Characteristics of Hypokinetic Dysarthria Patients' Speech based on Sustained Vowel Phonation and Connected Speech

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Abstract

This study investigated the characteristics of Parkinson's disease patients' speech through difference of measured cepstral values of speech assignment (sustained vowel phonation, connected speech) between normal adults and patient's with Parkinson's disease in Korea. Subjects of the study were 17 males with Parkinson's disease and control group was 28 healthy male adults without cranial nerve damage or disorder. Speech was collected in sustained vowel phonation and connected speech respectively. The cepstral analysis was used to Analysis of Dysphonia in Speech and Voice (ADSV) Model 5109 of KayPENTAX Corp. Difference of measured value between the groups was confirmed with independent t-test. As the result of independent t-test, there was significant difference in CPP, L/H ratio and CSID of sustained vowel phonation between groups. In contrast, in connected speech, all the measured values have no significant difference between the two groups except CPP. Parkinson's disease patients had difference in speech characteristics depending on speech assignment (sustained vowel phonation, connected speech). Based on the results of this study, analysis on connected speech other than sustained vowel phonation is essentially required in order to precisely identify the speech characteristics Parkinson's disease patients.

Keywords: Parkinson's disease, Cepstral analysis, Connected speech

1. Introduction

With rapid aging, interest in old-age neurological disorders is on the rise. Among them, Parkinson's disease is the second most common degenerative disease which is a typical neurological motor dysfunction caused by decline of dopamine production in substantial nigra [1]. In general, outbreak of Parkinson's disease radically increases in old age and approximately 1% of elderly population is estimated to have the disease and its prevalence rate is higher in females than in males [1]. As a progressive disease, the symptoms of Parkinson's disease gradually worsen and most of the patients die of dementia or dysphagia in 10 years [2].

Major symptoms of Parkinson's disease are classified into motor symptoms and non-motor symptoms. Motor symptoms which are also called primary symptoms are rigidity, rest tremor, bradykinesia and instability [3]. Non-motor symptoms are autonomic nervous system disorder and cognitive impairment. Besides, during the process of Parkinson's disease, paralysis, weakness of articulation muscles and neurogenic speech disorders caused by rigidity occur. Major neurogenic speech disorders found in Parkinson's diseases are dysarthria and dysphagia and dysarthria is so common that 90% of patients with Parkinson's disease experience the disorder [4].

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Rest tremor in Parkinson's disease manifests itself in terminal joints such as fingers and wrists in the speed of 4~6Hz and such tremor occurs in articulation muscles such as jaw and tongue, ultimately affecting speech [5]. Therefore, reflecting such characteristics, Parkinson's disease is named hypokinetic dysarthria in Speech-Language Pathology [3].

Treatment of Parkinson's disease generally focuses on maintaining functions in order for patients to keep ordinary life by relieving degenerative symptoms. Especially, since communication ability is essential in the interaction with other people and affects quality of life, it is important to investigate characteristics of hypokinetic dysarthria to enhance the quality of life of the patients with Parkinson's disease.

As the result of study on the speech characteristics of hypokinetic dysarthria, major characteristics reported were monopitch, reduced stress, monoloudness, imprecise consonants, inappropriate silences, harsh voice, breathy voice and variable rate [3]. These results, however, mainly reflect auditory-perceptive characteristics and have following limitations. First, although auditory-perceptive assessment is mainly used as method of evaluating speech characteristics of Parkinson's disease, this assessment lacks reliability and validity [6]. Second, most of the preceding studies which acoustically analyzed Parkinson patients' speech excluded severe cases of Parkinson's disease from their researches, which make them difficult to interpret as general characteristics of Parkinson's disease [7]. Third, there is lack of studies on Korean speakers with Parkinson's disease. Fourth, although preceding studies reported speech characteristics in vowel prolongation task [8], it is difficult to find out precise speech characteristics of Parkinson's disease with vowel prolongation task alone. Especially, even though these studies used Multi-Dimensional Voice Program (MDVP) as a measuring tool, MDVP can draw out reliable results only in the case when subjects can pronounce vowel for more than 3 seconds and what is more, its reliability decreases for aperiodic voices [8]. Therefore, reliable acoustic analysis is required which includes irregular voices.

