ROLE OF THE COMPUTERIZED SPEECH LAB (CSL) AND MULTI-DIMENSIONAL VOICE PROGRAM (MDVP) IN VOICE DISORDERS’ INSTRUMENTAL DIAGNOSTICS

Dobrinka GEORGIEVA 1
Ana STEFANOVSKA 2

Center for Logopedics and Speech-hearing rehabilitation, South-West University "Neofit Rilski"- Blagoevgrad, Republic of Bulgaria

Abstract

It is a fact that voice pathology has an expressed frequent appearance in the last decades and the problem of voice disorders and their speech therapy assessment is not elaborated enough in the logopedical literature in Bulgaria and Macedonia. One of the basic factors on which treatment effectiveness depends is the correct diagnosis from logopedics point of view on which treatment program could be established.

The purpose of the present article is to present a new instrument for a secondary voice assessment—an acoustic analysis of the voice as a part of Computerized Speech Lab (CSL) named Multi-Dimensional Voice Program (MDVP).

There is no developed PhD on voice pathology the last 3 decades in Republic of Bulgaria. In comparison with language, fluency and articulation disorders, voice disorders are considerably ignored and neglected. The speech-language pathologists do not feel very well prepared to work with this kind of pathology.

Key words: voice disorders, diagnostics, CSL, MDVP

Address requests for reprint to:
Dobrinka GEORGIEVA
Deputy rector of South-West University
66 Ivan Mihailov Str. 2700 Blagoevgrad, Republic of Bulgaria
e-mail: doby_logo@abv.bg
Georgieva & Sparangis (2001) study showed that among Bulgarian and Greek speech-language therapists the laryngectomy and voice disorders are among less preferred for logopedical work. Data obtained from the above research study among Bulgarian speech therapists pointed that only 13.63% of them want to work with cases of laryngectomy, aphonia and dysphonia, vocal mutation because such kind of disorders can normally be treated dominantly in clinical conditions. Only 9.09% of the clinicians in both countries are occupied with clinical management of phonation disorders. The situation is totally different regarding to the speech pathologists and therapists in USA. They are not inconvenienced to work with patients with voice disorders (St. Louis & Durrenberger, 1993). Some of the main causes for speech therapists reluctance to treat voice disorders are: (i) students' insufficient University training, (ii) limited number of publications about this subject in Bulgarian language, (iii) limited number of patients they are working with, and (iv) the lack of instruments for appropriate diagnostics and logopedical therapy. We do not ignore the fact that many years in Bulgaria the Speech-Language Therapy was treated as part of Special Education and medical training of the students in the fields of Phoniatrics, Otorhinolaryngology or Audiology was ignored or limited. Commonly used source in this area was manual Bases of Phoniatrics written by leading European phoniatrist Prof. Ivan Maksimov (1983). The last decade in developed countries where Logopedics was established in health sciences area like USA, Canada, Australia, Japan, France, Belgium, Sweden, Denmark the voice pathology and associated disorders are included as an essential part of Medical speech-language pathology (Aronson, 1985; Le Huche & Allali, 1984 a; Le Huche & Allali, 1984 b; Johnson & Jacobson, 2006). The main goals of the present theoretical examination are (i) to present a model of voice assessment and especially acoustic secondary diagnostic (from the speech therapist point of view), and (ii) for every separate described parameter to offer an appropriate instrumental equipment.
It is quite popular in speech-language practice that voice evaluating process starts after filling in a questionnaire about case history. Deem & Miller (2000) suggested a short summary for evaluation of the voice characteristics.

**Table 1. Summary of the procedures used in the voice evaluation process (according to Deem & Miller, 2000, p. 36).**

<table>
<thead>
<tr>
<th>Procedure Description</th>
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<tbody>
<tr>
<td>A. Obtain:</td>
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<tr>
<td>A1. An audiocassette-or videotape-recorded sample of the patient's voice (using standard reading passage)</td>
</tr>
<tr>
<td>A2. A description of the patient’s vocal fold structure and function from a laryngologist</td>
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<tr>
<td>B. Speech-language pathologist have to evaluate:</td>
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<tr>
<td>B1. Respiratory capabilities</td>
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<tr>
<td>B2. Strength of glottal closure</td>
</tr>
<tr>
<td>B3. Pitch range, optimal pitch, and habitual pitch of the voice</td>
</tr>
<tr>
<td>B4. Vocal loudness level</td>
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<tr>
<td>B5. Voice quality</td>
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<tr>
<td>B6. Endurance for speech production</td>
</tr>
<tr>
<td>B7. Sites of vocal hyperfunction/hypofunction</td>
</tr>
<tr>
<td>B8. Oral-periphery, motor, and sensory aspects of the patient’s speech musculature</td>
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</table>
Speech-language pathologist should possess built abilities and specific knowledge for identifying the next three basic components of voice evaluation:

