and pharyngeal muscles, and reaches the superior esophageal sphincter muscle, completing the oropharyngeal phase. Along with this movement, the larynx elevates in the antero-superior direction. To investigate this pattern, it is necessary to detect the start of a series of swallowing movements from the external body surface. In a previous report, electromyograms (EMG) recorded with surface electrodes was used to detect the initiation of the contraction of the anterior digastric muscle which was defined as the start of swallowing[8]. However, since many muscles are present in the cervical region, the contraction of the anterior digastric muscle have not been accurately measured. We speculated that if laryngeal movement could be used as a marker to search for the start of swallowing, it could provide another standard for investigating the swallowing movement. In this study, we designed a device to detect the onset of laryngeal movement in order to compare the laryngeal movement with the EGM initiation of the anterior digastric muscle.

EXPERIMENTAL METHODS

The subjects were five healthy males volunteers without any disorders in oral function. The subjects were instructed to sit on a chair with their occlusal plane horizontal to the floor. The laryngeal movement detector designed in this study was attached to the cervical area (Fig. 1). This detector consisted of two sets of three pressure sensors with diameters of 6 mm, aligned equidistantly with an inter-center distance of 8 mm, as shown in Fig. 1. The sensor outputs were fed into a dynamic strain amplifier for detection of the pressure applied to the sensor. The first pressure sensor was placed on the skin surface of the thyroid cartilage, so that the sensor output was maximized when the larynx was in the resting position, and it decreased into a lower level when the larynx deviated superiorly. EMG electrodes were attached to the skin in the region corresponding to the anterior digastric muscles. The subject kept 1 ml of water in the oral cavity and swallowed immediately after being instructed to "swallow" by the operator. EMG and movement of the larynx were recorded by a computer for 5 seconds from the time when the instruction was provided. The time lag between the onset of the laryngeal movement was determined as the time when the voltage output from the first pressure sensor started to decrease. This time and the initiation of the electromyogram of digastric muscles were both measured.

Recording condition of EMG

Muscle activity was recorded for 5 seconds with 1 kHz of sampling rate. Therefore, the sample values included 5,000 points (1,000 Hz × 5 s). Each RMS value was defined as the square

