

Original Research Article

A study of quantitative and qualitative analysis of standardized speech samples in persons suffering from dysarthria due to various neurological disorder

Somesh Maheshwari*

Department of Medicine, MGM Medical College and MY Hospital, Indore, MP, India.

Received: 06 July 2020

Revised: 06 August 2020

Accepted: 02 September 2020

***Correspondence:**

Dr. Somesh Maheshwari,

E-mail: dr.someshmaheshwari@gmail.com

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ABSTRACT

Background: Dysarthria is manifested as a disorder of movement, it is important to recognize that sensori-motor integration (with tactile, proprioceptive, and auditory feed-back representing the crucial sensory components) is essential to speech motor control, from this standpoint, most or all dysarthria localized to the central nervous system should be thought of as sensori-motor rather than simply motor disturbances.

Methods: This non-interventional, cross-sectional comparative, observational study, conducted in 100 study subjects (50 cases and 50 controls) from March 2016 to February 2017 at MGM medical college and MY hospital Indore, MP, India.

Results: The mean age of normal population was 53 years and that of dysarthric population was 55 years. Among the dysarthric group, there were 10 cases of ataxic dysarthria, 23 cases of spastic dysarthria, and 9 cases of hypo kinetic dysarthria. There were 20 cases of mild dysarthria 19 cases of moderate dysarthria and 10 cases of severe dysarthria. In ataxic dysarthria, pitch break was found in 6 out of 10 subjects. It was found that there is negative predictive value 93.33%, and positive predictive value, 77.14% in spastic dysarthria and negative predictive value, 83.33% and positive predictive value, 90.90% in ataxic, whereas negative predictive value, 85.71% and positive predictive value, 95.34% in hypo kinetic dysarthria.

Conclusions: Different types of dysarthria when analyzed with software tool after extracting pitch and formants showed specific patterns. These patterns correlated with the clinical diagnosis. And Pattern recognition of different dysarthria will help to identify the types of dysarthria in scientific way and prevent inter-subject variability.

Keywords: Ataxic dysarthria, Pattern recognition, Proprioception, Hypokinetic dysarthria, Spastic dysarthria, Sensory-motor integration

INTRODUCTION

Dysarthria is a neurological motor speech disorder that is characterized by slow, weak, imprecise, and/or uncoordinated movements of the speech musculature. Common causes of dysarthria includes neurological disorders such as stroke, brain injury, brain tumors, and conditions that cause facial paralysis or tongue or throat muscle weakness.

Two broad classes of speech disorder have been subsumed under rubric of motor speech disorders; dysarthria and apraxia of speech. These two concepts were introduced early in the history of clinical neurological medicine and are associated with Jean Charcot and Hugo Liepmann.

Fourier transformation is an operation that maps a function to its corresponding Fourier series or to an

analogous continuous frequency distribution.¹ The Fourier transform decomposes any function into a sum of sinusoidal basis functions.²

F0 variability seen in parkinsonism disease is seen during prodromal phase of illness can be used as a useful biomarker to evaluate the efficacy of pharmacological interventions in early disease process.³ Formant analysis which is considered as a function of vocal tract can be affected by deficits in articulatory control and mobility of the same.⁴ Zwirner and Barnes reported increased variability of first formant (F1) values during vowel prolongations.⁵ Speakers with Parkinson's disease (PD) were found to have reduced F1–F2 vowel space, compared to control speakers.⁶ Connor et al reported that F1 and F2 transition rates were flatter in hypo kinetic dysarthria compared to control subjects.⁷ Flint et al examined F2 characteristics for PD and normal subjects and found flatter F2 transition rates in the PD patients.⁸ Le Dorze et al proposed smaller F0 difference in Parkinson patients compared to normal subjects.⁹ Canter reported a higher F0 level and reduced F0 range in speech of patients with PD. Turner et al showed smaller vowel space areas in speech of amyotrophic lateral sclerosis patients compared with neurologically normal subjects.¹⁰

Dysarthria may affect all dimensions of speech, namely articulation, resonance, voice and prosody, resulting decreased intelligibility. The dysarthria reflect neuromuscular disturbances of strength, speed, tone, steadiness, or accuracy of the movements that underlie the execution of speech. By definition, they do not include disorders attributable to anatomical deformities, faulty learning, or psychopathology.

Although dysarthria is manifested as a disorder of movement, it is important to recognize that sensorimotor integration (with tactile, proprioceptive, and auditory feed-back representing the crucial sensory components) is essential to speech motor control. From this standpoint, most or all dysarthria localized to the central nervous system should be thought of as sensori-motor rather than simply motor disturbances.

Intelligibility is defined as the accuracy with which a listener is able to decode the acoustic signal of speakers. Since intelligibility can be considered as the product of the four main dimensions of speech, measuring a person's intelligibility is highly relevant in clinical practice.

