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# APPLICATION OF ACOUSTIC SPEECH ANALYSIS IN AMYOTROPHIC LATERAL SCLEROSIS SUBJECTS

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**Abstract** Assessment of dysarthria in ALS patients has not been fully studied. The aim of the study was to assess a typical dysarthria profile for different ALS group. 53 patients with definite /n=27/ or probable /n=26/ ALS /according to WFN criteria/ were studied. Each patients had three acoustic, computer-analysed tests. The following consonants and vowels: *"R", "L", "D", "T", M", "W", "P", 'B", "G", "K", "H", "Q", "O", "U", "I"* were chosen for analysis. We used the Euclidian principle for analyses of sequences of sound formants and the mean sound distances from the pattern /Δf=125 Hz, ΔT=9ms, Δs=0,5dB/. Our study showed the occurrence of characteristic dysarthria profile in different ALS groups ie. for bulbar group: *"B", "O", "I", "W", "T"* and for the limb group: *"B", "I", T", "W", "O"* were the most deformed. We also demonstrated that preclinical dysarthric disorders occur among the ALS limb group. This study indicated a possibility of detecting and monitoring dysarthria in ALS based on acoustic speech analysis of changes in certain sounds.

## Introduction:

Amyotrophic lateral sclerosis (ALS) is a progressive disorder in which degeneration of upper and lower motor neurones leads to subsequent weakness of bulbar, limb, thoracic and abdominal muscle with relative sparing of oculomotor muscles and sphincter function. Neurodegenerative process of cortical, brainstem and spinal cord motorneurones is of unknown origin [1]. Most often the signs of motoneurones' degeneration occur first in the limbs. Early bulbar symptoms, i.e. dysarthria, dysphagia and sometimes pathological emotional lability, are less frequent and appear in 25% of patients. Death from ventilatory failure ensues usually within 5 years from onset. Patients with bulbar signs deteriorate more rapidly, usually 1 or 2 years after diagnosis [1,2]. The mechanism underlying this differences in rate of disease progression is unknown. Currently there is no quantitative test available to assess progression of bulbar dysfunction (dysarthria, dysphagia).

Dysarthria in ALS is characterised by grossly defective articulation, extremely slow laborious speech, marked hypernasality and severe harshness . In addition to strained/strangled voice there is almost a complete disruption of prosody [1]. Only few detailed reports have been published on the nature of speech and voice changes during the course of ALS. Dysarthria has been studied by application of physiological (electromyographic and kinematic) and computerised acoustic method [3, 4, 5, 6, 7, 8, 9]. The attempt to define the specific profile of dysarthric speech, by acoustic computer analysis based on the Euclidian principle, has never been previously undertaken in ALS patients.

The aim of the study was to evaluate if a specific dysarthria profile exists in ALS patients and if it could be useful in Clinics for assessment of speech dysfunction.

## Material and methods

*Subjects:* In the ALS group were 53 patients (21 female, 32 male), mean age of 53.66± 10.30 (29-76 yrs). Patients with only sporadic ALS were studied and classified as definite (n=27) or probable (n=26) ALS based on the El Escorial WFN criteria [10]. The duration of ALS symptoms ranged from a few months to 2 years. Each patient was visited every 10-12 weeks, by the same neurologist. ALS patients were categorised into two groups : the bulbar group ( A, n=15, patients with presence of dysarthria) and the limb group (B, n=38, patients with no clinical evidence of bulbar or corticobulbar involvement). The control group consisted of 30, aged and sex -matched subjects (19 female, 11 male), aged 46.87± 6.24 (24-78 yrs) with no prior history of neurological disease, speech, hearing, voice, or language disorders. The control group provided the basic pattern for computerised acoustic analysis.

