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ORIGINAL ARTICLE

Visual assessment of voice disorders in patients with occupational dysphonia

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Abstract

Introduction. In a group of persons using the voice occupationally, the frequent symptoms are hoarseness, voice fatigability and aphonia. Pathological changes in the larynx may have organic or functional character which require different methods of treatment and rehabilitation. Visualization of vibrations of the vocal folds is an essential condition for an appropriate assessment of the causes of dysphonia.

Objective. The purpose of the study is assessment of the usefulness of a high-speed imaging (HSI) system in the diagnosis of functional and organic dysphonia of occupational character, compared with digital kymography (DKG) and digital stroboscopy (DS) with a high resolution module.

Material and methods. The study group consisted of 64 patients with voice quality disorders with features of occupational dysphonia. The control group consisted of 15 patients with euphonic voice. Analysis of the voice quality parameters during phonation of the 'e' vowel was performed using HSI, DKG and stroboscopy of high resolution, by means of a digital HS camera (HRES Endocam, Richard Wolf GmbH, Knittlingen, Germany). Vocal folds vibrations were registered at the rate of 4,000 frames per second.

Results. HSI is the most reliable diagnostic tool giving the possibility of an analysis of the true vibrations of the vocal folds. It also enables an observation of the aperiodicity of vibrations of the vocal folds, while DS with high resolution allows diagnosis of the periodicity of the vibrations.

Conclusions. HSI is particularly useful in the diagnosis of neurologically-based pathology of the voice (paralytic dysphonia) and organic dysphonia. The quickest method of diagnosing the phonatory paresis of the glottis is DKG. The advantage of both HSI and DKG is the non-invasiveness of examinations; however, their limitations are time-consuming and the high cost of equipment.

Key words

high-speed imaging (HSI), vocal fold vibration, stroboscopy, digital kymography (DKG), mucosal wave (MW), voice pathology

INTRODUCTION

Voice quality disorders – dysphonias – appear commonly, and in most cases occur in persons working with the voice occupationally. Professions which belong to this group are teachers, actors, singers, judges, lawyers, prosecutors and speakers. Voice disorders can occur in the form of hoarseness, voice fatigability and aphonia. They may appear in the early period of voice work, which is a sign of adaptation to the new requirements for the phonatory organ. They occur the most frequently after 10 years of work with voice, connected with occupational full load of voice. In this period, the common symptoms reported by patients are the presence of a dense secretion in the throat, the need for chronic cough and intensive dryness of the oral cavity mucosa, especially during phonation. Visualization of the vibrations of the vocal fold is an essential condition in the assessment of causes of dysphonia [1, 2, 3, 4, 5, 6, 7, 8]. The significant meaning have the techniques: high-speed imaging (HSI) which allows assessment of a true view of vocal folds vibrations at a rate of 4,000 frames per second, digital kymography (DKG) and digital stroboscopy (DS) with a high resolution module using a digital camera (HRES Endocam, Richard Wolf GmbH) [2, 8, 9, 10]. Pathological changes diagnosed in the larynx may have a functional or organic background, which requires different therapy and methods of rehabilitation [1, 6, 11, 12, 13, 14].

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Objective. The aim of the study is assessment of the usefulness of a high-speed imaging (HSI) system in the diagnosis of functional and organic dysphonia of an occupational character, compared with digital kymography (DKG) and digital stroboscopy (DS) with a high resolution module.

MATERIALS AND METHOD

The study group consisted of 64 patients with voice disorders and 15 subjects with euphonic voice. Patients were treated in the Phoniatry Outpatient Clinic of the Medical University in Białystok in northeast Poland, and diagnosed in the Department of Clinical Phonoaudiology and Logopedics at the same medical university, in 2011–2013. The age range of patients diagnosed with dysphonia was from 24–71 years (average 47 years). The group consisted of 51 (80%) female and 13 (20%) male patients.

The control group consisted of 15 subjects aged from 27–69 years (average 44 years) – 10 (67%) females and 5 (33%)

males. The group included non-smokers, non-professional voice working subjects, without diagnosed gastroesophageal reflux or pathology of respiratory tracts. Patients from both groups did not differ statistically significantly, taking into consideration age and gender.

