

# Application of High Speed Digital Imaging (HSDI) technique and voice acoustic analysis in the diagnosis of the clinical form of Presbyphonia in women

**Authors' Contribution:**  
 A – Study Design  
 B – Data Collection  
 C – Statistical Analysis  
 D – Data Interpretation  
 E – Manuscript Preparation  
 F – Literature Search  
 G – Funds Collection

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## ABSTRACT:

**Introduction:** The aging process of voice begins after the age of 60 and has an individually variable course. Voice quality disorders at this age are called senile voice (Presbyphonia or Vox Senium). Voice pathology is particularly severe in women.

**Aim:** The aim of the study was to diagnose the clinical form of Presbyphonia in elderly women using High Speed Digital Imaging (HSDI) and acoustic voice analysis.

**Material and methods:** Study included 50 elderly women (average age 69) with dysphonia (Group I). Control group (Group II) included 30 women (average age 71) without voice quality disorders. Visualization assessment has been conducted with HSDI with High Speed camera (HS). Acoustic evaluation of voice included analysis isolated vowel "a" and continuous linguistic text with Diagnoscope Specialista software. Maximum Phonation Time (MPT) has been determined.

**Results:** In Group I, 78% of women revealed vocal folds vibrations asymmetry, vibration amplitude increase, Mucousal Wave (MW) limitation and Type D glottal insufficiency (GTs). Acoustic voice analysis proved decrease in Fo, increase in Jitter, Shimmer, Noise-to-Harmonics Ratio (NHR). In 22% of women, next to vibrations asymmetry, vibration amplitude reduction and MW limitation, Type E GTs have been found. Acoustic voice analysis revealed slight decrease in Fo and the presence of numerous non-harmonic components in the glottis region.

**Conclusions:** Vocal folds visualization with HSDI showed edema, less often atrophy in elderly women. Both forms of dysphonia were caused abnormal values of Fo, Jitter, Shimmer, NHR in the acoustic voice evaluation and significant reduction of MPT.

## KEYWORDS:

acoustic analysis, clinical voice assessment, High-Speed Digital Imaging, Presbyphonia, vocal folds vibration, voice changes

## ABBREVIATIONS

**CNS** – Central Nervous System  
**ELS** – Committee on Phoniatrics of the European Laryngological Society  
**F0** – Fundamental Frequency  
**GTs** – Glottal Closure Types  
**HS** – High Speed camera  
**HSDI** – High Speed Digital Imaging  
**MPT** – Maximum Phonation Time  
**MW** – Mucousal Wave  
**NHR** – Noise-to-Harmonics Ratio  
**OQ** – Open Quotient  
**WHO** – World Health Organization

## INTRODUCTION

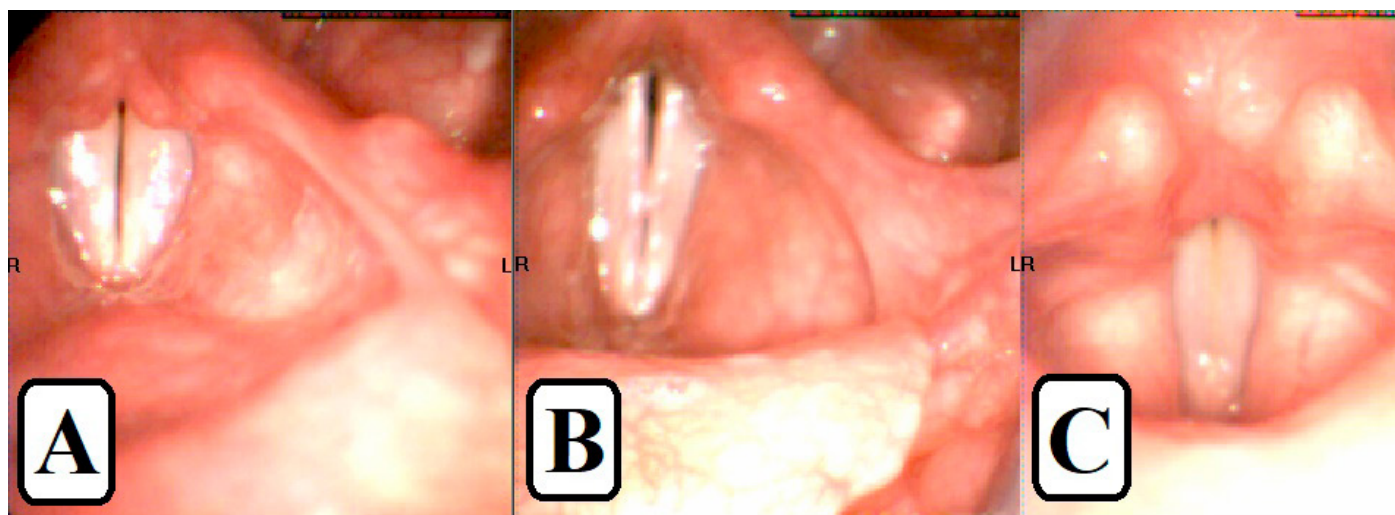
The population of our country is relatively younger in relation to that of the European Union. However, in our country there has also