- Patient's voice characteristics and their dynamics in the time (Ludlow, 1995; Polow & Kaplan, 2000);
- The severity level of voice disorders-by applying voice profile elaborated by Wilson & Rice (1977) or Boone's scale (1993);
- Of effectiveness of speech-language therapy management (permanently ignored and unfamiliar field in Bulgaria), (Case, 2002).

Standard description of the patient's vocal folds
structure and function, A2 can be made by setting precise diagnostics of voice disorders by application of indirect laryngoscopy (stroboscopy). Stroboscopy and laryngeal imaging systems produced by the Japanese company KayPentax are applied in the South West University Center for Logopedics and Speech-hearing rehabilitation. This equipment is used in 90% of the fifty top-rated ENT departments in the USA. Kay’s laryngeal imaging product line includes videokymography (VKG) and system for high-speed video systems. Both of these instruments provide the ability to view vocal fold physiology regardless of vibratory pattern (onset of phonation, severity of the voice disorder, etc).

Evaluation of patient's ability for breathing, B1 uses application of phonatory aerodynamic system (pas) for measuring airflow, pressure, and other parameters related to speech and voice production. PAS calculates average phonatory flow rate, sound pressure level, fundamental frequency, vital capacity, glottal resistance, subglottal pressure, and efficiency measurement. The procedure includes:

- High voice reading a standard paragraph of text;
• fulfillment of tasks for evaluating of prolonged voice production—for example pronouncing "a-a-a" for about 8 seconds
• prolonged pronunciation of sounds s/z.

As a basic instrument for measuring B1, the use of spirometer or magnetometer is also suggested. They ensure important information about the vital capacity, capacity inspired/ expired air, quantity of air for a single time inhalation and exhalation. They define type of breathing (abdominal, clavicular, diaphragmal), also the phonatory and respiratory efficiency (estimated so called time for maximal phonation-TMP). Usually at prolonged voice phonation, TMP is in the frames of 15-20 seconds (minimal value is 14.3 seconds for women and 15 seconds for men). Children of primary school age are asked to phonate at least in frames of 10 seconds. Lower values of TMP indicate about insufficiency of respiratory function.

The stroboscopy and laryngeal imaging systems give possibility for assessing the quality of glottis's opening and closing, B2. For the aim most often the patient is asked to pronounce certain sound with hard voice attack or to cough harshly and sharply. Assessment of B3, B4, and B5 are realized (for the first time in logopedic's practice in Bulgaria at South West University) through application of software products of Computerized Speech Lab (see, table No. 2). Since 1994 the stroboscopy was used for clinical purposes in Prof. Doskov's voice lab in Bulgarian Medical Academy.

Assessment of B4, level of intensity, loudness of voice is a part of the diagnostics of voice functioning. It allows:
• audiometric examination;
• subjective assessment of voice intensity;
• patient's ability to change it's voice intensity (Le Huche & Allali, 1984 a).
Assessment of B5, the quality of voice is one of the difficult task because of it's relation to the distribution of acoustic energy in the vocal spectrum. Voice quality doesn't exist as a single quantity, for ex. as the intensity and pitch are. It is necessary in this case to distinguish quality disorders of phonation and quality disorders of resonance. At voice disorders voiceless is examined (heard air jet while phonating) by Huang (1998). It is a result of fast, voiceless air, passing through the glottis. There is a description on Table No. 3. of an appropriate diagnostics equipment.

Table 2. Program products of CSL for instrumental diagnostics of B3, B4 and B5.