Intelligibility assessments are mainly based on auditory perceptual judgments involving a speaker, a message, a transmission system, and a listener. Consequently, estimating or measuring intelligibility is a subjective procedure which has a lot of intrinsic variable. Assessments are constructed in such a way that listeners' variables are managed resulting in an acceptable level of reliability.

Dysarthric speech sounds can still be properly characterized in term of articulatory features; such a characterization offers a better basis for providing the clinician with information that is directly related to speech therapy.

METHODS

This study was performed in the department of medicine, MGM medical college and MYH hospital, Indore, MP, India, in patients with dysarthria due to various neurological disorders.

Source of patients

Patients from medicine and neurology outpatient department of M.Y. hospital visited from March 2016 to February 2017. Patients admitted in medicine department of M.Y. Hospital. Patients were being recalled from data base in neurology department of M.Y. hospital.

Study design

This was a non-interventional, cross-sectional comparative, observational study. The primary objective was to compare proportion of patients after both clinical diagnosis and acoustic analysis technique. The secondary objective was to correlate demographic and clinical features of dysarthric patients. The primary endpoint of this study was number of subjects with all four types of dysarthria in both clinical diagnosis and pattern recognition after acoustic analysis.

Sample Size

Sample sizes of 100 participants, 50 were control (normal) subjects and 50 were dysarthric patients due to various neurological disorders.

Inclusion criteria were, stroke patients with aphasia as determined by NIH stroke scale and HASIT scores, Parkinson disease patient with dysarthria as determined by UPDRS, ataxia patient with dysarthria as determined by SARA, male and female sex both capable of responding to various assessment methods, age between 18 to 80 years, consent by both patient and care taker are included, literate patients (capable of reading and writing) and persons with Hindi as primary language. Exclusion criteria were, patient with markedly reduced or minimal speech output, patient with severe disability so as to incapable to attend outdoor clinic, patient with visual loss who cannot read target text paragraph, patient with hearing loss who cannot listen to repeat the target text paragraph, patient with Psychotic disorder who are uncooperative, patient with cleft lip & palate, patient with edentulism both complete and partial, patient with dentures both complete and partial, patients with acute alcohol intoxication.

Method of assessment

All assessments were performed in 2-3 sessions depending on cooperation by patient and care taker, history taking, general and systemic examination, neuro imaging results review, NIH stroke scale and HASIT score in aphasia patients, UPRDS scale for Parkinsonism, SARA scale for cerebellar ataxia.

Speech recording and acoustic analysis of standardized speech sample

Patients were asked to read one Hindi (local language) standard paragraph and word exercise for articulatory muscles, verbals and repetition of words. Their speech was recorded using a voice recorder under ideal conditions in a quiet room to avoid external sounds. The phrases and first sentence of the reading paragraph were extracted using Audacity version 2.0.5, speech waveforms were exported to pratt vocal toolkit version (5.3.53) and pitch F0, formants F1 and F2 and pitch break were considered as deterministic parameters and were extracted for categorizing patients according to different types of dysarthria. Detailed study of extracted features to identify underlying characteristics within types of dysarthria was done. Signal characteristics and nature of F0, F1, and F2 for each of four different types of dysarthria known from previously published literature were referred to categorize patients on basis of their disorder type. All patients were initially diagnosed by neurologist based on their phonations and latter were

subjected to acoustic analysis using software. Reassessment of the dysarthria types in patients based on findings from acoustic analysis.

Statistical analysis

To test the statistical significance of the association of clinical diagnosis with different categorical variables, Chi-square test was done and p value less than 0.05 was considered to be significant. To compare the results of pattern recognition by software tool with the clinical diagnosis, Mc Nemar Chi-square test was done. The validity parameters such as sensitivity, specificity, positive predictive value, negative predictive value, and accuracy were computed for comparing assessment of pattern recognition by software tool with the clinical diagnosis. Severity based classification was also done using formant range and by calculating F2 range/F1 range.

RESULTS

Our study group included hundred persons. Of which 50 were normal (control) subjects and 50 were those with dysarthria. The mean age of normal population was 53 and that of dysarthric population was 55 which were comparable. In our study population, there were 19 females and 31 males. Among the dysarthric group, there were 10 cases of ataxic dysarthria, 23 cases of spastic dysarthria, and 9 cases of hypo kinetic dysarthria (Table 1).

Table 1: Dysarthria type and severity wise comparison.

