ACOUSTIC FINDINGS OF VOICE DISORDERS IN HUNTINGTON'S DISEASE COMPARED TO PARKINSON'S DISEASE

J. Rusz[1,2], J. Klempir[2], E. Baborova[2], T. Tykalova[1], V. Majerova[2], R. Cmejla[1], E. Ruzicka[2], J. Roth[2]

[1] Department of Circuit Theory, Czech Technical University in Prague, Faculty of Electrical Engineering, Prague, Czech Republic
[2] Department of Neurology and Centre of Clinical Neuroscience, Charles University in Prague, First Faculty of Medicine, Prague, Czech Republic
ruszjan@fel.cvut.cz

Abstract: **One common finding in Huntington's disease (HD) is related to phonatory disruptions that can be perceptually characterized by harshness, strained-strangled voice quality, and pitch fluctuations. These alterations of voice occur mainly as a consequence of underlying involuntary contractions, variable muscle tone, or even tremor of laryngeal musculature. Recently, several new acoustic analysis methods have been introduced to capture different aspects of these phonatory abnormalities. In this report, we summarize objective acoustic metrics suitable for assessment of phonatory dysfunction and provide their classification accuracy in separation between patients with HD and healthy controls. For this purpose, data consists of 272 phonations collected from 34 individuals with HD and 34 healthy controls. As impairment of phonatory function in HD was found across all investigated measurements, voice analysis may potentially serve as a marker of disease progression.**

Keywords: **Huntington's disease, hyperkinetic dysarthria, dysphonia, acoustic analysis, classification.**

I. INTRODUCTION

Huntington's disease (HD), which is caused by an expansion of the number of CAG repeats located on the short arm of chromosome 4 at 4p16.3 [1,2], is a chronic, degenerative, neuropsychiatric disorder, characterized by progressively increasing of choreiform movements,. In the course of the illness, the patients with HD typically develop a distinctive alteration of speech termed as hyperkinetic dysarthria [3]. Hyperkinetic dysarthria in HD is mainly affected by the involuntary contractions of speech mechanism musculature, occurring mainly as a consequence of underlying choreatic movements. Such involuntary contractions of vocal muscles can especially transcend during speaking task such as sustained vowel phonation which demands stable coordination of the jaw, tongue, palate, and facial movements. Recently, we have introduced several metrics that were sensitive to differentiate between healthy and HD voices [4]. The aim of the current study was to review the most successful algorithms to capture phonatory dysfunction in HD and investigate their ability to predict HD membership.

II. METHODS

A. Data

The data for this study were collected as the part of the previous study [4]. From 2011 to 2012, a total of 34 Czech native participants (15 men and 19 women) with genetically verified HD were recruited. Their mean age was 45.2 ± SD 13.3 (range 23–67) years, mean age at HD onset was 39.3 ± 13.5 (14–62) years, mean disease duration 5.9 ± 3.1 (2–16) years, and average number of CAG triplet repeats 46.4 ± 5.8 (40–70). As a control group, 34 persons (15 men and 19 women) of comparable age, mean age 45.5 ± 13.6 (range 24–68) years, with no history of neurological or communication disorders were included. None of the participants had undergone voice therapy and all gave their consent to the vocal tasks and recording procedure. Every subject was instructed to perform sustained phonation of the vowel /a/ and vowel /i/, each one repeated two times.

B. Acoustic measurements

Acoustic analyses were performed using several phonatory measurements in order to investigate different aspects of speech in HD patients and controls. To assess airflow insufficiency, we examined maximum phonation time (MPT) [5], and MPT until the occurrence of the first voice break (MPT_{VB}) [4]. To investigate aperiodicity, we evaluated number of voice breaks (NVB) and degree of voicelessness (DUV) [6]. With respect to irregular

Claudia Manfredi (edited by), *Models and analysis of vocal emissions for biomedical applications : 8 th international workshop : December 16-18, 2013*
ISBN 978-88-6655-469-1 (print) ISBN 978-88-6655-470-7 (online) © 2013 Firenze University Press

vibrations of vocal folds, we extracted fundamental frequency variations (F0 SD) [7], recurrence period density entropy (RPDE) [8], and pitch period entropy (PPE) [9]. To examine signal perturbations, we investigated jitter and shimmer [6]. To capture problems with increased noise, we calculated harmonics-to-noise ratio (HNR) [6], and fluctuation analysis (DFA) [8]. Finally, we have also introduced new acoustic parameter related to articulation deficiency based upon mel-frequency cepstral coefficients (hereinafter, MFCC) [4], which was defined as the mean of the standard deviations of the 1st-12th MFCCs using the implementation of Brooke's Matlab toolbox [10].

C. Classification experiment

Each designed acoustic feature underwent classification experiment, where support vector machine (SVM) with Gaussian radial basis kernel was used to decide whether the speech performance belongs to HD or control speaker. The cross-validation scheme was applied where all data (136 phonations of HD patients and 136 phonations of controls) were randomly separated into training (80%) and testing (20%) subsets; the process of cross-validation was repeated 20 times for each parameter.