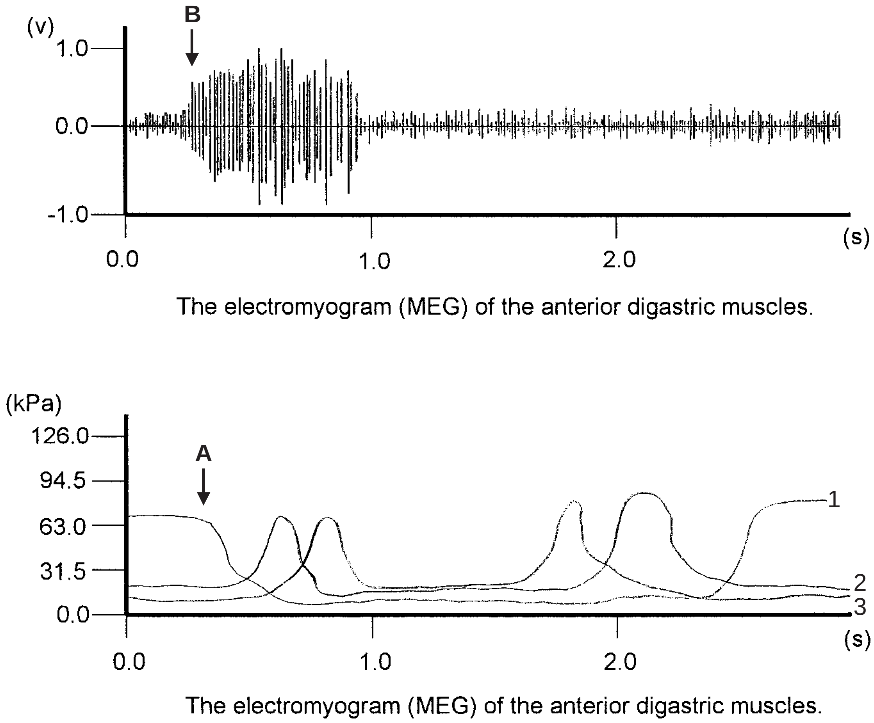

Fig. 2 The onset of the laryngeal movement was defined as the time when the output voltage of the first sensor started to decrease and the electromyogram of the anterior digastric muscles was initiated. (The time lag = A–B)

root of the square sum of each sample value. The base line was determined as mean root mean square (RMS) value during the first one second (1,000 Hz × 1 s). The time point at which the RMS value preceded the base line by two times was registered as the onset time of the EMG. Surface electromyograms (EMGs) were recorded with a pair of electrodes from the anterior digastric muscle. EMG data were band-pass filtered with 30–1,000 Hz.

Laryngeal movement detector

A bridge circuit was inserted in the pressure sensor (Kyowa Electric Company). Resistance of a bridge circuit was changed by pressing the surface of the sensor. The change in resistance was proportional to the pressure and could be recorded as a difference of voltage.

Dynamic strain amplifier

A direct current amplifier was used and the degree of amplification could be set to eight levels; 1, 10, 20, 50, 100, 200, 500 and 1,000 times. In this study, it was set at 1,000 times.

Computer: PC9821 Xa10
Program: Borland C++

The sensitivity of the pressure sensor was 0.317 mV/V. The frequency of the AD converter was changeable from 0.002 Hz to 10,000 Hz. In this study, the sampling rate of the AD converter was set at 1,000 Hz.

RESULTS AND DISCUSSION

An example of the voltage waveform obtained by the laryngeal movement detector is shown in Fig. 2. The EMG of the anterior

Table 1 Time lag (ms)

	1	2	3	4	5	Average	S.D.
N 1	59	102	58	72	61	70.4	±18.5
N 2	92	86	75	84	67	80.8	± 9.8
N 3	76	87	63	71	83	76.0	± 9.5
N 4	49	67	55	76	62	61.8	±10.5
N 5	88	114	87	69	79	87.4	±16.7

The time lag between the onset of the laryngeal movement was defined as the time between the point when the output voltage of the first pressure sensor started to decrease and the initiation of the electromyogram of the suprahyoid muscles. The time lags are averaged from each subject's five measurements.

digastric muscle was recorded simultaneoursly. After repeated trials of swallowing 1 ml of water, each subject could produce similar voltage waveforms that were obtained from the first to third pressure sensors of the laryngeal movement detector. The electromyogram of the anterior digastric muscles was analyzed after this voltage waveform became stable in each subject. The time lag between the onset of the laryngeal movement and the initiation of the electromyogram of the anterior digastric muscles was measured 5 times in 5 subjects. In the results, the measured time lag values varied from plus 49 ms to plus 114 ms (Table 1). Previous reports[1,2,5] have noted that laryngeal movement started later than the initiation of the electromyogram of the anterior digastric muscles, and our previous results have always been consistent with this finding unpublished.

Several studies in recent years have discussed the central regulation system of swallowing movements[3,4,6,7]. If the starting points of the contraction of each muscle and the movement of the larynx could be recorded simultaneously and could be used as reference points, it should be possible to compare variations in the swallowing movement. In this study, we used three pressure sensors to detect the starting point of laryngeal movement. As we expected, the first sensor was maximized in output while the larynx was in the rest position, and decreased when the larynx deviated upward (Fig. 2). The second and the third pressure sensors mimicked the pattern of the first one. These data showed that our device could record the movement and the position of larynx. In order to apply this device to the study of swallowing movement, we are now trying to establish experimental conditions that enable us to induce reproducible swallowing movements, as discussed in this paper.

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