*Procedure:* Each patient (47 out of 53) underwent acoustic and computer-based speech sounds and voice articulation testing. These were recorded during three test sessions every 10-12 weeks. Only two patients died before the third acoustic test and three patients were excluded because their state deteriorated quickly (due to anarthria) prior to the third acoustic examination. One patient did not appear for the third test. Two speech tasks were performed by each subject (ALS and control group). First, each subject read and repeated a test sound three times. In the second task, each subject read and repeated three times a standard sentence. The tasks were tape-recorded. The following consonants and vowels were analysed: R, L, D, T, M, W, P, B, G, K , H, Q , O, U, I. They were analysed separately and then in the standard polish sentence: *W CALYM KRAJU DZIS JEST LADNA POGODA (in whole country is fine weather).* The sounds and the standard sentence were written on flashcards and presented to the subjects. Subjects were instructed to read the sounds and the test sentence. The acoustic signal of speech was transduced by a microphone (Bruel&Kjaer), placed approximately 10 cm from the subject's mouth, and then recorded on a low-noise tape (NAGRA IV SJ, Kudelski SA). All sessions for all subjects were recorded in a sound-proof room. The sound measurements, including articulation time and pause duration, were made using a sonograph (Bruel&Kjaer, 3348) set to a wideband filter (FF-2425, Bruel&Kjaer) of 25 Hz and a frequency range from 0 to 7000 Hz. The tape-recorded speech samples of the separate sounds and the standard sentence were studied with spectrograms prepared with a spectrograph and then with a microcomputer speech analysis program (computer PC 486). This programme allows to measure the mean sound distances between chosen consonants and vowels in ALS patients and to compare them with the basic pattern in the control group. The change of sound articulation was measured using the time-frequency computer analyses, ($\Delta f$=125 Hz, $\Delta T$=9ms, $\Delta s$=0,5dB). The Euclidian principle was applied to assess the sound mean distances from the pattern in the matrix (characteristic attribute: M0, M1, M2, WS1, WS2, WS3, WS4). Finally this prompted the selection of the most discriminatory sounds.

*Statistical data;* For statistical analyses t-Student tests was used to compare demographic data between ALS and control subjects, and mean sound distances between bulbar, limb and control groups. ANOVA was used to test difference between the mean value of the mean sound distances in both ALS groups and the mean sound distances of the pattern (control subjects) at first and third acoustic analyses.

**Results**

Based on the initial analyses following sounds were chosen for further studies: "B","I","O","W","T". Acoustic analyses were done by measuring the mean distances between the sound and the pattern in the three acoustic tests. In the control group the maximum mean sound distance for chosen sounds was $\bar{x}$ = 0.12, and in all ALS group $\bar{x}$= 0.62. The differences between the mean distances for each sound in both ALS groups were significant ($p < 0.001$). Table 1 demonstrate the mean sound distances in the ALS and control subjects at the first examination.

Table 1. The comparison of mean sound distances in all ALS patients as compared to the control subjects (t- Student, independent test)