As an alternative to MDVP, cepstral analysis is recently being used. Cepstral analysis is a measuring method which computes spectrum with logarithm and makes Fourier transformation on it and this method produces reliable results in both vowel and connected speech and has the strength that it can also analyze voices with severe noises [9]. This study investigated the characteristics of Parkinson's disease patients' speech through difference of measured cepstral values of speech assignment (sustained vowel phonation, connected speech) between normal adults and patient's with Parkinson's disease in Korea.

2. Methods

2.1. Subjects

Subjects of the study were 17 males with Parkinson's disease and control group was 28 healthy male adults without cranial nerve damage or disorder (Table 1). They were given sufficient explanation regarding the purpose and experimental method of this study before participating and gave voluntary consent. This protocol was approved by the Institutional Review Board of BMH hospital. Standard for Parkinson's group were those who passed more than 2 years after the breakout of the disease with stage 3 or lower in Hoehn-Yahr scale [10] and without stroke or depression.

Table 1. General Characteristics of Subjects, Mean±SD

	Normal (n=28)	Parkinson's disease (n=17)
Age (yrs)	65.0±4.4	66.3±3.8
Education (yrs)	6.0±3.5	6.0±3.1
H-Y stage	N/A	2 or 3

H-Y stage: Hoehn and Yahr scale

2.2. Measurements

This study used Analysis of Dysphonia in Speech and Voice (ADSV) Model 5109 of KayPENTAX Corp. for recording and analysis and headset-type PG48-LC of Shure Corp. for microphone. During collection of data, distance of 5cm was maintained between microphone and mouth. As for recording environment, sampling rate was set in 44,100 Hz and quantization in 16bit. ADSV is based on cepstral analysis and able to reliably measure severely damaged voice or voice with short sustained time of phonation as well as connected speech [9].

The mathematical relation for computing cepstrum are as follow:

$$C_c(n) = \frac{1}{2\pi} \int_{-\pi}^{\pi} \log(|s(\omega)|) e^{\int \omega n d\omega}$$

$$= \frac{1}{2\pi} \int_{-\pi}^{\pi} \log(|s(\omega)| e^{\int \angle s(\omega)}) e^{\int \omega n d\omega}$$

$$= \frac{1}{2\pi} \int_{-\pi}^{\pi} \log(|s(\omega)|) e^{\int \omega n d\omega} + j \frac{1}{2\pi} \int_{-\pi}^{\pi} \angle s(\omega) e^{\int \omega n d\omega}$$

$$C_c(n) = C_r(n) + jC_i(n)$$

Major measuring indexes are presented in Table 2.

2.3. Analysis

Data were collected in voice test laboratory of B hospital from March through August in 2014 in the following 2 methods; first, for natural voice production of vowel, subjects were asked to utter their names and comfortably pronounce vowel /a/ for 5 seconds and repeated it twice. If the subjects could not sustain vowel /a/ for 5 seconds, they were asked to produce the sound as long as they could. Second, by referring to preceding studies [11], connected speech was collected by using a 4-syllable Korean sentence of "Onul kalga naeil kalga? (Shall we go today or tomorrow?)".

Analysis was conducted on 1/3 point from the start of the vowel with stable pulse bar and consistent horizontal line of formant, loudness and pitch. Whole section of connected speech was analyzed except pause. Difference of measured value between the groups was confirmed with independent t-test. All analyses were performed using IBM SPSS version 21.0 (IBM, Inc., Chicago, Illinois).

Table 2. Indexes of ADSV

Index	Explanation
CPP (dB)	Defined as difference in strength between total regression line of cepstrum and cepstral peak. The better the quality of voice, the higher the score.

L/H ratio (dB)	Threshold is 4, 000Hz and its score is low in abnormal voice.
CPPF0 (Hz)	Defined as average frequency of CPP which is in the range of 60~300Hz of vocal sound among analyzed voices.
CSID	Its score is high in abnormal voice.

