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Non-invasive assessment determine the swallowing and respiration dysfunction in early Parkinson's disease

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ABSTRACT

Introduction: Dysphagia is common among patients with Parkinson's disease. Swallowing and its coordination with respiration is extremely important to achieve safety swallowing. Different tools have been used to assess this coordination, however the results have been inconsistent. We aimed to investigate this coordination in patients with Parkinson's disease using a non-invasive method.
Methods: Signals of submental muscle activity, thyroid cartilage excursion, and nasal airflow during swallowing were recorded simultaneously. Five different water boluses were swallowed three times, and the data were recorded and analyzed.
Results: Thirty-seven controls and 42 patients with early-stage Parkinson's disease were included. The rates of non-expiratory/expiratory pre- and post-swallowing respiratory phase patterns were higher in the patients than in the controls ($P < 0.001$). The rates of piecemeal deglutition when swallowing 10-ml and 20-ml water boluses and overall were also significantly higher in the patients (all $P < 0.001$). There were differences in oropharyngeal swallowing parameters between the patients and controls, including a pharyngeal phase delay with longer total excursion duration and excursion time in the patients swallowing small water boluses (1 ml, 3 ml and 5 ml), but no difference in the length of swallowing respiratory pause.
Conclusion: Oropharyngeal swallowing and its coordination with respiration are affected in patients with early-stage Parkinson's disease, and safety compensation mechanisms were used more than efficiency during swallowing. The results of this study may serve as a baseline for further research into new treatment regimens and to improve the management of swallowing in patients with Parkinson's disease.

1. Introduction

Parkinson's disease (PD) is the second leading cause of neurodegenerative disease worldwide [1]. Patients with PD usually present with swallowing dysfunction which is associated with a poor quality of life [2]. Dysphagia can cause morbidities including dehydration, malnutrition, aspiration and pneumonia, and in severe cases, mortality. Although dysphagia is a common symptom in PD, it is a difficult to identify swallowing dysfunction in the early stage of PD [3].

In the majority of patients with PD, dysphagia is related to oropharyngeal phases that present with a prolonged oropharyngeal transit time and delay in the initiation of swallowing [4]. One study showed that patients with PD with dysphagia and aspiration pneumonia had a significantly longer swallowing time including a longer pharyngeal transit time and onset of pharyngeal swallowing than in those patients with PD with dysphagia but without aspiration pneumonia [5]. An association between pulmonary dysfunction and swallowing impairment in patients with PD has also been reported [6]. However, these previous studies did not focus on the coordination of swallowing and respiration.

The coordination of respiration in the swallowing process involves a protective deglutitive pause and respiratory phase pattern, both of which are essential for safe swallowing without aspiration [7]. In PD, this coordination deviated from normal controls has been

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demonstrated. The instrumental tools used to study the coordination of swallowing and respiration in PD include videofluoroscopy swallowing study (VFSS) [8] or non-invasive swallowing assessment technique [9,10] which combined with respiratory monitoring. Newer studies on swallowing have focused on non-invasive techniques in neurological diseases [11–15] which are advantageous for follow-up studies when repeated outcome measurements are needed. But, no combination of respiration monitoring in their studies was found. In our previous studies, we established a non-invasive assessment system to examine the coordination of swallowing and respiration in the elderly and patients with subacute unilateral stroke and obstructive sleep apnea (OSA) [16–18]. However, few studies have used non-invasive tools to study the coordination of swallowing and respiration in PD [9,10]. Using VFSS in PD, post-swallowing inspiration and shorter swallowing apnea duration are important indicators of penetration or aspiration [8]. Nevertheless, oropharyngeal swallowing parameters and the coordination of swallowing with respiration in the early stage PD have not been thoroughly investigated. In this study, we aimed to use our non-invasive system recording more data and analyzing precisely to examine differences in the coordination of oropharyngeal swallowing and respiration between patients with the early stage of PD and normal controls.

2. Methods

2.1. Hardware and software

Our non-invasive electrophysiological swallowing and respiration assessment system was based on the BIOPAC MP100 system (BIOPAC System, Goleta, CA, USA). The sensors used to detect the bio-signals of swallowing and respiration, and the Force Sensing Resistor (FSR) fixation method are same as our previous research [16,19].