Analysis of the voice quality parameters was carried out using a digital HS camera (HRES Endocam 5562, Richard Wolf GmbH, Knittlingen, Germany) during phonation of the 'e' vowel, registering the images of vibrations of the vocal folds at the rate of 4,000 frames per second, with a pixel resolution of 256×256. 1,000 frames of duration 250 ms deriving from the file of 2–3 seconds of phonation were examined. The investigation was performed only once per patient, using a rigid endoscope with 90° optics (Richasrd Wolf GmbH). The record duration usually amounted to 2 seconds. Playback of the recorded sequence was variable and usually set at 15 frames per second. This display allowed assessment of the vibration of the vocal folds for 8.88 minutes in slow motion mode. The equipment also provides the possibility to select the recorded sequences. Digital kymographic analysis, using full frame image obtained by recording high-speed imaging with rate of 4,000 frames per second was also carried out, using camera software HRES (Richard Wolf GmbH). Mucosal wave (MW), amplitude, periodicity of vibrations, phase of phonatory closure of the glottis, and symmetry of vibrations of the vocal folds were also analyzed.

In order to visualize the vibrations of the vocal folds, the stroboscopic examination of the larynx using the high resolution module with the tool HRES Endocam 5562 (Richard Wolf GmbH) was carried out. The parameters were analysed of amplitude, regularity, symmetry of vibrations, mucosal wave and phase of phonatory closure of the glottis during phonation of 'e' vowel by use of a rigid endoscope with 90° optics (Richard Wolf GmbH).

In the statistic analysis of results, the t-Student test was used with the determination of coefficient *p*. Statistically significant values were set at $p \leq 0.05$.

RESULTS

In the group of 64 patients with voice pathology, functional dysphonia was registered in 20 (31%) cases, and organic dysphonia and in 44 (69%) cases. In 12 (18.8%) patients, hyperfunctional dysphonia was diagnosed. Phonatory paresis of the glottis was observed in 27 (42.2%) patients; secondary hypertrophic changes in 8 (12.5%), unilateral paralytic dysphonia in 7 (10.9%), bilateral vocal folds paralysis in 4 (6.25%), vocal nodules in 3 (4.7%), vocal folds oedema in 2 (3.1%), and polyp of the larynx in 1 (1.6%) patient (Fig. 1).

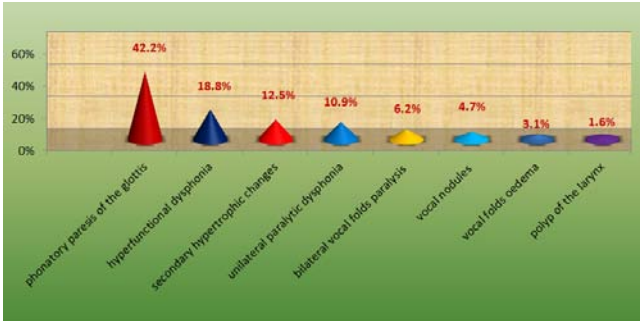

Figure 1. Characteristics of clinical types of dysphonia in analyzed group of patients

In the control group of 15 subjects, there were none with voice pathology or changes in the larynx in the sensor test.

In both groups there were no statistically significant differences when taking into consideration age ($p \leq 0.06$) and gender ($p \leq 0.07$).

In the group of patients with hyperfunctional dysphonia, HSI examination revealed a decreased vibration amplitude, excessive phonatory closure of the glottis, asymmetry and aperiodicity of vibrations. In hypofunctional dysphonia, increased vibration amplitude was observed. In DKG examination in hypofunctional dysphonia, an incomplete glottal closure was observed. In stroboscopic assessment in hyperfunctional dysphonia, a decreased vibration amplitude and limited mucosal wave were registered. In hypofunctional dysphonia, an increased vibration amplitude was clearly visible. In the group of patients with phonatory paresis of the glottis, the kymographic examination revealed aperiodic vibrations, decreased vibration amplitude and lack of glottic closure (Fig. 2).

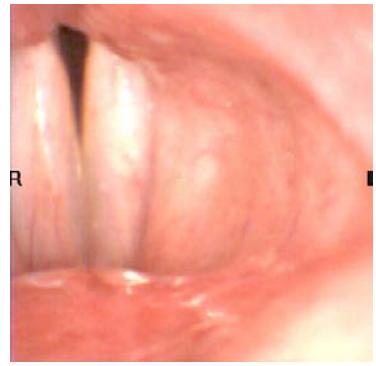

Figure 2. Phonatory paresis of the glottis (HSI)

In the examination by HSI in patients with secondary hypertrophic changes of the vocal folds, aperiodicity and asymmetry of vibrations, asymmetry of mucosal wave and pathologic glottal closure were registered (Fig. 3).