ADSV= Analysis of Dysphonia in Speech and Voice

3. Results

Measured values of cepstral analysis based on speech assignment of normal adult and patients with Parkinson's disease are presented in Table 3. As the result of independent t-test, there was significant difference in CPP, L/H ratio and CSID of sustained vowel phonation between groups Table 1. In CPP, Parkinson's disease patients were 11.3dB while normal adults were 14.1dB and in L/H ratio, Parkinson's disease patients were 28.5dB while normal adults were 33.3dB, showing that normal adults were much higher than Parkinson's disease patients ($p<0.05$). In CSID, Parkinson's disease patients (8.3) were significantly higher than normal adults (-1.5) ($p<0.05$). In CPPF0, there was no significant difference between the two groups. In connected speech, all the measured values have no significant difference between the two groups except CPP. Normal adults (8.8dB) had significantly higher CPP than Parkinson's disease patients (7.1dB) ($p<0.05$).

Table 3. Measured Values of Cepstral Analysis based on Speech Assignment of Normal Adult and Patients with Parkinson's Disease, Mean±SD

Index	Sustained vowel		p	Connected speech		p
	PD	NA		PD	NA	
CPP (dB)	11.3±4.6	14.1±1.6	0.03	7.1±2.2	8.8±1.5	0.01
L/H ratio (dB)	28.5±6.8	33.3±4.5	0.01	35.3±5.5	36.1±4.8	0.62
$CPPF_0$ (Hz)	136.8±18.5	142.6±20.1	0.78	161.3±15.2	158.8±17.1	0.15
CSID	8.3±7.5	-1.5±6.8	0.01	N/A	N/A	N/A

PD= Parkinson's disease; Na=normal adult

4. Discussion

As the result of investigating the difference of measured cepstral values of normal adults and Parkinson's disease patients, in sustained vowel phonation, Parkinson's disease patients were significantly lower in CPP and L/H ratio than comparison group ($p<0.05$) but were significantly higher in CSID. This result can be explained with 2 possibilities. First, the reason is that CPP is a parameter for the level of harmonics and normal voice shows structure of harmonics frequency better in periodic signals than voice of Parkinson's disease patients [12]. Thus, there is possibility that Parkinson's disease characterized by instability of voice and breathiness had significantly lower CPP value than normal adults.

Second, three is a possibility that weak respiration of Parkinson's disease affected L/H ratio. In general, as voice with weak respiration has low energy in high frequency domain, it produces low L/H ratio [12]. Parkinson's disease patients experience decrease in lung capacity from the onset of the disease and lack respiration support due to rigidity of chest wall, eventually having short speech and breathy voice [13]. In sum, it is supposed that neurological problems of Parkinson's disease change glottis and respiration and these

motor characteristics change acoustic characteristics, which eventually are perceived as abnormal speech by the listeners.

In connected speech of this study, there was no significant difference in the value of L/H ratio (dB) between groups, which is deemed to be the result of respiratory characteristics caused by the length of speech of Parkinson's disease patients. In a preceding study which analyzed the characteristics of Parkinson's disease patients' passage reading [14], Parkinson's disease patients had significant less syllables per breath than normal adults and short time to produce speech. In addition, in sentence reading assignment, Parkinson's disease patients had inappropriate stop in respiration, which caused inappropriate silences as well [13]. This study, however, used a short sentence with 4 syllables for connected speech assignment and 'pause' was excluded in the process of analysis. Therefore, it is supposed that, inappropriate respiration and resulting dysphonia were not observed in Parkinson's disease patients in connected speech assignment which used a short sentence unlike in preceding studies [13-14].

The limitations of this study are as follows; first, as the number of Parkinson's disease subjects was small, the study results cannot be generalized. Second, All subjects of this study were male. As there are differences in the characteristics of gender, studies to investigate the speech characteristics of each gender of Parkinson's disease patients are required in the future.

In sum, Parkinson's disease patients had difference in speech characteristics depending on speech assignment (sustained vowel phonation, connected speech). Based on the results of this study, analysis on connected speech other than sustained vowel phonation is essentially required in order to precisely identify the speech characteristics Parkinson's disease patients.

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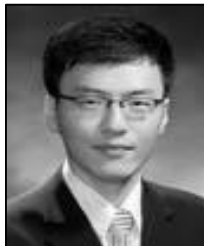
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