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TECHNICAL PROCEDURE

A Relation Between the Piezoelectric Pulse Transducer Waveforms and Food Bolus Passage during Pharyngeal Phase of Swallow

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Clinical significance

A portable device to measure laryngeal movements was developed with a Piezoelectric Pulse Transducer. Simultaneous recordings of the laryngeal movements, EMG, and VF elucidated the PPT waveforms and could detect bolus passage during the pharyngeal phase of swallow. This portable system has the possibility to measure the dynamic state of swallowing without VF.

Abstract

Purpose: Since a Piezoelectric Pulse Transducer (PPT) detects finger peripheral pulse-waves, the PPT has already been used to simply record the laryngeal upward-downward movements. However, a relation between the sensor output and movements of the pharynx, larynx, and esophagus was not clear. This study was aimed to elucidate a relation between the PPT waveforms and food bolus passage during the pharyngeal phase of swallow.

Methods: The laryngeal movements by the PPT, surface electromyography of the geniohyoideus muscle, and videofluorography were simultaneously recorded. To synchronize VF, the PPT waveforms, and EMG, we touched the neck surface lightly using a small metal ball both before and after swallowing, thereby putting marks on the VF and the waves of the PPT. Then, features in the waveform of the PPT were analyzed with a personal computer.

Results: The swallowed food bolus was stopped for a moment on the epiglottic vallecula, as observed by VF. This stop was also observed in the PPT waveform as a return to the baseline. The epiglottis returned to the original position at the end of swallowing, as can be observed by VF and by a small peak in the PPT waveform. The food bolus passage was divided into two periods on the PPT waveform: TA (transit period from the base of the tongue to the epiglottic vallecula), and TB (transit period from the epiglottic vallecula to the esophagus).

Conclusion: The PPT waveforms could detect bolus passage from the base of the tongue through the epiglottic vallecula to the esophagus.

Key words: swallowing function, laryngeal movements, piezoelectric pulse transducer, dysphagia

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Introduction

Videofluorography (VF) is useful to diagnose functional conditions of oral, nasopharyngeal, and laryngeal organs during swallowing.[1,2] Due to the X-ray exposure, however, VF is not appropriate for use over long-time or repeated examinations. Furthermore, VF cannot be applied at bedside. A pressure sensitive sensor has been applied to measure the mechanical upward and downward movements of the larynx,[3,4] but it often could not detect the laryngeal movements in women during swallowing due to small and/or flat thyroid cartilage. To measure the laryngeal movements, we applied a Piezoelectric Pulse Transducer (PPT) which could detect finger peripheral pulse-waves by being fixed to the neck surface. Although the piezoelectric sensor has also already been used to simply record the laryngeal upward-downward movements,[5,6] a relation between the sensor output and movements of the pharynx, larynx, and esophagus was not clear.

The aim of this study was to elucidate the relation between the PPT waveforms and food bolus passage during the pharyngeal phase of swallow and to develop a portable system to measure food bolus passage non-invasively at bedside.

Materials and methods

The laryngeal movement was measured with a pulse transducer for finger peripheral pulse-wave measurements (Pulse Transducer: MLT1010, PowerLab AD Instrument, Fig. 1) that was fixed to the neck under the right auricular at the same level as the thyroid cartilage. Surface electromyography (EMG) of the right geniohyoideus muscle was recorded with bipolar surface electrodes (interelectrode distance was 20mm) to monitor muscle activities during swallowing (Fig. 2).

Simultaneous recordings of the laryngeal movements, EMG, and VF (MULTISKOP, SIEMENS) were performed. VF was recorded from the monitor output on a digital video recorder. The PPT waveforms and EMG were recorded through the Power Lab system (AD Instrument). To synchronize VF, the PPT waveforms, and EMG, we touched the neck surface lightly using a small metal ball both before and after swallowing, thereby putting marks on the VF and the PPT waveforms (Figs. 3). Then, the data were analyzed with a personal computer.

The subjects of this experiment were 3 healthy males (28-40 years old) who understood the purpose of this research and gave their consent to participate in this study. Five milliliters of 50% barium liquid was put on the center of the tongue and each subject was instructed to swallow it at once in a sitting posture.

Our research was approved by the ethics committee of Niigata University Faculty of Dentistry. Moreover, the research content was sufficiently explained to the examinees, and their consent was obtained in written form.