III. Results

According to the SVM classifier, four metrics including MPT, MPT_{VB}, F0 SD, and MFCC achieved greater classification accuracy exceeding 80% in differentiation between HD and control speakers (Table 1). The best single parameter reflecting phonatory dysfunction in HD was found to be MPT_{VB} with classification accuracy of 89.4 ± 3.9% (sensitivity: 91.8 ± 4.9%; specificity 87.9 ± 5.5%). This parameter represents sudden phonation interruptions and can be associated with motor impersistence, which is the inability to sustain certain simple voluntary act such as keeping the tongue protruded or maintaining a firm grip.

Table 1: List of classification results of acoustic phonatory measures with mean and standard deviation (SD) values for differentiation between patients with HD and healthy controls.

Parameter	Classification score % (Mean ± SD)			Rank
	Overall	Sensitivity	Specificity	
Airflow insufficiency				
MPT	85.5 ± 4.6	92.1 ± 5.5	81.3 ± 5.4	3rd
MPT_{VB}	89.4 ± 3.9	91.8 ± 4.9	87.9 ± 5.5	1st
Aperiodicity				
NVB	65.5 ± 6.1	80.9 ± 9.4	60.5 ± 4.0	9th
DUV	72.8 ± 6.1	93.8 ± 5.7	65.7 ± 4.3	6th
Irregular vibrations of vocal folds				
F0 SD	84.9 ± 4.3	92.3 ± 4.6	80.2 ± 5.1	4th
RPDE	79.9 ± 5.4	86.1 ± 6.9	76.0 ± 6.0	5th
PPE	68.5 ± 6.1	68.6 ± 6.7	69.2 ± 6.9	7th
Signal perturbations				
Jitter	63.8 ± 5.8	66.7 ± 6.7	62.1 ± 5.6	10th
Shimmer	62.5 ± 5.9	67.3 ± 9.0	60.3 ± 4.9	12th
Increased noise				
HNR	62.9 ± 5.8	67.4 ± 8.6	60.7 ± 4.7	11th
DFA	66.1 ± 5.1	69.8 ± 6.3	63.9 ± 4.6	8th
Articulation deficiency				
MFCC	88.8 ± 3.6	92.4 ± 4.6	86.2 ± 4.9	2nd

MPT = maximum phonation time, MPT_{VB} = maximum phonation time until first break, NVB = number of voice breaks, DUV = degree of voicelessness, F0 SD = variability of fundamental frequency, RPDE = recurrence period density entropy, PPE = pitch period entropy, HNR = harmonics-to-noise ratio, DFA = detrended fluctuation analysis, MFCC = mel-frequency cepstral coefficient.

IV. Discussion

The current study shows the potential of voice analysis in documentation the degree and patterns of hyperkinetic dysarthria in HD. The patients with HD showed deterioration in all measured parameters, however, the most prominent pattern of dysphonia was related to sudden phonation interruptions with classification accuracy up to 90% in prediction of HD group membership.

Our findings are in accordance with previous studies reporting voice in HD patients as harsh, breathy, strained-strangled with irregular pitch fluctuations and arrests [5,11-13]. Considering main phonatory deficits in patients with HD revealed in this study from physiological point of view, we can hypothesize that (a) airflow insufficiency and aperiodicity reflected by sudden phonation interruptions are a consequence of choreatic contractions, abnormal muscle tone, or hyper-adduction of vocal folds, (b) articulation deficiency is mainly caused by problems in coordination of articulators including misplacement of tongue, lips, jaw, and face, whereas (c) irregular vibrations of vocal folds manifested as pitch fluctuations occur as a consequence of inefficient nervous system control.

In fact, recognizing of specific signs of speech and voice disorders can provide important clues about the etiology of the disease, and may be useful in differential diagnosis [3,14,15]. Comparing the current finding of hyperkinetic dysarthria in HD patients to better described hypokinetic dysarthria in Parkinson's disease (PD) patients, we can note several differences. Both hyperkinetic and hypokinetic dysarthrias manifest decreased quality of voice (breathiness, harshness, hoarseness) [16]. In contrast, the higher incidence of voice breaks seems to be more specific for hyperkinetic dysarthria. Slight misplacement of articulators during phonation captured by MFCC has also been shown in PD

[17], whereas parkinsonian patients do not manifest such marked pitch fluctuations as observed in HD subjects [7]. Table 2 summarizes main results for HD group and compares it to previous findings in PD group.

V. Conclusion

A precise description of vocal patterns may significantly contribute to existing assessment batteries for monitoring disease onset and progression, and may be beneficial in the differential diagnosis of movement disorders. In addition, a qualitative description of voice dysfunction may be helpful to gain better insight into the pathophysiology of the vocal mechanism. In practice, the measurement of speech is non-invasive, fast, easy to apply, and inexpensive. Future studies combining various aspects of voice may extend our knowledge to identify longitudinal changes of phonatory dysfunction in HD patients as well as in subjects at risk for HD.