<table>
<thead>
<tr>
<th>Софтверски продукт (Software product)</th>
<th>Дијагностицира (Diagnoses)</th>
</tr>
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<tbody>
<tr>
<td>MDVP - Multidimensional Voice Program</td>
<td>Разработен како докторска дисертация од Бугаринот д-р Делийски (види Deliyski &amp; Orlikoff, 1991; Deliyski, Orlikoff &amp; Kahane, 1991; Drumeva, Doskov, Boyanov &amp; Deliyski, 1988). Програмата мери обективно количински вредности на продолжителната фонација, кои се експонираат графички и нумерички на дисплей во боја. Обично се приложува веднаш после стробоскопското изпитување пред и после хируршка интервенција и/или логопедската терапија на гласот. Може да обезбеди и аеродинамичко изпитување. Дијагностиката на пертурбациите на интензитетот (jitter) и амплитудата (shimmer) на гласот се прави преку извлекување на примерок од гласот. MDVP обезбедува квантитативна и квалитативна оценка на повеќе од 20 параметри на гласот при единочно фонирање. Има нормативни карактеристики за Бугари.</td>
</tr>
<tr>
<td>Real Time Pitch</td>
<td>Ја покажува на дисплей фундаменталната фреквенција и релативно интензитетот на височината на гласот во реално време. Акцентот, временскиот модел, интонацијата, саканата височина на гласот и/или амплитудата се оценуваат за време на говорењето.</td>
</tr>
<tr>
<td>Visi-Pitch IV</td>
<td>Вклучува MDVP, Real Time Pitch, DAF (Delayed Acoustic Feedback) како и спектрограми, направени во реално време. Таа е еден од стандартните модули во CSL. Продукцијата во реално време се користи за артикулациони тренинг и логопедска терапија на нарушувањата на гласот.</td>
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Оценката на B5, качеството на гласот е една од тешките задачи, бидејќи е сврзана со распределување на акустичката енергија во вокалниот спектар. Квалитетот на гласот (voice quality) не постои како еднозначна величина, како интензитетот и височината, на пример. Во случајот е неопходно да се разликуваат нарушувањата на квалитетот на фонацијата и нарушувањата на квалитетот на резонанцата. Каже нарушувањата на гласот се испитува безгласност (случината воздушна струја за време на фонација), Huang (1998). Таа се должи на брзинот, безгласен воздух, кој премина преку гласот. На табелата бр. 3 е описана соодветната дијагностичка опрема.

Табела 2. Програмски продукти на CSL за инструменталната дијагностика на Б3, Б4 и Б5.
Table 3. Assessment of the voice quality through applying instrumental diagnostics in South West University’s Speech-language pathology and speech-hearing rehabilitation center.

<table>
<thead>
<tr>
<th>Квалитативни нарушавања на фонацијата (Qualitative disorders of phonation)</th>
<th>Квалитативни нарушавања на резонанцата (Qualitative disorders of resonance)</th>
</tr>
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<tr>
<td>Параметар (Parameter)</td>
<td>Инструментална дијагностика (Instrumental diagnostics)</td>
</tr>
<tr>
<td>Оценка на импеданцата (Impedance assessment)</td>
<td>Применување на електроглотовограф (EEG). EEG ја мери импеданцата низ ларинксот, преку две те електроди наместени на вратот за да обезбедат браново прикажување кое ги претставува динамиката на гласните звици и контактните модели. Ги демонстрира вибрацијските движења на гласните звици при тврд или мек гласовен атак во реално време. Ние користиме модел 630 на KayPentax. (Application of electroglottograph (EGG). EEG measures impedance across the larynx, via two electrodes placed on the neck, to provide a revealing waveform display representing vocal fold dynamics and contact patterns. It demonstrates vibration movements of the vocal folds at hard or soft voice attack in real time. We use model 6130 by KayPentax).</td>
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Multi-dimensional voice program (MDVP)-model 5105

MDVP is innovated by the Japanesse company KayPentax with scientific mentor the Bulgarian engineer Dimitar Delyiski, director of Laboratory of Voice Pathology at University of South Carolina, Columbia, USA.

MDVP is “the gold standard software tool for quantitative acoustic assessment of voice quality, calculated more than 22 parameters on a single vocalization” (KayPentax, 2007). MDVP is a commonly purchased option for Multi-Speech and CSL (Computerized Speech Lab). It provides a robust multi-dimensional analysis of voice with graphic and numerical presentation of analysis results calculated in seconds. MDVP is the leading program for voice analysis in use around the world. MDVP is delivered in two versions, a basic version and an advanced version. It is designed to make standard operations readily accessed by way of a mouse, toolbar icons, and pull-down menus.