Dysarthria type	Severity N (%)			Total N (%)
	Mild	Moderate	Severe	
Ataxic	7 (70)	2 (20)	1 (10)	9 (100)
Hypokinetic	3 (33.3)	5 (55.6)	1 (11.1)	9 (100)
Mixed	2 (25)	2 (25)	4 (50)	8 (100)
Spastic	9 (39.1)	10 (43.5)	4 (17.4)	23 (100)
Total	21 (42)	19 (38)	10 (20)	50 (100)

Pearson Chi-Square=9.277, p=0.159

Table 2: Age and severity wise comparison.

Age group (years)	Severity N (%)			Total N (%)
	Mild	Moderate	Severe	
<40	4 (40)	5 (50)	1 (10)	10 (100)
>60	4 (26.7)	9 (60)	2 (13.3)	15 (100)
40-60	13 (52)	5 (20)	7 (28)	25 (100)
Total	21 (42)	19 (38)	10 (20)	50 (100)

As per clinical severity, patients were divided into those with mild dysarthria, moderate dysarthria and those with severe dysarthria. There were 20 cases of mild dysarthria 19 cases of moderate dysarthria and 10 cases of severe dysarthria (Table 2). We tried to identify specific patterns among types of dysarthria. Pitch was analyzed; it was found that F0 jitter is found to be associated with spastic dysarthria in 60.8%, of cases 14 out of 23 dysarthria

subjects, but was not found in any of the normal population. In ataxic dysarthria, pitch break was found in 6 out of 10 subjects. F0 Break was associated with 60% of ataxic subjects.

When the hypo kinetic dysarthria was analyzed, it was found that F0 flat or monotonicity was found in 66.6% hypo kinetic dysarthria, 6 out of 9 in dysarthric subjects.

F0 flatness is found to be significantly associated with dysarthric patients. The agreement of diagnosis by pattern recognition was compared with that of clinical diagnosis; it was found out that there is an accuracy of 82.0% in Spastic dysarthria. When the normal population and dysarthric population was compared on the basis of pattern recognition and clinical diagnosis, it was found that there is sensitivity of 96.4% and specificity of 63.6% in Spastic dysarthria. It was found that there is Negative predictive value, 93.33%, and Positive predictive value, 77.14% in spastic dysarthria (Table 3).

Table 3: Comparison between pattern recognition and clinical diagnosis in spastic dysarthria patients.

Pattern recognition	Clinical diagnosis		Total N (%)
	Negative	Positive	
Negative	27 (96.4)	8 (36.4)	35 (70)
Positive	1 (3.6)	14 (63.6)	15 (30)
Total	28 (100)	22 (100)	50 (100)

Pearson Chi-Square=21.166, p=0.000, accuracy=82.0%, negative predictive value=93.33%, sensitivity=96.4%, positive predictive value=77.14 %, specificity=63.6%.

Accuracy was 90.0% in ataxic dysarthria, sensitivity of 97.6% and specificity 55.6% in ataxic, negative predictive value, 83.33% and positive predictive value, 90.90% in ataxic dysarthria (Table 4).

Table 4: Comparison between pattern recognition and clinical diagnosis in ataxia dysarthria patients.

Pattern recognition	Clinical diagnosis		Total N (%)
	Negative	Positive	
Negative	40 (97.6)	4 (44.4)	44 (88)
Positive	1 (2.4)	5 (55.6)	6 (12)
Total	41 (100)	9 (100)	50 (100)

Pearson Chi-Square=19.718, p=0.000, accuracy=90.0%, negative predictive value=83.33%, sensitivity=97.6%, positive predictive value=90.90%, specificity=55.6%.

Table 5: Comparison between pattern recognition and clinical diagnosis in hypokinetic dysarthria patients.

Pattern recognition	Clinical diagnosis		Total N (%)
	Negative	Positive	
Negative	41 (97.6)	2 (25)	43 (86)
Positive	1 (2.4)	6 (75)	7 (14)
Total	42 (100)	8 (100)	50 (100)

Pearson Chi-Square=28.434, p=0.000, accuracy=94.0%, negative predictive value=85.71%, sensitivity=97.6%, positive predictive value=95.34%, specificity=75%.

Accuracy was 94%, sensitivity of 97.6% and specificity of 75% in hypo kinetic, negative predictive value, 85.71% and Positive predictive value, 95.34% in hypo kinetic (Table 5). It was also found that duration of speech in second's increases as clinical severity

increases. Formant range and F2/F1 range decrease as clinical severity increases.

DISCUSSION

Acoustic analysis of normal and dysarthric population was done. The pitch and formant frequency of both were analyzed. Patterns recognized in each type of dysarthria are as follows, spastic dysarthria, F0 jitter.