Acknowledgment

This research was supported by the Czech Science Foundation (GACR 102/12/2230) and Czech Ministry of Education (MSM 0021620849).

Table 2: Summary of results: comparison of voice features between patient and controls groups for HD and PD.

Parameter	Group	
	HD	**PD**
Airflow insufficiency		
MPT	↑↑↑	—
MPT_{VB}	↑↑↑	—
Aperiodicity		
NVB	↑	—
DUV	↑↑↑	—
Irregular vibrations of vocal folds		
F0 SD	↑↑↑	—
RPDE	↑↑↑	↑↑
PPE	↑↑↑	↑↑
Signal perturbations		
Jitter	↑↑	↑↑↑
Shimmer	↑↑	↑↑↑
Increased noise		
HNR	↑↑↑	↑↑↑
DFA	↑↑↑	—
Articulation deficiency		
MFCC	↑↑↑	↑

—: no difference, ↑ slightly affected ($0.01 \leq p < 0.05$), ↑↑ affected ($0.001 \leq p < 0.01$), ↑↑↑ markedly affected ($p < 0.001$).
¥ For the purposes of comparison, the data for PD group were adopted from our previous study [18]. Note that HD and PD groups have different characteristic related to duration and severity of disease.

References

[1] Kremer B, Goldberg P, Andrew SE, Theilmann J, Telenius H, et al. (1994) A worldwide study of the Huntington's disease mutation: The sensitivity and specificity of measuring CAG repeats. New Engl J Med 330: 1401–1406.
[2] Hayden MR (1981) Huntington's chorea. New York, Springer-Verlag, pp. 59–92.
[3] Duffy JR (2005) Motor Speech Disorders: Substrates, Differential Diagnosis and Management, 2nd ed., Mosby, New York, p. 592.
[4] Rusz J, Klempir J, Baborova E, Tykalova T, Majerova V, et al. (2013) Objective acoustic quantification of phonatory dysfunction in Huntington's disease. PLoS One 8: e65881.
[5] Ramig LA (1986) Acoustic analysis of phonation in patients with Huntington's disease. Preliminary report. Ann Otol Rhinol Laryngol 95: 288–293.
[6] Boersma P, Weenink D (2001) PRAAT, a system for doing phonetics by computer. Glot International 5: 341–345.
[7] Rusz J, Cmejla R, Ruzickova H, Ruzicka E (2011) Quantitative acoustic measurements for characterization of speech and voice disorders in early untreated Parkinson's disease. J Acoust Soc Am 129: 350–369.
[8] Little MA, McSharry PE, Roberts SJ, Costello DA, Moroz IM (2007) Exploiting Nonlinear recurrence and Fractal scaling properties for voice disorder detection. Biomedical Engineering Online 6: 23.
[9] Little MA, McSharry PE, Hunter EJ, Spielman J, Ramig LO (2009) Suitability of dysphonia measurement for telemonitoring of Parkinson's disease. IEEE Trans Biomed Eng 56: 1015–1022.
[10] Brookes M (2009) VOICEBOX, Speech Processing Toolbox for Matlab, Department of Electrical & Electronic Engineering, Imperial College.
[11] Zwirner P, Murry T, Woodson GE (1991) Phonatory function of neurologically impaired patients. J Commun Disord 24: 287–300.
[12] Hartelius L, Carlstedt A, Ytterberg M, Lillvik M, Laakso K (2003) Speech disorders in mild and moderate Huntington's disease: Results of dysarthria assessment of 19 individuals. J Med Speech-Lang Pa 1:1–14.
[13] Velasco Garcia MJ, Cobeta I, Martin G, Alonso-Navarro H, Jimenez-Jimenez FJ (2011) Acoustic analysis of voice in Huntington's disease. J Voice 25: 208–217.
[14] Skodda S (2012) Analysis of voice and speech performance in Parkinson's disease: a promising tool for the monitoring of disease progression and differential diagnosis. Neurodegen Dis Manage 2: 535–545.
[15] Kim Y, Kent RD, Weismer G (2011) An acoustic study of the relationships among neurologic disease, dysarthria type, and severity of dysarthria. J Speech Lang Hear Res 54: 417-429.

[16] Sapir S, Ramig L, Fox C (2008) Speech and swallowing disorders in Parkinson's disease. Curr Opin Otolaryngol Head Neck Surg 16: 205-210.
[17] Tsanas A, Little MA, McSharry PE, Spielman J, Ramig LO (2012) Novel speech signal processing algorithms for high-accuracy classification of Parkinson's disease. IEEE T Bio-Med Eng 5: 1264–1271.
[18] Rusz J, Cmejla R, Ruzickova H, Klemir J, Majerova V, et al. (2011) Acoustic assessment of voice and speech disorders in Parkinson's disease through quick vocal test. Movement Disord 26: 1951–1952.