Questions about voice assessment are broadly discussed in speech therapy literature. In the last decade of XX century for speech-language pathologists, the diagnostics with MDVP’ application evokes greatest interest.

How MDVP proceeds?

Organization of the Radial Graph

There are 19 parameters extracted on the radial graph, organized in 5 groups.

First group are jitter and evaluate different forms of perturbation, short and long term frequency perturbations:

- Jita-Absolute Jitter (in voice, pitch disturbance; cycle-to-cycle variation in the periods of glottal cycles; used as basis for perceived roughness; also means variations in vocal frequency; often heard in dysphonic voices; rhythmic variations in the frequency (Hz) of a sound), (Nicolosi, Harryman, Kresheck, 2004).
- Jitt-Relative average perturbations.
- PPQ-Pitch Period Perturbation Quotient.

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- Jitt-Relative average perturbations.
- PPQ-Pitch Period Perturbation Quotient.
• sPPQ-коefficient за период на мека височина на пертурбација.
• vFo-варијација на фундаменталната фреквентност.
• Параметрите sPPQ и vFo покажуваат колку е силен треморот.

Втората група се Shimmer (ShdB) параметрите, се мерат во dB и ги оценуваат амплитудните пертурбации:
• Shimmer-кратки и долги амплитудни пертурбации (ги означува циклус-кон-циклус варијациите во амплитудата на глоталните пулсирања кои се појавуваат кога индивидуата се обидува да издржи фонација на константна фреквентција и интензитет; придонесува во перцепцијата на р kapsaост. Исто така означува ритмички варијацији на интензитетот (db) на звук (Nikolosi, Harryman, Kreshneck, 2004).
• APQ-коefficient на амплитудните пертурбации.
• sAPQ-коefficient на мека амплитудна пертурбација.
• vAm-врв на амплитудни варијации.

Третата група се параметрите сврзани со шумот:
• NHR-сооднос на хармоничноста на шумот.
• VTI-индекс на турбуленција на гласот.
• SPI-индекс на мека фонација.

Четврта група се треморните параметри:
• FTRI-индекс за фреквенција на треморниот интензитет.
• ATRI-индекс за амплитуден тремор на интензитетот.

Петта група се параметрите за паузи на гласот и субхармоничност:
• DVB-степен на гласовни паузи.
• DSH-степен на субхармоничност.
• DUV-степен на безгласност и критериум за хиперфункција.

Второ групирање на параметрите: параметрите од 1-11 се фреквентни, а SPI, VTI и NHR се временски. За секоја од група од овие параметри имаме седум одделни прозорци (A, B, C, D, E, F, G).

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Second group are Shimmer (ShdB) parameters, evaluate amplitude perturbations in dB:
• Shimmer-Short and long terms of amplitude perturbations (denotes the cycle-to-cycle variations in amplitude of glottal pulses that occur when an individual attempts to sustain phonation at a constant frequency and intensity; contributes to the perception of roughness. Also means rhythmic variations in intensity (db) of a sound (Nicolosi, Harryman, Kresheck, 2004).
• APQ-Amplitude Perturbation Quotient.
• sAPQ-Smoothed amplitude perturbation quotient.
• vAm-Peak amplitude variation.

Third group are noise related parameters:
• NHR-Noise-to-harmonic ratio.
• VTI-Voice turbulence index.
• SPI-Soft phonation index.

Fourth group are tremor related parameters:
• FTRI-Frequency tremor intensity index.
• ATRI-Amplitude tremor intensity index.

Fifth group are parameters related to voice breaks and subharmonics:
• DVB-Degree of voice breaks.
• DSH-Degree of subharmonics.
• DUV-Degree of voiceless and criteria for hyper function.