been a systematic progress of the aging process observed for many years [1]. Anatomical changes during aging also affect the organs associated with voice formation. In the elderly, laryngeal muscle atrophy, decreased elasticity of the vocal ligaments, ossification of the laryngeal cartilage and degenerative changes of the vocal fold mucosa with thickening of the epithelium may be observed [2–4]. Aging of the voice, also called presbyphonia or Vox senium, begins after the age of 60 and has an individually variable course. According to the traditional World Health Organization (WHO) classification, the age of 60–75 is accepted as the definition of "elderly". During this period, the voice acquires the features of dysphonia. In women, it becomes hoarse, weak, flat and low, which is particularly worrying for them, because in their opinion it resembles a male voice [2, 4, 5].

Subjective methods should not be ignored in diagnostics of the quality of voice in the elderly, however, objective examinations are the starting point for accurate diagnostics suggesting methods of therapy and rehabilitation by reducing the severity of symptoms and preventing disease development.

**Tab. I.** One-way analysis of variance of Open Quotient (OQ) in the study group.

GROUPS	COUNT	SUM	MEAN	VARIANCE		
Anterior segment (Group A)	39	12.27	0.31462	0,017451822		
Middle segment (Group A)	39	10.22	0.26205	0,024069366		
Posterior segment (Group A)	39	34.75	0.89103	0,032519973		
Anterior segment (Group B)	11	4.52	0.41091	0,035549091		
Middle segment (Group B)	11	10.04	0.91273	0,004821818		
Posterior segment (Group B)	11	5.85	0.53182	0,003256364		
Source of variance	SS	df	MS	F	P-value	F-test
Between groups	11,4370465	5	2,287409301	101,3549161	2,22985E-45	2,2770436675
In groups	3,24983683	144	0,022568311			
Total	14,68688333	149				

**Fig. 1.** (A) Edema of vocal folds in a 68-year-old woman (HSDI); (B) Atrophy of vocal folds in a 66-year-old woman (HSDI); (C) Vocal folds in a 66-year-old woman from the control group (HSDI).

Objective diagnostics include visualization methods, such as endoscopic and stroboscopic examinations of the larynx, with or without visual track, acoustic voice testing and assessment of the Maximum Phonation Time [2, 6–13]. It should be emphasized that stroboscopy only allows for assessment of the apparent movement of the vocal folds, which makes it impossible to accurately assess the vibrations. High Speed Digital Imaging, as one of the visualization methods, is the only imaging examination that allows an objective assessment of the real vibrations of vocal folds, which makes it unique in the process of objective diagnosis [10–12, 14–18].

Elderly dysphonia (Presbyphonia) causes significant discomfort and a decrease in the quality of life. Elderly communication disorders are usually associated with social withdrawal, depressive disorders and anxiety [2].

## AIM OF THE STUDY

The aim of the study was to diagnose the clinical form of dysphonia (Presbyphonia) in elderly women using High Speed Digital Imaging (HSDI) and acoustic analysis of voice.

