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Alterations in oropharyngeal sensory evoked potentials (PSEP) with Parkinson's disease

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ABSTRACT

Movement of a food bolus from the oral cavity into the oropharynx activates pharyngeal sensory mechanoreceptors. Using electroencephalography, somatosensory cortical-evoked potentials resulting from oropharyngeal mechanical stimulation (PSEP) have been studied in young healthy individuals. However, limited information is known about changes in processing of oropharyngeal afferent signals with Parkinson's disease (PD). To determine if sensory changes occurred with a mechanical stimulus (air-puff) to the oropharynx, two stimuli (S1-first; S2-s) were delivered 500 ms apart. Seven healthy older adults (HOA; 3 male and 4 female; 72.2 ± 6.9 years of age), and thirteen persons diagnosed with idiopathic Parkinson's disease (PD; 11 male and 2 female; 67.2 ± 8.9 years of age) participated. Results demonstrated PSEP P1, N1, and P2 component peaks were identified in all participants, and the N2 peak was present in 17/20 participants. Additionally, the PD participants had a decreased N2 latency and gated the P1, P2, and N2 responses (S2/S1 under 0.6). Compared to the HOAs, the PD participants had greater evidence of gating the P1 and N2 component peaks. These results suggest that persons with PD experience changes in sensory processing of mechanical stimulation of the pharynx to a greater degree than age-matched controls. In conclusion, the altered processing of sensory feedback from the pharynx may contribute to disordered swallow in patients with PD.

1. Introduction

In persons with Parkinson's disease (PD), dysphagia can result from motor or sensory abnormalities (Born et al., 1996; El Sharkawi et al., 2002; Hunter et al., 1997; Miller et al., 2006; Mu et al., 2012; Pitts et al., 2009; Pitts et al., 2008; Pitts et al., 2010; Potulska et al., 2003; Robbins et al., 1986; Troche et al., 2010; Troche et al., 2008). Throughout the progression of PD, up to 100% of individuals experience some form of dysphagia and aspiration pneumonia is a leading cause of death in these patients (Akbar et al., 2015; Martinez-Ramirez et al., 2015; Pennington et al., 2010). Aspiration can be caused by uncoordinated movements or significant delays in the initiation of the swallow (Hammond and Goldstein, 2006; Kendall and Leonard, 2001; Logemann et al., 2008; Martin et al., 1994; Martinez-Ramirez et al., 2015).

Swallow is initiated by stimulation of the oropharyngeal wall, and the afferent information is processed by cortical and subcortical structures including the brainstem, pons, thalamus, primary sensory cortex, and limbic structures (Bosma, 1957; Davenport et al., 2011; Doty, 1968; Doty and Bosma, 1956; Gestreau et al., 1996; Gow et al., 2004; Hartnick et al., 2001; Hukuhara and Okada, 1956; Jean, 1984; Kennedy and Kent, 1988; Kern et al., 2001; Saito et al., 2002; Sumi, 1967; Umezaki et al., 1997; Vantrappen and Hellemans, 1967). The cerebral cortex is thought to be important in sensory processing, attention, and the affective process of the stimulus (Ashraf et al., 2008; Babiloni et al., 1999; Chan and Davenport, 2008; Colon et al., 1983; Crowley and Colrain, 2004; Davenport et al., 2007; Davenport et al., 1996; Davenport et al., 2000; Davenport et al., 1986; Desmedt et al., 1983; Folstein and Van Petten, 2008; von Leupoldt et al., 2013). To evaluate this sensory system, an air-puff was applied to the oropharyngeal wall and cortical sensory evoked potentials (EP) were recorded from the scalp using electroencephalography (EEG) (Wheeler-Hegland et al., 2010, 2011). Wheeler-Hegland, et al. (2011) established in young healthy adults

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that there is cortical processing of pharyngeal mechanical stimulation, termed oropharyngeal sensory evoked potential (PSEP). Additionally, this technique can evaluate whether the processing of the information changes during a paired stimulus paradigm (500 ms interval), termed sensory gating (Chan and Davenport, 2009, 2010; Chan and Davenport, 2008; Wheeler-Hegland et al., 2010).

Sensory gating is a process by which redundant sensory information is inhibited from reaching the cortex (Chan and Davenport, 2010; Chan et al., 2012; Chan and Davenport, 2008; McCormick and Bal, 1994; McCormick and Bal, 1997). The thalamus is thought to be one of the most important neuroanatomical substrate responsible for sensory gating (Gaudreau and Gagnon, 2005; McCormick and Bal, 1994), and has been hypothesized to be part of the suprapontine areas involved in swallowing (Mosier and Bereznaya, 2001). During sleep, rhythmic burst firing inhibits the vast majority of sensory information from reaching the cortex, yet during wakefulness, single spike activity allows the thalamus to have finer control (McCormick and Bal, 1994; McCormick, 1992). Projections from the thalamus are processed in layer IV of the somatosensory cortex, which in turn has extensive projections to the thalamus. This establishes a feedforward and feedback system, creating a cortical-thalamic loop to prevent the cortex from being flooded by redundant sensory information (McCormick and Bal, 1994; McCormick and Bal, 1997). In this loop, the thalamus acts as a "gate," allowing the primary stimulus to reach the cortex while inhibiting subsequent or redundant information. Wheeler-Hegland et al. (2010) provided evidence of limited gating of the PSEP in young healthy adults, and more specifically that central processing of mechanical stimulation to the pharyngeal wall is different than other somatosensory modalities i.e. respiratory-related (Chan and Davenport, 2009; Chan and Davenport, 2008) and auditory (Korzyukov et al., 2007) which had significant suppression of the second stimulus event. We hypothesize that limited gating of pharyngeal mechanical stimulation is advantageous for effective airway protection, due to the time-course of the pharyngeal phase of swallow and the ability of humans to perform sequential swallow tasks. This current project tests the hypothesis that since sensory evoked potentials have been used as diagnostic indicators of PD (Boecker et al., 1999; Di Lazzaro et al., 1999; Rossini et al., 1989), significant decreases in the latency and gating ratios of the PSEP component peaks would be found.