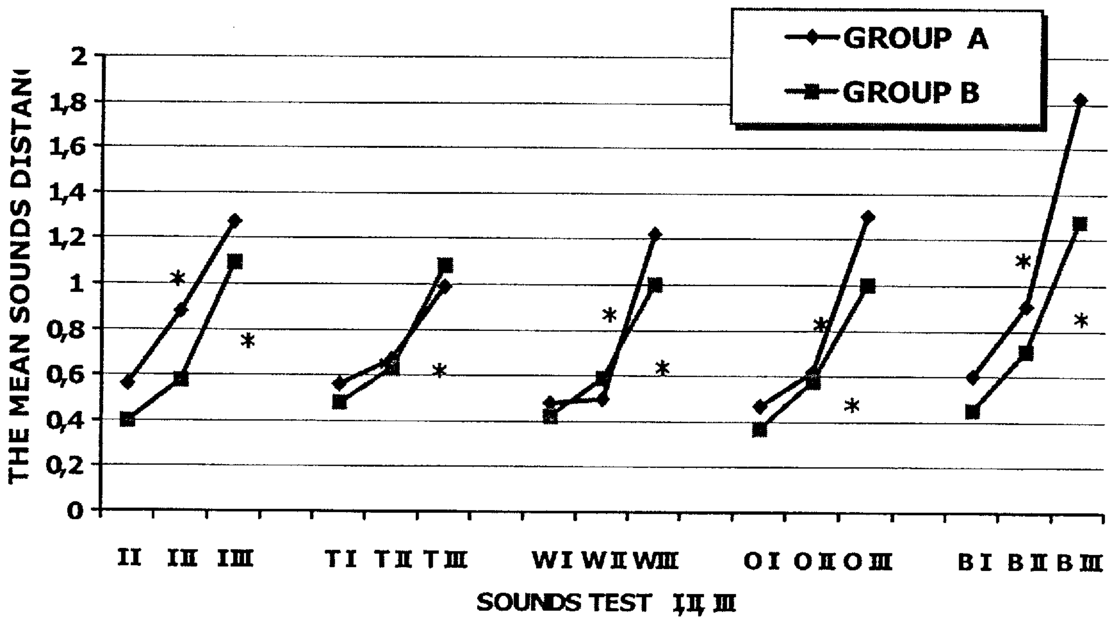
| Sounds | Control group N = 30 | | ALS group N = 47 | | Value *P* |
|---|---|---|---|---|---|
| | $\bar{x} \pm$ SD | | $\bar{x} \pm$ SD | | |
| I | 0.08 ± 0.03 | 0.04 – 0.13 | 0.50 ± 0.23 | 0.20 – 1.36 | *< 0.001* |
| T | 0.11 ± 0.03 | 0.05 – 0.18 | 0.59 ± 0.18 | 0.27 – 0.94 | *< 0.001* |
| W | 0.08 ± 0.03 | 0.02 – 0.15 | 0.57 ± 0.25 | 0.24 – 1.30 | *< 0.001* |
| O | 0.10 ± 0.04 | 0.05 – 0.20 | 0.46 ± 0.19 | 0.10 – 1.11 | *< 0.001* |
| B | 0.12 ± 0.05 | 0.04 – 0.22 | 0.62 ± 0.25 | 0.20 – 1.47 | *< 0.001* |

When comparing the mean sound distance to the control group (pattern) we noted a significant increase of the mean distances of all chosen sounds over the time of study. It was seen in all ALS groups, ($p<0.001$) (table 2, figure1).

Table 2. The comparison of mean distances of the chosen sounds in all ALS patients as compared to the control group. Acoustic computer analyses, test I-III.( *ANOVA test*)

| Group | Sounds | **The mean sound distances as compared to the control pattern. Acoustic computer- analyses, test I-III** | | | |
|---|---|---|---|---|---|
| | | *ANOVA* | | | |
| | | **Test I** | **Test II** | **Test III** | **Value p** |
| | | $\bar{x} \pm SD$ | $\bar{x} \pm SD$ | $\bar{x} \pm SD$ | |
| **Bulbar** | I | 0.56 ± 0.31 | 0.88 ± 0.27 | 1.27 ± 0.32 | < *0.001* |
| | T | 0.56 ± 0.18 | 0.67 ± 0.11 | 0.99 ± 0.18 | < *0.001* |
| | W | 0.48 ± 0.21 | 0.50 ± 0.21 | 1.22 ± 0.35 | < *0.001* |
| | O | 0.47 ± 0.22 | 0.62 ± 0.24 | 1.30 ± 0.32 | < *0.001* |
| | B | 0.60 ± 0.25 | 0.91 ± 0.26 | 1.82 ± 0.11 | < *0.001* |
| **Limb Group** | I | 0.40 ± 0.15 | 0.58 ± 0.23 | 1.09 ± 0.18 | < *0.001* |
| | T | 0.48 ± 0.18 | 0.63 ± 0.18 | 1.08 ± 0.27 | < *0.001* |
| | W | 0.42 ± 0.26 | 0.59 ± 0.23 | 1.00 ± 0.27 | < *0.001* |
| | O | 0.37 ± 0.16 | 0.58 ± 0.21 | 1.00 ± 0.23 | < *0.001* |
| | B | 0.45 ± 0.24 | 0.71 ± 0.31 | 1.28 ± 0.37 | < *0.001* |

Figure 1. The comparison of mean distances of the chosen sounds in the bulbar group (group A) and in the limb group (group B) as compared to the control pattern. Acoustic computer analyses, test I-III.( *ANOVA test*)