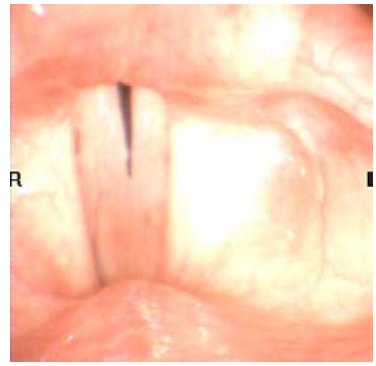

Figure 3. Secondary hypertrophic changes of vocal folds (HSI)

In stroboscopic examination, a clearly visible asymmetry of vibrations of the vocal folds and a limited mucosal wave were observed (Fig. 4).

In patients with unilateral paralytic dysphonia, by using the HSI method, aperiodicity and asymmetry of vibrations, limited or lack of mucosal wave and pathologic phonatory closure of the glottis were observed. In DKG examination, irregularity of vibrations of the vocal folds, their asymmetry and lack of phonatory glottic closure were performed (Fig. 5).

Figure 4. Secondary hypertrophic changes of vocal folds (DS with high resolution)

High resolution stroboscopy revealed in all cases decreased amplitude of vibrations of the vocal folds and in 2 (29%) patients limited mucosal wave was observed.

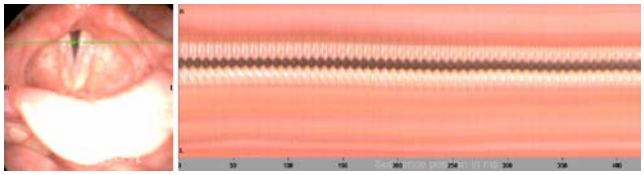

Figure 5. Unilateral paralytic dysphonia (DKG)

In all patients with vocal nodules using HSI method, aperiodicity, irregularity of vibrations and limited mucosal wave were registered. Pathologic phase of phonatory glottic closure was registered in DKG. In high resolution stroboscopy, apart from the pathologic phase of glottal closure, a limited mucosal wave was observed.

In the group of patients with vocal folds oedema, with usage of the HSI method, irregularity, asymmetry, increased amplitude of vibrations of the vocal folds and the pathologic phase of glottal closure in the posterior part were observed. In DKG examination, irregularity and asymmetry of vibrations, as well as lack of complete glottal closure, especially in the area of the posterior commissure of the larynx, were observed. Stroboscopic examination in all patients revealed a limited mucosal wave, asymmetry of vibrations and decreased amplitude (Fig. 6).

Figure 6. Vocal folds oedema (DS with high resolution)

In the group of patients with polyp of the larynx, using HSI, irregularity, decreased amplitude, asymmetry of vibration of the vocal folds and pathologic phase of phonatory glottal closure was registered (Fig. 7). DKG examination revealed irregularity and asymmetry of vibrations and pathologic phase of phonatory glottal closure. In stroboscopic assessment, asymmetry and irregularity of vibrations as well as pathologic phase of phonatory glottal closure were registered.

Figure 7. Polyp of the larynx (HSI)

In the control group in all patients, using HSI examination, regularity and symmetry of vibrations, the presence of mucosal wave and the physiological phase of phonatory glottal closure were observed.

In DKG examination, regular and symmetric vibrations with the presence of the physiological phase of phonatory glottal closure and mucosal wave were registered.

In the stroboscopic assessment of the larynx, vibrations of the vocal folds were regular and symmetric. Complete phonatory glottal closure was observed. In all cases, a physiological mucosal wave was registered.

DISCUSSION

The frequent symptoms reported by persons working with voice occupationally are hoarseness, voice fatigability, a tickle in the larynx and throat, dryness of oral cavity mucosa and even aphonia. The above-mentioned ailments appear most frequently in persons with long work experience (above 10–15 years). The voice quality and its parameters depend on the integral functioning of voice organ – the larynx, respiratory system, articulators and resonant cavities. The correct vibration of the vocal folds is an essential condition of the physiological voice – euphonic. Mobility of the vocal folds is determined by their unchangeable layered structure. Irregularity, asymmetry and asynchrony of vibration of the vocal folds is the cause of voice quality disorders in the form of hoarseness. The pathological changes in the larynx may have functional or organic character. The accurate and quick diagnosis of voice pathology gives the possibility of an adequate therapy and rehabilitation, which guarantees a return to phonatory function of the larynx. An incorrect diagnosis may be the cause of advanced types of organic dysphonia which are an indication for phonosurgical intervention. Among innovative methods of diagnosis, in the first place should be emphasized the technique of high-speed imaging (HSI).