Difference from the conventional method

Figure 4 shows the synchronized data of the PPT waveforms, EMG, and VF images on a personal

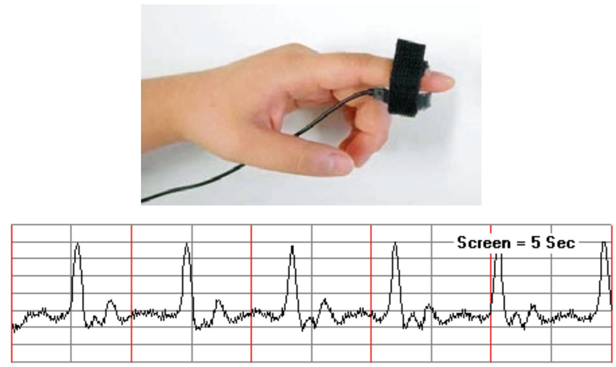

Fig. 1 Piezoelectric Pulse Transducer (PPT). A PPT was attached to the finger tip with a Velcro® belt. The PPT measured changes in force or pressure, and waveforms represented finger blood pressure pulse.

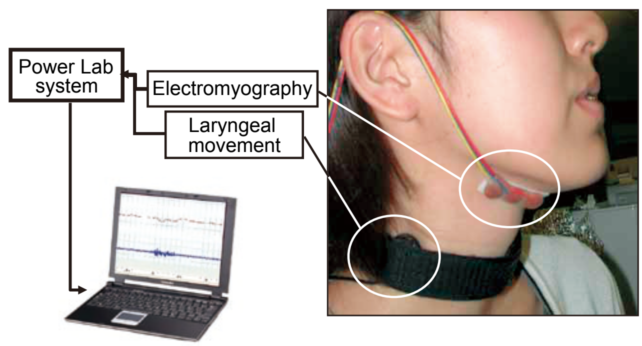

Fig. 2 Simultaneous recordings of the laryngeal movements and EMG.

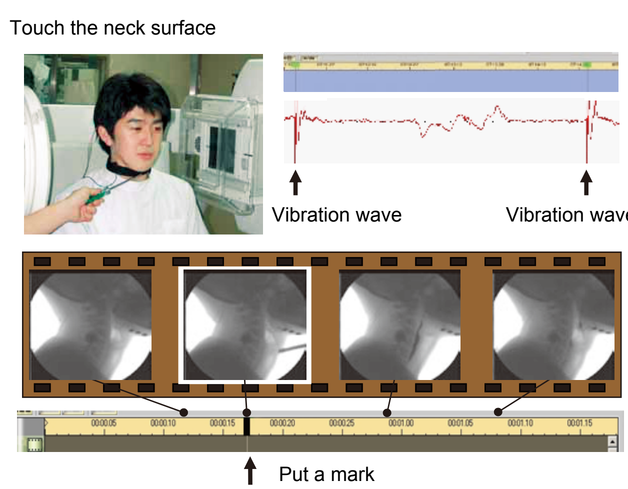

Fig. 3 Method to synchronize VF with the PPT waveform. We generated a vibration wave on the PPT waveform by touching the neck surface lightly with a small metal ball both before and after swallowing. Then, we put a mark (vertical line) on the VF recordings, in which the ball touched the neck surface. The VF and PPT waveform data synchronized in this way were fed thereafter into a personal computer.

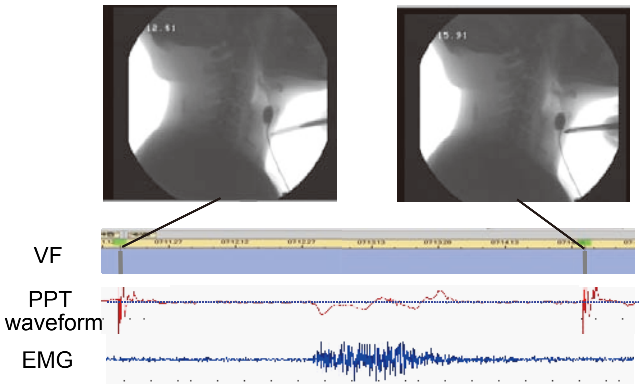

Fig. 4 Synchronized data of the PPT waveforms, EMG and VF. The vertical lines on the VF recordings coincided with the vibration waves on the PPT waveforms. Data of VF, PPT and EMG were synchronized.

computer. The relation between the waveform of the PPT and bolus passage during the pharyngeal phase of swallow could be determined by synchronized marks on the VF and the PPT waveform.

Effect or performance

In all subjects, the laryngeal movements during swallowing showed a "W-type" waveform, which showed good intra-individual repeatability (Fig. 5).

The starting point of swallowing (point "a" in Fig. 6) was decided from the onset of the geniohyoideus muscle activities and the PPT waveform. A small upward movement of the hyoid bone was observed by VF at point "a". The swallowed food bolus was stopped for a moment on the epiglottic vallecula, as observed by VF (point "b" in Fig. 6). This stop was also observed in the waveform of the PPT as a return to the baseline. Upward and forward movement of the larynx, backward folding of the epiglottis, and downward movement of the bolus were observed just after point "b" by VF. The epiglottis, which was closing the trachea, returned to the original position at the end of swallowing, as can be observed by VF and by a small peak in the waveform of the PPT (point "c" in Fig. 6).