These results proved the progression of pathological changes (i.e. slowness of the speech) for all examined sounds in both ALS groups. We draw attention to the significant increase of the mean distances for chosen sounds over the three acoustic tests of all examined sounds, in the nondysarthric limb ALS group (table 2). To characterise the apparent specific dysarthria profile of ALS, the patients underwent a third acoustic speech test which compared the mean sound distances to those of the controls, and in which the Euclidian principle was applied The significant increase in mean distances for the chosen sounds obtained between the first and the third test were compared to the control (table 2). In the bulbar group, consonant "T" distance increase was the smallest (0.99- absolute value based on Euclidian principle) while consonant "B" distance increase was the most significant (1.82) (table 3).

Table 3. The comparison of mean distances of the chosen sounds in the bulbar group as compared to the control pattern. Acoustic computer analyses, test I-III . *Euclidian principle.*

| EUCLIDIAN PRINCIPLE | **Test I** | **Test II** | **Test III** |
|---|---|---|---|
| Sound "B" | *0.56* | *0.88* | *1.82* |
| Sound "O" | *0.47* | *0.62* | *1.3* |
| Sound "W" | *0.48* | *0.5* | *1.22* |
| Sound "T" | *0.56* | *0.67* | *0.99* |
| Sound "I" | *0.56* | *0.88* | *1.27* |

In the limb group, the increase of the distances for sounds "O" and "W"(both at 1.00) was the smallest, and this of consonant "B" was the most significant (1.28) (table 4)

Table 4. The comparison of mean distances of the chosen sounds in the limb group as compared to the control pattern. Acoustic computer analyses, test I-III . *Euclidian principle.*

| EUCLIDIAN PRINCIPLE | **test I** | **Test II** | **Test III** |
|---|---|---|---|
| Sound "B" | 0.45 | 0.71 | 1.28 |
| Sound "O" | 0.37 | 0.58 | 1.00 |
| Sound "W" | 0.42 | 0.59 | 1.00 |
| Sound "T" | 0.48 | 0.63 | 1.08 |
| Sound "I" | 0.40 | 0.58 | 1.09 |

Figure 2. The comparison of mean distances of the chosen sounds in the bulbar group as compared to the control pattern. Acoustic computer analyses, test I-III . *Euclidian principle*

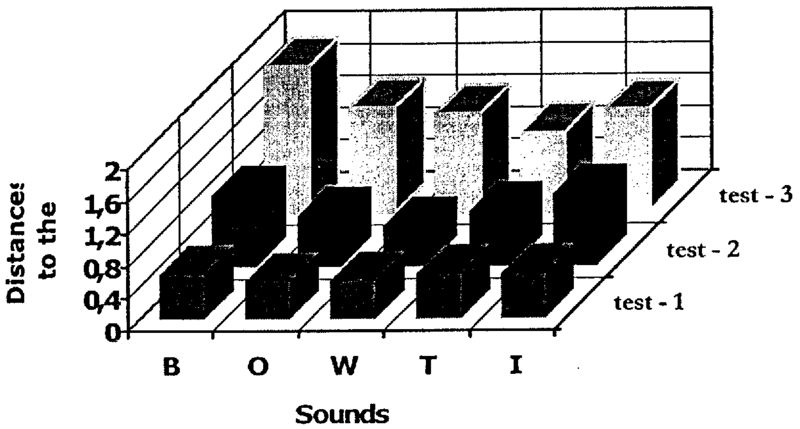
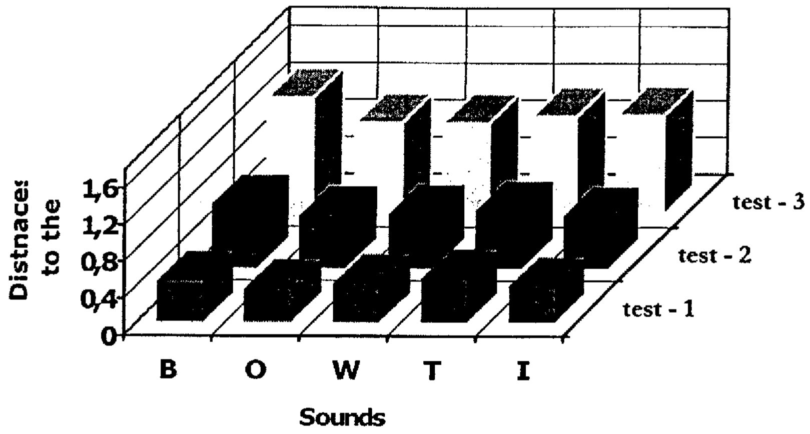