First recordings of the vibrations of the vocal folds using high-speed (HS) filming technique were performed by Farnsworth in 1940 [2, 7]. Recordings related to the human larynx, however, were carried out primarily only

for research purposes [7]. Limitations of the practical use were the result of technical difficulties connected with the playback of recordings, their analysis and obtaining an image [7]. Currently available techniques in digital sequences allow analysis of the true vibrations of the vocal folds. It has been carried out since 1995 in studies connected with the improvement of high-speed filming techniques in terms of image quality, registration speed, and the ability to store and collect recordings (archiving) [7, 15, 16].

Since 2006, the possibility of recording high-speed imaging in colour has been used, thanks to the system introduced by the firm of Richard Wolf GmbH in Knittlingen, Germany [2]. In 1994, videokymography was used as a high-speed (HS) method giving the possibility of visualizing vibrations of the vocal folds [6, 17]. The mucosal wave (MW) is the most important parameter determining vibrations of the vocal folds which can be analyzed with the usage of indirect imaging techniques, such as electroglottography (EGG) or photoglottography (PGG) and visualization techniques – stroboscopy, videokymography (VKG) and high-speed imaging (HSI) [6]. Indirect techniques are insufficient for the assessment of the mucosal wave and should be supported by visualization techniques [6]. According to clinicians, the most useful technique is endoscopy of the larynx by means of a rigid endoscope [6, 9]. The authors of many publications claim that stroboscopy should be used as a preliminary examination in the diagnosis of voice quality pathology. The advantages which support the usage of this method are its low cost and an ability to achieve quick results. However, it should be considered the illusion of image created by stroboscopy. This technique allows the registration of only 30 frames per second and gives a virtual and slow-motion image [6]. Moreover, this technique also has a number of limitations, such as its effectiveness in only referring to periodic vibrations of the vocal folds, and lack of usefulness in cases of aperiodic vibrations. This fact indicates the limitation of diagnostic effectiveness of stroboscopy in the assessment of mucosal wave morphology [6]. According to Patel et al. [12], stroboscopic examination is 37% less useful in voice quality disorders arising from neuromuscular pathologies and in organic pathologies of the larynx. Bonilha et al. [1], in evaluating the diagnostic value of stroboscopy and high-speed videoendoscopy (HSV), found particular effectiveness of stroboscopy in the examination of functional dysphonia, assessing the symmetry of vibrations of the vocal folds (41%). However, Krausert, Schade et al. [6, 18] claim that only the HSI method allows for observation of aperiodic vibrations of the vocal folds, which is impossible using laryngeal stroboscopic examination. Many authors indicate the usefulness of acoustic voice analysis, combined with the HSI technique, as an objective analysis of vibrations of the vocal folds [19]. Miyaji et al. [20] appreciate the role of HSI in the diagnosis of diplophonia, pointing out the significance of voice quality assessment using the GRBAS scale, especially the G, R and B parameters. According to the authors, the HSI technique is particularly useful in cases of dysphonia with irregular vibrations of the vocal folds and incorrect glottal closure [20, 21].

According to Braunschweig et al. [9], the HSI method is especially useful from the diagnostic aspect in the assessment of clinical type of functional dysphonia, taking into consideration the ability to register vibrations of the vocal folds in real time, which enables a precise differentiation. The presented method is objective and qualitatively constant in a diagnostic procedure, and facilitates a differentiation between physiological and pathological voices [9]. Kendall et al. [22] compared the diagnostic usefulness of HSI and videostroboscopy in the assessment of parameters describing the vibrations of the vocal folds in a group of 50 healthy individuals with no evidence of voice quality disorders (non-smokers, without reflux or respiratory tracts pathology). Periodicity of the vibrations of the vocal folds, amplitude, morphology of the mucosal wave, vibration symmetry and phase of glottal closure were analyzed. No significant differences were found between the usage of both diagnostic methods, taking into consideration all evaluated parameters, with the exception of vibration periodicity [22]. According to Kendall et al. [22], HSI should be used in the basic diagnosis of voice pathologies with impaired periodicity of the vibrations of the vocal folds. In the opinion of Krausert et al. [6], stroboscopic examinations of the larynx should be used only to record periodic vibrations of the vocal folds. According to the authors, only HSI enables observation of aperiodic vibrations of the vocal folds, which is not possible using stroboscopy. However, an adequate amount of registered images is about 4,000 frames per second, because 2,000 frames per second appears to be insufficient to assess the mucosal wave (MW) with a high frequency of vibrations of the vocal folds registered, for example, in females.