2. Methods

2.1. Participants

The Institutional Review Board at the University of Florida approved the study (IRB 1113–2008). Twenty participants were recruited for this study: seven healthy older adults (HOA; 72.2 + 6.9 years of age), and thirteen participants with idiopathic PD (67.2 + 8.9 years of age). The diagnosis of PD was made by a fellowship-trained movement disorders neurologist according to the United Kingdom (UK) brain bank criteria. Participants were tested on their prescribed PD/non-PD medication(s). All participants self-reported no history of head or neck cancer, neurologic disease (except for idiopathic PD), chronic respiratory diseases, history of smoking within the last 10 years, or dysphagia. Participants were asked to refrain from caffeine intake for at least twelve hours prior to the study, due to the known effects of caffeine on evoked potentials (Conners, 1979; Emerson et al., 1988; Tharion et al., 1993; Wolpaw and Penry, 1978).

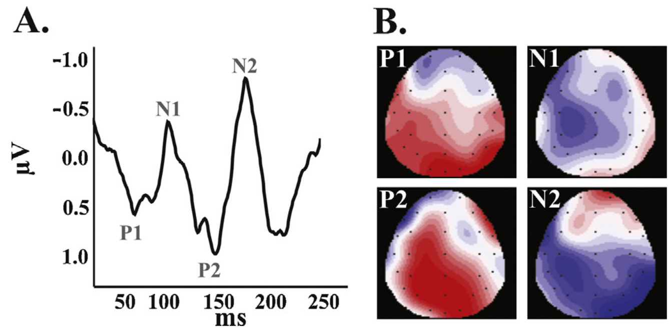

Fig. 1. (A) Example of a pharyngeal sensory evoked potential (PSEP) waveform. The component peaks P1, N1, P2, and N2 are labeled. (B) The hot spot electrode was determined using the waveform and two-dimensional map. Positive charge is characterized in red, and negative charge is characterized in blue.

2.2. Oropharyngeal sensory evoked potentials (PESP)

The PSEP protocol was conducted according to the technique of Wheeler-Hegland and colleagues (Hegland et al., 2011). Participants were seated comfortably with the back, neck and head supported. A 32-electrode Neuroscan Quickcap^{TM} (based on the International 10–20 system) was positioned on the participant's head and connected to the SynAmps^2 Neuroscan System. Electro-conducting gel was applied through each electrode in order to establish scalp contact and maintain impedance levels below 5 kΩ. Bipolar electrodes were placed on the skin above and below the left eye for recording vertical electro-oculogram (VEOG) activity. Synamps amplifiers (Neuroscan, El Paso, TX) and SCAN version 4.3 acquisition software (Neuroscan, El Paso, TX) was used to record the EEG signal onto a desktop computer. The EEG activity was referenced to linked earlobes. The sampling rate was set to 1000 Hz per channel with an applied bandpass filter of DC to 200 Hz. SCAN version 4.3 analysis software (Neuroscan, El Paso, TX) was used for data analysis (see below).

A certified clinically competent speech-language pathologist (CCC-SLP) administered the air-puff protocol (author, TP). A mouthpiece with a polyethylene tube was placed in the mouth, and a flexible laryngoscope was inserted through the tube (identical to Wheeler-Hegland et al. (2011) Fig. 1). The laryngoscope images were displayed, but not recorded, on a computer screen. Both the laryngoscope and computer were components of the JEDMED StroboCAM II® system (JEDMED Instrument Co., St Louis, MO). In this manner, the laryngoscope allowed for visualization and verification of tube placement for air-puff delivery. The laryngoscope itself was covered with a hygienic sheath (Slide-On® Sheath for Sensory Testing, Medtronic Xomed, Inc., Jacksonville, FL) that has a small port through which the air-puffs were delivered. The port was connected to an air tank, connected to a solenoid valve, which delivered air-puffs through the laryngoscope tube. When a second investigator (author KH) triggered a solenoid valve, air under positive pressure was delivered through the tubing onto the participant's pharyngeal surface. Two air-puffs (S1, first stimuli; S2, second stimuli) were delivered with an inter-stimulus interval of 500 ms. The pressure was regulated at approximately 20–30 cm H_2O. Of note, the pressure varied depending on the participant's relative comfort, without triggering a cough, swallow or gag. Each air-puff was delivered for approximately 150–200 ms. A 750 ms EEG and pressure sample epoch was recorded from the onset of the air-puff pressure. A total of 256 EEG epochs of air were presented. To ensure limited muscle contraction of the face and neck, the participants were intermittently asked to relax and not bite down on the mouthpiece. Additionally, to reduce Alpha–rhythms, the participants were asked to keep their eyes open and watch a movie.