## MATERIAL AND METHODS

The study group – Group I – consisted of 50 women aged 60 to 75. The average age was 69, which classified the age of examined patients as elderly according to WHO. Patients were not professional voice users during their activity. Subjective examination did not reveal the existence of chronic respiratory diseases and the coexistence of inflammation of the upper respiratory tract. All diagnosed women were non-smokers.

The control group – Group II – consisted of 30 women aged 66 to 75 years old. The average age was 71. Women did not report any complaints from the vocal organ and did not use their voice professionally. Patients revealed no coexistence of chronic respiratory diseases and inflammation of the upper respiratory tract. All patients were non-smokers.

Both groups did not differ statistically significantly in terms of age.

Patients were diagnosed at the Department of Clinical Phonoaudiology and Speech Therapy, Medical University of Białystok, and treated at the Phoniatic Outpatient Clinic of the University Hospital in Białystok in 2018–2019 due to voice quality disorders.

In laryngeal imaging, HSDI by R. Wolf GmbH was used with a High Speed camera (HS) and a rigid endoscope with 90° optics of the same manufacturer. Symmetric vibration with the vocal folds was assessed on a scale according to Shaw and Deliyski, as well as Mucosal Wave morphology (MW) and glottal closure types (GTs) according to the Committee on Phoniatrics of the European Laryngological Society (ELS). Asymmetry of the vocal folds was classified according to the Shaw-Deliyski scale, determining the difference in vibration in the right and left vocal fold. The difference of 1 point is mild, 2 points – average, 3 points – serious, above 4 points – deep asymmetry of vibrations of the vocal folds.

The type of glottal insufficiency was defined as: rectangular – (A), hourglass – (B), triangular – (C), V-shaped – (D) and insufficiency in the middle segment – (E).

HSDI allowed the assessment of Open Quotient (OQ) of the glottis in the anterior, middle and posterior sections.

Acoustic evaluation of voice was conducted using the DiagnoScope Specjalista by DiagNova Technologies. The fundamental frequency of the laryngeal tone – Fundamental Frequency (F0), Jitter, Shimmer, Noise-to-Harmonics Ratio (NHR) were tested. The recorded voice samples were analyzed by narrowband spectrography. The vowel “a” pronounced in isolation 3 times with a 1-second pause in phonation was assessed, as well as a continuous linguistic, phonemically balanced text starting with the words: “Today is nice weather” (“Dziś jest ładna pogoda”). The study was conducted in an acoustically silenced room using a SHURE SM86 microphone with cardioid features and extended upper band. The average value of Maximum Phonation Time (MPT) of vowel “a” was determined, and the results were given as seconds.

One-way analysis of variance was used in the statistical evaluation of objective results.

## RESULTS

In Group I – the study group, in 39 (78%) women (Group A) HSDI imaging revealed an increase of vocal fold mass, asymmetry of vocal folds classified as average according to the Shaw-Deliyski scale (2 points), increase of vibration amplitude, reduction of MW and glottal insufficiency in the posterior segment classified as type D (GTs) according to the ELS classification.

The value of OQ in the anterior segment of the glottis was on average 0.31; in the middle segment – 0.26 and posterior segment – 0.89.

In 11 (22%) women (Group B) from Group I, we found a decrease in vocal fold mass, atrophy during breathing and phonation, vocal folds vibration asymmetry classified as mild according to Shaw-Deliyski scale (1 point), reduction of vibration amplitude, reduction of MW and glottal insufficiency in the middle segment classified as type E (GTs) according to the ELS classification. The value of OQ in the anterior segment was 0.41 on average; in the middle segment – 0.91 and in posterior – 0.53 (Fig. 1.).