Thus, the food bolus passage was divided into two periods on the waveform of laryngeal movement recorded by the PPT (Fig. 7): TA (from point a to point b; transit period from the base of the tongue to the epiglottic vallecula), and TB (from point b to point c; transit period from the epiglottic vallecula to the esophagus). In our previous study,[7] the duration of TA increased with the food concentration level, while the duration of TB remained unchanged. The increase of the food concentration level made swallowing subjectively more difficult by a sensory evaluation method. Therefore, the time needed for the food to pass from the base of the tongue to the epiglot-

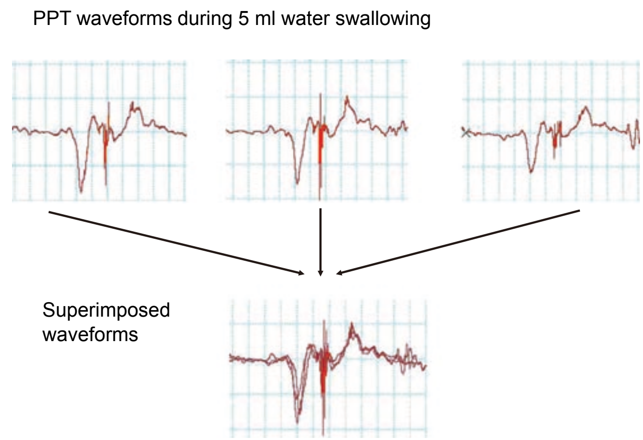

Fig. 5 Waveform reproducibility of the PPT. Three PPT waveforms during 5ml water swallowing were superimposed. The PPT gave two deflections with generally opposing polarity during each swallow. Sharp peaks of the waveforms between two deflections represented swallow sounds.

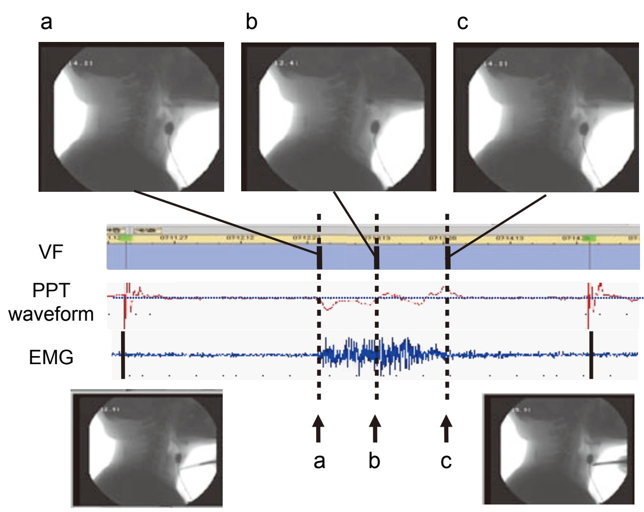

Fig. 6 Simultaneous recordings of the PPT waveforms, EMG and VF. a: The beginning of the PPT wave deflections coincided with the onset of the geniohyoideus muscle activity. The point "a" was defined as the start point of the bolus passage during pharyngeal phase of swallow. b: The food bolus was stopped for a moment on the epiglottic vallecula, as observed by VF. At this point "b", the PPT wave returned to the baseline since there was no change in force or pressure. c: A small peak in the PPT wave coincided with the point at which the epiglottis returned to the original position at the end of the bolus passage during swallowing, as can be observed by VF.

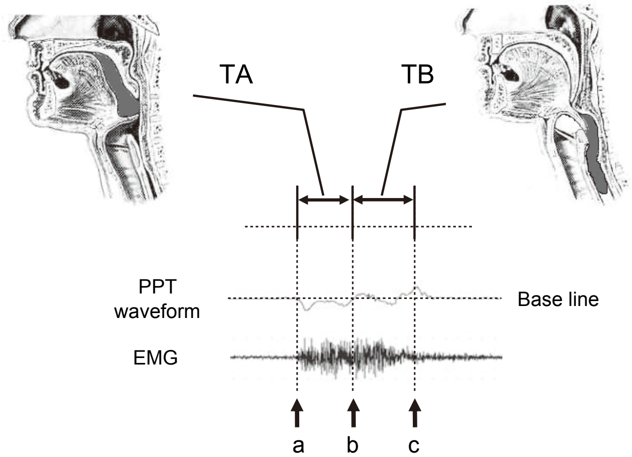

Fig. 7 Transit period of the bolus.

tis seems to affect the evaluation of swallowing easiness.

Conclusion

Features in the waveform of the PPT were elucidated by the synchronized data of the PPT, VF and EMG. Simultaneous recordings of the laryngeal movements, EMG, and VF showed that the PPT waveforms could detect bolus passage from the base of the tongue through the epiglottic vallecula to the esophagus.

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