F0 jitter or shimmer is a character described in pitch in which the pitch randomly varies over consecutive periods. The increased association of F0 jitter in dysarthric population may be explained by the harshness of the voice in this population which is due to time-varying characteristics of the vocal tract and vocal folds. Teager et al reported that the character of F0 jitter is more associated with harsh speech.⁹ This is more apparent in those with spastic dysarthria.¹⁰ In a study conducted by Thoppil MG pitch was analyzed; it was found that F0 jitter is found to be associated with spastic dysarthria in 64.3% cases; it was found out that there is an accuracy of 85.7% in Spastic dysarthria and sensitivity of 93% and specificity of 72%. In our study Pitch was found to be associated with 60.3% cases and there is an accuracy of 82.0% in spastic dysarthria and sensitivity of 96.4% and specificity of 63.6%. On comparison of pitch of normal speech with spastic speech, demonstrates F0 jitter.¹¹

Ataxic dysarthria, F0 break. In a study conducted by Ackermann and Zeigler Ackermann suggested that increased pitch levels observed in dysarthric subjects may be related not to altered vocal tension but to altered sensory feedback from the laryngeal structures such that increased vocal effort is used by the ataxic speaker to overcome the sensory disturbance.¹³ They also noticed pronounced pitch fluctuations in the pitch contour among patients with ataxic dysarthria. In a study conducted by Thoppil MG pitch was analyzed; it was found that F0 break was found in 6 out of 7 subjects and in our study found in 6 out of 10 subjects of ataxic dysarthria; it was found out that there is an accuracy of 85.7% in ataxic dysarthria and sensitivity of 93% and specificity of 72%. In our study there is an accuracy of 90.0% in ataxic dysarthria and sensitivity of 97.6% and specificity of 55.6%. On comparison of pitch of normal speech with ataxic speech demonstrates F0 break.

Hypokinetic dysarthria, F0 monotonicity. Canter noted decreased F0 range during syllable production and during paragraph reading in Parkinson's disease.¹² Metter and Hanson showed that there is decreased F0 variability in Parkinson's disease compared to normal subjects. Hypo kinetic dysarthria seen in Parkinson's disease is characterized by hoarse speech with low volume and compulsive repetition of syllables with monopitch and monoloudness. In a study conducted by Thoppil MG pitch was analyzed; it was found that F0 flat or monotonicity was found in 62.5% of hypo kinetic dysarthria, In our study F0 monotonicity, associated with 66.6% of cases of hypo kinetic dysarthria; it was found out that there is an accuracy of 85.7% in Hypo kinetic

dysarthria and sensitivity of 93% and specificity of 72%. In our study there is an accuracy of 94.0% in Hypokinetic dysarthria and sensitivity of 97.6% and specificity of 75.0%. On comparison of pitch of normal speech with hypokinetic speech, demonstrates F0 monotonicity.

In our study, it was found that formant range and F2/F1 range decrease when severity increases. F1 and F2 transition rates were flatter in hypokinetic dysarthria compared to control subjects. When F2 characteristics for PD and normal subjects were examined we found flatter F2 transition rates in the PD patients during sentence reading. We also found that as duration of speech increases, clinical severity also increases. There was a significant correlation between severity of dysarthria and formant range. On comparison of formant range of normal speech with severe dysarthria demonstrates that the formant range (F1 and F2) decreases as severity of speech increases.

When the normal population and dysarthric population was compared on the basis of pattern recognition and clinical diagnosis study conducted by Thoppil MG sensitivity is 93% and specificity is 72%. In our study, it was found that there is sensitivity of 96.4%, and specificity of 63.6%. In spastic dysarthria and sensitivity of 97.6% and specificity 55.6% in ataxic. Whereas sensitivity of 97.6% and specificity of 75% in hypokinetic. However, more than one pattern was identified in 16 patients. It possibly suggests that these patients had mixed dysarthria by pattern recognition although clinically there appeared to be pure spastic, ataxic or hypokinetic dysarthria. Mixed dysarthria are more common than clinically suspected. Hence Pattern recognition of different dysarthria will help Neurologist to identify the types of dysarthria in scientific way and prevent inter-subject variability.

CONCLUSION

Different types of dysarthria when analyzed with software tool after extracting pitch and formants showed specific patterns. These patterns correlated with the clinical diagnosis. And Pattern recognition of different dysarthria will help to identify the types of dysarthria in scientific way and prevent inter-subject variability.

ACKNOWLEDGEMENTS

Sincerely thanks to Dr. A. Pauranik, former professor, division of neurology, department of medicine, MGM medical college and MY Hospital for his support and guidance throughout this study.

Funding: No funding sources

Conflict of interest: None declared

Ethical approval: The study was approved by the Institutional Ethics Committee

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Cite this article as: Maheshwari S. A study of quantitative and qualitative analysis of standardized speech samples in persons suffering from dysarthria due to various neurological disorder. *Int J Adv Med* 2020;7:1527-31.