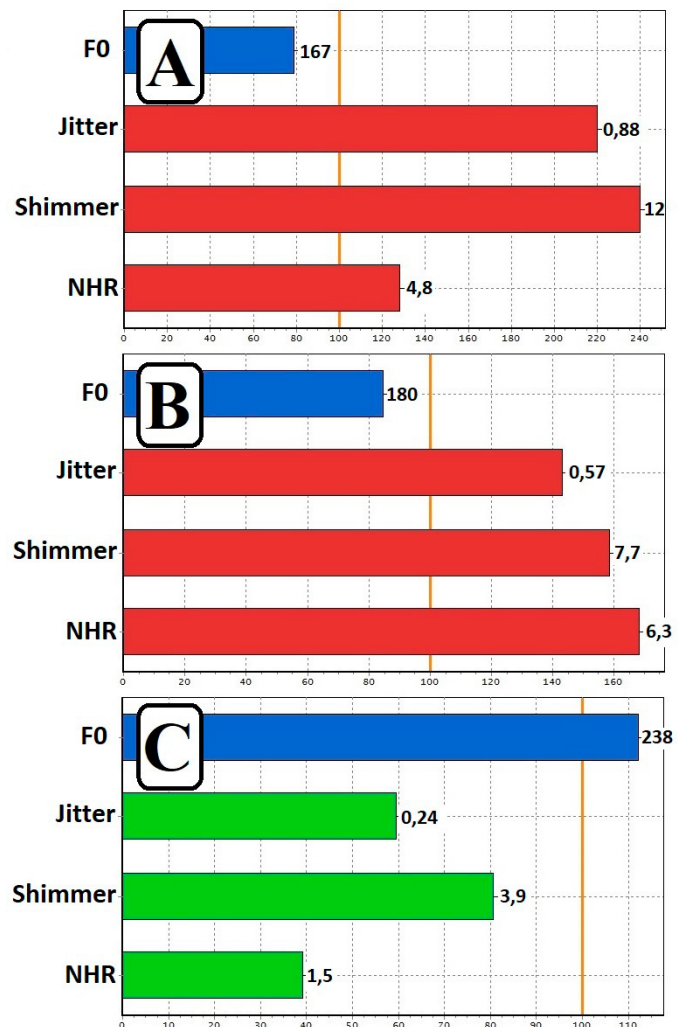


Fig. 2. (A) Collective analysis of acoustic parameters of voice in a 68-year-old woman with vocal fold edema; (B) Collective analysis of acoustic parameters of voice in a 66-year-old woman with vocal fold atrophy; (C) Collective analysis of acoustic parameters of voice in 62-year-old woman from control group (Diagnoscope Specjalista).

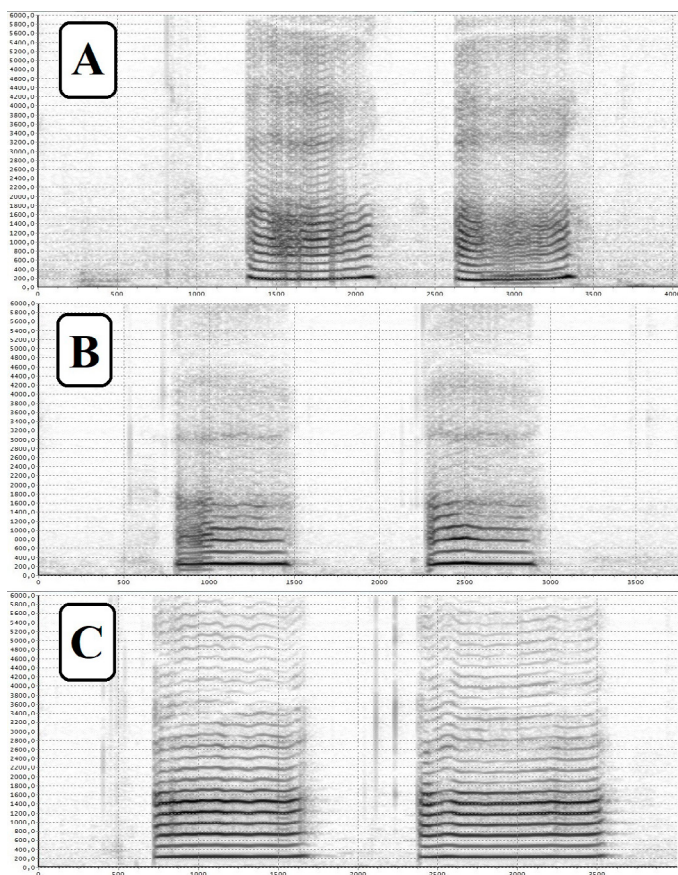
A statistical analysis of the obtained results of OQ was conducted, in which a one-way analysis of variance was used (Tab. I.).