Second grouping of parameters: 1-11 parameters are frequency and SPI, VTI and NHR are temporary (window C). For every group of these parameters there are seven separate windows (A, B, C, D, E, F, and G).
МДВП-парааметри кои не се распоредени на радијалниот графикон
- DSH-(Степен на субхармоничност (%))-пресметана релативна проценка на субхармоничност на Fo компонентите во гласовниот примерок.
- DUV-(Степен на безгласност (%))-пресметана релативна проценка на нехармоничните области (кајде што Fo не може да се открие) во гласовниот примерок. Во случај на неподдржана фонација од почетокот до крајот на добивањето на податоците, DUV ќе ги проценува исто и паузите пред, после и/или меѓу гласовниот/те примерок/ци.
- Fhi-(Највисока фундаментална фреквенција /Hz/-за сите изведени периоди на височината).
- Flo-(Најниската фундаментална фреквенција /Hz/-за сите изведени периоди на височината.
- Fo-(Пресечна фундаментална фреквенција /Hz/-за сите изведени периоди на височината (реципрочно за моменталните периоди на височината).
- Mfo-(Слаба фундаментална фреквенција /Hz/-за сите изведени моментални периоди на височината.
- NSH-(Број на субхармонични сегменти)-откривени за време на анализата.
- NUV-(Број на безгласни сегменти)-откривени за време на автокорелацијските анализи.
- NVB-(Број на гласовни паузи)-покажува колку пати генерираната Fo била прекината од почетокот на првата до крајот на последната гласовна област.
- PER-(Периоди на височина)-откривени за време на период-кон-период екстракцијата на височината.
- PFR-(Обсег на фонаторно-фундаменталната фреквенција)-обсегот меѓу Fhi и Flo изразен во број од семи-тонови.
- SEG-(Тотален број на сегменти)-пресметани за време на автокорелацијските анализи.
- STD-(Стандардна девијација на фундаменталната фреквенција /Hz/-во анализиранот примерок на гласот

МДВП-parameters not located on the radial graph
- DSH-(Degree of subharmonics /%-)-Estimated relative evaluation of subharmonics to Fo components in the voice sample.
- DUV-(Degree of voiceless /%-)-Estimated relative evaluation of nonharmonic areas (where Fo cannot be detected) in the voice sample. In case of nonsustained phonation from the beginning to the end of the data acquisition, DUV will evaluate also the pauses before, after and/or between the voice sample(s).
- Fhi-(Highest fundamental frequency /Hz/-) For all extracted pitch periods.
- Flo-(Lowest fundamental frequency /Hz/-) For all extracted pitch periods.
- Fo-(Average fundamental frequency /Hz/-) For all extracted momentum fundamental frequency values (reciprocal of momentum pitch periods).
- Mfo-(Mean fundamental frequency /Hz/-) For all extracted momentum pitch periods.
- NSH-(Number of subharmonic segments)-Found during analysis.
- NUV-(Number of unvoiced segments)-Found during the autocorrelation analysis.
- NVB-(Number of voice breaks)-Shows how many times the generated Fo was interrupted from the beginning of the first until the end of the last voiced area.
- PER-(Pitch periods)-Detected during the period-to-period pitch extraction.
- PFR-(Phonatory fundamental frequency range) -Range between Fhi and Flo expressed in number of semi-tones.
- SEG-(Total number of segments)-Computed during the autocorrelation analysis.
- STD-(Standard deviation of the fundamental frequency /Hz/-) Within the analyzed voice sample.
• To-(Average pitch period /ms/)-For all extracted pitch periods.
• Tsam-(Peak amplitude variation /%-)-Length of analyzed data sample.
• vAm-(peak amplitude variation /%-)-Relative standard deviation of the period-to-period calculated peak-to-peak amplitude. It reflects the very long-term amplitude variations within analyzed voice sample.
• vFo-(Fundamental frequency variation /%-)-Relative standard deviation of the period-to-period calculated fundamental frequency. It reflects the very long-term variations of Fo for all analyzed voice samples.

On the radial graph the norm is presented in light-green color, standard deviation is presented in dark-green color, and pathology is presented in red color.

According to the standards of the American National Center for Voice and Speech (Titze, 1994), microphone for diagnostics is AKG-Acoustic. The microphone should be set at 45 degrees of mouth, at 2.5 cm distance and speaking should last at least 8 seconds. 14 samples on the average should be made in noise isolated room with 38 dB.

Tips on analyzing voice patterns

Voice analysis is best accomplished by an organized protocol of perceptual evaluation, aerodynamic analysis, acoustic analysis, electroglot- tographic analysis, and image analysis. MDVP is part of the acoustic analysis. MDVP and CSL can be used effectively for perceptual analysis by storing samples of the patient's voice (usually sustained voice and read passage) and critically listening to these stored voice samples juxtaposed with past visits to help hear changes in the voice. MDVP, CSL and Multi-Speech include program functions for this purpose.

The real-time EGG program can be used for electroglot- tographic analysis of signals. This is especially useful for hypertensive or pressed voice because the real-time feedback of EGG quotients can make various voice breaks behaviors very clear to patients.