2.2. Participants, experimental protocol, and data collection

2.2.1. Participants

Forty-two patients with PD and 37 normal volunteers were recruited for the non-invasive swallowing and respiration tests. The Unified Parkinson Disorder Rating Scale (UPDRS) was completed to rule out PD symptoms in the normal controls, and the UPDRS was also completed by the patients with PD on the same day as non-invasive swallowing and respiration assessments.

2.2.2. Exclusion criteria of all participants

The healthy volunteers had no known history of dysphagia, cardiopulmonary disease, neurological disease, chronic indigestion disorder, any disease of the head and neck. The patients with PD who had a previous history of other neurological diseases, head and neck cancer, chronic obstructive pulmonary disease, or dementia were also excluded.

The protocol of this study was approved by the ethics committee of our hospital (No. 102-5410B), and written informed consent was obtained from all participants before swallowing data collection.

2.2.3. Inclusion criteria for the patients with PD and protocols

All of the patients with PD were diagnosed according to the UK Brain Bank diagnostic criteria of idiopathic PD [2]. They had all visited our out-patient clinics for treatment, and they were all stage I-III on the H&Y disability scale [20] after being rated by two board-certified neurologists who specialized in PD. Patients were only accepted if they had followed an unaltered protocol of anti-parkinsonian medication for at least 2 months and their disease was stable.

2.2.4. Protocol of non-invasive swallowing and respiration assessment

After two ECG adhesive electrodes were placed for submental sEMG, FSR sensors for the laryngeal excursion [16], and nasal cannula for respiration were appropriately placed on the subject. Each participant was then instructed to swallow five types of water bolus at room temperature, three times for each bolus, in the following order: 1 ml, 3 ml, 5 ml, 10 ml, and 20 ml. In total, 15 swallows per participant were obtained. The oropharyngeal swallowing and respiratory signals, including the temporal parameters of thyroid cartilage motion, swallowing respiratory pause (SRP), pre- and post-swallowing respiratory phase patterns, and piecemeal deglutition during swallowing of the 10 ml and 20 ml water boluses were analyzed.

2.2.5. The parameters of oropharyngeal swallowing signals and respiration coordination

2.2.5.1. Pre- and post-swallowing respiratory phase patterns. Four respiratory phase patterns describe the pre- and post-deglutition respiration signals of inspiration or expiration: expiration-expiration (EX/EX) (Fig. 1), expiration-inspiration, inspiration-expiration, and inspiration-inspiration [21]. In general, the EX/EX pattern is the major, dominant, and protective type [22].

2.2.5.2. Piecemeal deglutition and dysphagia limit. The maximal volume of water bolus that can be swallowed in one swallow is called the “dysphagia limit”. If the volume of the bolus fed into the mouth exceeds the dysphagia limit, it is absolutely necessary to divide this bolus into smaller volumes and swallow them successively. This protective swallowing process is called “piecemeal deglutition”. A dysphagia limit of less than 20 ml has been recommended in patients with neurogenic dysphagia [13].

2.2.5.3. Latency and duration of oropharyngeal swallowing (Fig. 1). Data on temporal events including the latency and duration of oropharyngeal swallowing were analyzed and integrated with signals obtained from the submental sEMG and FSR. The onset of the oral phase was defined as the beginning of submentalis activity based on sEMG measurements. The onset latency of the laryngeal upward excursion was defined as the duration from the onset of sEMG to the onset of laryngeal excursion. The laryngeal upward excursion time (ET) was defined as the duration of the first downward deflection recorded by FSR. The duration of the second deflection was defined as the duration of laryngeal downward excursion for relocation [11]. The total excursion time (TET) was defined as the sum of ET and duration of the second deflection. The validity of these parameters as measurements of the different pharyngeal stages has previously been demonstrated [23].

2.2.5.4. Swallowing respiratory pause (SRP). SRP is a protective phenomenon during swallowing that allows for safe swallowing without aspiration [24]. Thus, SRP, the duration of airway closure during swallowing, was measured to quantify the performance of deglutitive apnea (Fig. 1).

2.2.6. Statistical analysis

All statistical analyses were performed using SPSS software version 12.0 (SPSS Inc., Chicago, IL). The data obtained from the three separately recorded swallowing trials of each bolus size without piecemeal deglutition were averaged. Two-way repeated measures ANOVA tests were used. The independent variables were oropharyngeal parameters and SRP, and the subject group and three small bolus volumes (1 ml, 3 ml, and 5 ml) were dependent variables to examine the interaction and main effects. For numbers

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