In Group I, in 39 (78%) women an average F0 of 164 Hz was recorded; Jitter, Shimmer and NHR were above normal. Narrowband spectrography revealed the existence of numerous non-harmonic components in the medium and high frequency levels of the F2, F3 and F4 formants. The average MPT value was 11 seconds.

In Group I, in 11 (22%) women the average F0 of 195 Hz was recorded. Jitter, Shimmer and NHR exceeded normative values. Narrowband spectrography revealed numerous non-harmonic components only in the high frequency range of the F3 and F4 formants. The average MPT value was 12 seconds (Fig. 2.).

In Group II – the control group, in 28 (93%) women the vocal folds were even, smooth and of normal mass. The vibrations were symmetrical according to the Shaw-Deliyski scale. In the remaining 2 (7%) women, the vocal folds revealed vibration asymmetry classified





**Fig. 3.** a. Narrowband spectrography in a 68-year-old woman with vocal fold edema; b. Narrowband spectrography in a 66-year-old woman with vocal fold atrophy; c. Narrowband spectrography in a 62-year-old woman from control group (Diagnoskope Specjalista).

as mild according to the Shaw-Deliyski scale (1 point). The mass of the folds was reduced, the edges were even and smooth. In 3 (10%) women, glottal insufficiency classified as type E (GTs) was recorded. In 30 (100%) women, the vibration amplitude and MW were normal.

In Group II, the average F0 value was 198 Hz. Jitter and Shimmer were at the normal limit. In 5 (14%) women, NHR parameters exceeded normative values. Spectrographic analysis of voice showed the existence of harmonics and few non-harmonics, especially in the range of high frequency levels (Fig. 3.). The average MPT value was 19 seconds.

In the statistical analysis of OQ results, one-way analysis of variance was used (Tab. I).

## DISCUSSION

Life expectancy of Polish residents is systematically extended, both in women and men [1]. Efficient communication with the environment in the elderly depends on a well-functioning hearing organ, registering external stimuli, as well as the voice and speech organ enabling verbal contact with the environment. Elderly (according to WHO this regards individuals after 60 years of age) patients present disorders of voice quality called *Vox senium* or presbyphonia; especially women [19–22].

The causes of dysphonia in the elderly are involution changes in the Central Nervous System (CNS), degenerative changes within the vocal organ and age-related hormonal changes [5, 19–22]. Accurate diagnosis of the clinical form of dysphonia in the elderly ensures rapid implementation of voice therapy and rehabilitation, significantly improving prognosis. Among many diagnostic tools, special attention should be given to objective methods, the results of which are repeatable and comparable, allowing archiving of tests and monitoring of therapy and rehabilitation. Objective methods include visualization techniques, such as stroboscopy and laryngeal endoscopy with video tracking [2, 20, 23]. Stroboscopic examination allows only to obtain an apparent image of vibrating vocal folds [14]. Among the visualization techniques, only HSDI provides an objective assessment of real vibrations of the vocal folds [13–15]. This method allows recording of vibrating vocal folds at 4.000 frames per second with a HS high speed camera. The assessment used for objective diagnosis of dysphonia includes voice acoustic examination. This study permits the assessment of a number of acoustic parameters, of which the most important diagnostically are: F0, Jitter, Shimmer, NHR objectively confirming the severity of voice disorders [7, 9, 19, 22, 24, 25]. In elderly women, we observe increased dysphonia due to edema of the vocal folds [5, 27].