Acoustic analysis typically includes also of the following elements:
1. **Voice Range Profiling (VRP):** The Voice range profile (i.e., phonotogram) is well-established methodology in Europe but is not often used in the USA. KayPentax has a program, named VRP, for the CSL system.

2. **Pitch Range Analysis:** Pitch range and habitual pitch analysis are best accomplished with the Real-Time Pitch program, which has built-in protocols for gathering and reporting this information.

3. **Habitual Pitch Analysis.**

4. **Spectrographic Analysis.**

5. **Voice parameter Analysis:** MDVP performs the voice parameter analysis of sustained voice.

**Spectrographic analysis**

The National Center for Voice and Speech (NCVS) recommended that a voice evaluation should include a spectrographic analysis first, to "type" patients for voice analysis. Only a vocalization with sufficient degree of periodicity (i.e., type 1) should be analyzed with a voicing parameter method of analysis, as used by MDVP. That is, type 2 vocalizations which are either too a periodic, include too many voice breaks, or have excessive subharmonic content, cannot be effectively analyzed with MDVP. Chaotic voices (type 3) also cannot be analyzed with a voicing parameter method. However, a spectrographic display effectively screens for voice types. The NCVS report should be read in its entirety for a more complete presentation of this issue. NCVS sees vocalizations as divisible into three types:

<table>
<thead>
<tr>
<th>Тип 1:</th>
<th>Вокализации со средно периодична вибрација (пертурбација &lt;5%). Овој тип може јасно да биде анализиран со MDVP. <em>(Vocalizations with nearly periodic vibration (perturbation &lt;5%). This type can be clearly analyzed with MDVP).</em></th>
</tr>
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<tbody>
<tr>
<td>Тип 2:</td>
<td>Вокализациите со силни субхармонии и модулации. Овој тип на глас може да биде анализиран со визуелен дисплеј (како спектрографска анализа) и перцептуални процени, но безнаредно е со MDVP (напоменогаш MDVP може да даде параметри). <em>(Vocalizations with strong subharmonics and modulations. This type of voice can be analyzed with a visual display (such as spectrographic analysis) and perceptual ratings, but not reliably with MDVP (although MDVP may sometimes extract parameters).</em></td>
</tr>
</tbody>
</table>
In addition we present one case. On picture No. 1 are presented diagnostics results of an old man with granuloma and hyperfunction of voice, analysis of the results and directions to treatment.

MDVP analysis of results from Picture No. 1.

In this case study, the cycle-to-cycle fundamental frequency and amplitude values are slightly elevated above normative thresholds, and the long-term amplitude measurements are elevated, suggesting some inability to maintain periodic vibration due to disordered physiology. A retest may be needed to see if inability to hold steady amplitude is repeated.

Narrow spectral line reveals quasiperiodic Type 1 of voice with slight noise in upper frequencies.

Directions to the voice (speech therapy) treatment

Basic element in voice therapy in patients with contact granuloma should be the program for vocal hygiene. Food irritating granuloma, as hot drinks and spicy food, should be removed from the patient's diet, which should be modified to reduce the need of throat cleaning. Food which thick the saliva should be eliminated.
Whispering instead of normal phonation is not recommended, especially when patient's strains, which provokes muscular tension (Colton & Casper, 1996). The therapy should proceed with slow, relaxed steps, which helps in reducing patient's stress. Voice in patient's with granuloma is commonly asymptomatic, and decreased laryngeal pain is considered as a success in the treatment. Also, patient's concept for correct vocal production should be changed. Hard voice attack should be avoided.

Other important component of the treatment is the psychological. Therapist and patient must examine the relation between patient's voice and patient's own opinion about it. Therapy includes techniques reducing stress, muscular tension and relaxation exercises. All exercises should be recorded so the patient can listen and practice them.

We strongly recommend in this case study example the Boone voice therapy program for adult’ application.

Conclusion

Our short experience regarding to the standard MDVP version application in the Bulgarian logopedics-clinical practice show the excellent options for high level of it validity and reliability. The software is easy to use and quick. The four function keys perform all analyses.

MDVP is able to extract reliable measurements of voice behavior.

The full CSL equipment guarantees the high level of voice assessment and therapy. It is widely used KayPentax product for logopedics clinical conditions in more that 40 countries around the world.
Литература / References