Figure 3 . The comparison of mean distances of the chosen sounds in the limb group as compared to the control pattern. Acoustic computer analyses, test I-III . *Euclidian principle*




Our results indicate that the limb and bulbar ALS groups differ - in each the different consonants demonstrate the smallest deterioration of sound distance. On the basis of this, we designed a specific dysarthria profile for each ALS group. In the bulbar group it would be "B", "O", "I", "W", "T" (figure 2) while in the limb group: "B", "I", "T", "W", "O" (figure 3) (for both, the first sounds displayed have the biggest mean distance increase as compared to the control pattern).

**Conclusion**

Computer-based acoustic analyses relying on the Euclidian principle is a sensitive method for measurement of dysarthria. To our knowledge the presented acoustic method has not been used previously to assess dysarthria in ALS patients.

This study demonstrated that when ALS progresses over the time there is significant deterioration of speech and individual sound production as assessed by computer-based acoustic analyses. The disease affected sounds in both studied groups of patients, ie. with bulbar (dysarthric) or limb (nondysarthric) signs. In the bulbar group deterioration was significantly more rapid. We have identified and characterised a specific dysarthria profile for each ALS group. We have also shown deterioration in speech quality as measured by an increase in sound distance from the basic control pattern. This may allow earlier identification of imminent bulbar involvement.

Some of the acoustic aberrations have been noted in the dysarthric populations and affected perception of the fast speaking rate. Kent et al., [4, 11] studied the speech and voice in ALS patients with a number of techniques with a particular emphasis on placebo intelligibility. The measurement of intelligibility was accomplished by a multiple-choice, single-word identification test. Kent et al. [5, 11] studied the relationship between acoustic parameters of speech and intelligibility. Acoustic analyses of our speech tests showed that it is possible to measure an articulatory dysfunction in ALS patients with acoustic methods, as well as to form the characteristic "acoustic signatures", based on the Euclidian principle . Our results, based on the measurement of the mean distances in the chosen sounds, show a significant increase of these distances to the pattern. It helps to demonstrate the occurrence of a specific dysarthria profile, which is different for both examined ALS groups, as well as to allow to estimate the profiles' degree of abnormality. It suggested that the specific dysarthria profile for ALS patients as specified by the chosen mean sound distances may have its' origin in functional and structural changes reflecting motor neurone dysfunction in ALS, as well as the orofacial diadochokinesis in the speech production system (tongue, lips, soft palate, larynx). Abnormalities showed in this study are consistent with previous reports which showed disturbances of lingual, velopharyngeal and laryngeal articulation [12, 13, 14]. These authors defined three functional regions: articulatory (lips, tongue, mandibule), velopharyngeal (palate, pharynx), and phonatory (larynx) for studying myometric characteristics of the orofacial structures in both normal subjects and dysarthric patients. Our study demonstrated that the refined bending adjustments needed for lingual consonants are affected more than the gross positioning of the tongue body which is required to produce vowels. It is expected that intrinsic fibres are particularly important in producing bending movements of the tongue. Our hypothesis of disproportionate tongue weakness is supported by earlier clinical [15] and neuropathologic observations [16].

In our study we have also found that the non dysarthric limb ALS group with no clinical signs of bulbar or corticobulbar involvement, also demonstrated some changes in the mean sound distances in the following: "B","I", "T","W","O". The sounds could therefore be used as an early indication of a preclinical dysarthria in those patients. The occurrence of speech changes in ALS patients, apparently free of bulbar symptoms, has been described in literature, but the authors have used different methods [13, 14, 17]. Differences of the mean sound distances in this study with patients with and without dysarthria may be a good marker of the severity and progression of bulbar motoneurones dysfunction. Further studies are warranted.

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