In the diagnosed group of elderly women (Group I), edema was recorded in 78% of subjects. Using HSDI, asymmetry and increase in vibration amplitude, reduction of MW and increase in the opening factor (OQ) were found, especially in the posterior segment of the glottis to the average value of 0.89. The above parameters of visualization assessment using HSDI allowed for unambiguous recognition of edema in the vocal folds. In the remaining 22% of women in the diagnosed group, clear decrease in vocal fold mass, significant vibration asymmetry, decrease in vibration amplitude with MW limitation and GTs, especially in the middle segment with an average value of OQ – 0.91, were observed. The aforementioned imaging parameters indicated the existence of vocal fold atrophy in the diagnosed women. Similar changes in the larynx have been described by Hamdan et al. [20] who examined menopausal women, recording edema and vocal fold atrophy in this age group. Pruszcwicz described similar clinical forms of dysphonia in elderly people [5, 27]. Angerstein et al. [26] confirms the existence of edema of the vocal folds especially in elderly women and atrophy in the elderly. According to the authors, the changes are caused by the occurrence of atrophy within the elastic fibers of the lamella of the vocal folds and irregularities in the functioning of cricoarytenoid joints. According to Kosztyła-Hojna et al. [3], morphological changes within the vocal fold mucosa are a major cause of voice quality disorders in elderly men and women.

An important parameter for assessing voice quality is the MPT. This test is easy to perform and does not require complicated and expensive diagnostic equipment, which is particularly emphasized by Karlsen et al. [6]. In the diagnosed group of elderly patients (Group I), MPT decreased statistically significantly to the average value of 11 seconds, while in the control group the Maximum Phonation Time was 19 seconds on average. Acoustic evaluation of voice in the diagnosed group of women with vocal fold edema showed a decrease in F0 to an average of 164 Hz, while Jitter, Shimmer and

NHR were above normal, which confirmed the existence of severe voice quality disturbances in this group of patients. The decrease in F0 was observed due to an increase in vocal fold mass in women with vocal fold edema. Rapoport and Spazzapan et al. [11, 19], obtained similar results assessing the acoustic parameters of voice in elderly people with laryngeal edema. Narrowband spectrography in the group of diagnosed elderly women showed the presence of numerous non-harmonic components in the range of high frequency levels of F3 and F4 formants, especially in patients diagnosed with vocal fold atrophy. The presence of non-harmonic components generated in the glottic region confirms glottal insufficiency in the middle segment in women with atrophy.

HSDI in this group showed the type of GTs classified as type E and a high value of OQ in the middle segment of the glottis – 0.91. In addition to numerous non-harmonic components at a high frequency level corresponding to the F3 and F4 formants, women with vocal fold edema in narrowband spectrography were found with non-harmonic components in the medium and low frequency levels. The use of objective visualization techniques of the larynx and acoustic evaluation of voice in the diagnosis of the clinical form of dysphonia in elderly women is important due to the differences in therapy of edema and atrophic dysphonia. Rapid and accurate diagnostics guarantees effective voice treatment and rehabilitation, preventing disease progression. According to Eichhorn et al. [9], the elderly population is steadily growing, and older people are becoming an important component of society in economic, sociological and cultural aspects. According to the authors, further research on understanding the aging process of the human body and improving the quality of life in the elderly

are extremely important, which will undoubtedly provide efficient verbal communication with the environment [9].

## CONCLUSIONS

1. Edema of vocal folds, less frequently their atrophy, has been recorded in elderly women with presbyphonia;
2. Average asymmetry and increase of vibration amplitude, limitation of MW, GTs of type D and a high value of OQ in the posterior segment recorded by HSDI confirmed the edema of vocal folds;
3. Mild asymmetry and reduction of vibration amplitude, limitation of MW, GTs of type E and high value of OQ in the middle segment indicated vocal fold atrophy;
4. Decrease of F0 value, increasing Jitter, Shimmer, NHR in the voice acoustic examination and reduction of the MPT confirmed the existence of vocal fold edema;
5. In atrophic presbyphonia, a clear increase in NHR, a slight decrease in F0 in the acoustic evaluation of voice and reduction of the MPT have been recorded in women;
6. Narrowband spectrography showed the presence of non-harmonics in the medium and high frequency levels in the edematous presbyphonia and numerous non-harmonic components only at the high-frequency level in women with vocal fold atrophy.

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Competing interests:

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