Kymographic examination has significant diagnostic value in laryngeal pathology. It is based on an analysis of chosen fragments of a frame from a registered video using the HSI technique [14]. The kymogram, which is a graphic record of the movements of the vocal folds using the computer software of an HRES camera by the Wolf company, allows visualization of the presence of the mucosal wave, the closed and open phases of the glottis, periodicity of vibrations, symmetry of vibrations of both vocal folds (left-right) and vibration amplitude [6]. According to Krausert et al. [6], kymography used in conjunction with HSI enables the most adequate quantitative and qualitative evaluation of mucosal wave parameters. The HSI method allows to real analyse cycles of vocal folds vibration frame by frame, whereas kymogram is a sine wave which enables quantitative description of vocal folds movement, and assessment of amplitude, frequency and phase of vocal folds closure [6]. The HSI method combined with kymography provides the most applicable quantitative analysis of the mucosal wave [6]. Kymography provides the possibility of quantitative evaluation of mucosal wave parameters in pathology of voice quality, being the result of aerodynamic and asymmetry disorders. Videokymography (VKG) is a quicker method of mucosal wave measurement compared with HSI or digital kymography with HSI. Conceptually, the method is similar to DKG and is used to describe the mucosal wave in the form of kymograms. The reduction in time devoted to examination using digital kymography (DKG) with high-speed imaging (HSI) may result in increasing its diagnostic usefulness, enabling an applicable and objective diagnosis of voice quality disorders [6].

CONCLUSIONS

1. Occupational load of the voice is a cause of laryngeal pathology of functional or organic character.
2. The high-speed imaging (HSI) method is a non-invasive method of examination for the patient, allowing the analysis of the real vibrations of the vocal folds.
3. The limitations of HSI are the time-consuming examination and high cost of the equipment.
4. HSI is the most reliable technique visualizing aperiodicity of vibrations of the vocal folds, and it is especially useful in the diagnosis of neurologically-based and organic dysphonia.
5. Stroboscopy with a high resolution module (DS) provides a quick and comprehensive evaluation of the periodicity of vibrations of the vocal folds, which is especially valuable in the diagnosis of the clinical type of functional dysphonia.
6. Digital kymography (DKG) and HSI allow observation of the aperiodicity of the vibration of the vocal folds and pathologic phase of glottal closure, which facilitates the diagnosis of clinical types of organic dysphonia.

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REFERENCES

1. Bonilha HS, Deliyski DD, Whiteside JP, Gerlach TT. Vocal fold phase asymmetries in patients with voice disorders: a study across visualization techniques. Am J Speech Lang Pathol. 2012; 21(1): 3–15.
2. Inwald EC, Döllinger M, Schuster M, Eysholdt U, Bohr C. Multiparametric analysis of vocal fold vibrations in healthy and disordered voices in high-speed imaging. J Voice. 2011; 25(5): 576–590.
3. Kosztyła-Hojna B, Moskal D, Kuryliszyn-Moskal A, Andrzejewska A, Falkowski D. Morphological changes of the vocal fold mucosa in hyperfunctional dysphonia diagnosed by psychoacoustic and videostroboscopic methods. Adv Med Sci. 2011; 56(2): 343–51.
4. Kosztyła-Hojna B, Andrzejewska A, Moskal D, Rogowski M, Falkowski D, Kasperuk J. Morphological aspects of the euphonic voice. Folia Histochem Cytobiol. 2011; 49(1): 72–79.
5. Kosztyła-Hojna B, Kuryliszyn-Moskal A, Rogowski M, Moskal D, Dakowicz A, Falkowski D, et al. Wpływ wibracyjnej terapii stymulującej na jakość głosu w postaci hiperfunkcjonalnej dysfonii zawodowej. Otolaryngol Pol. 2012; 66(3): 219–226 (in Polish).
6. Krausert CR, Olszewski AE, Taylor LN, McMurray JS, Dailey SH, Jiang JJ. Mucosal wave measurement and visualization techniques. J Voice. 2011;25(4): 395–405.
7. Larsson H, Hertegard S, Lindestad PA, Hammarberg B. Vocal fold vibrations: high-speed imaging, kymography, and acoustic analysis: a preliminary report. Laryngoscope 2000; 110(12): 2117–2122.
8. Shaw HS, Deliyski DD. Mucosal wave: a normophonic study across visualization techniques. J Voice. 2008; 22(1): 23–33.
9. Braunschweig T, Schelhorn-Neise P, Dollinger M. Die Untersuchung funktioneller Stimmstörungen mit Hilfe der Hochgeschwindigkeitsvideotechnik. Laryngorhinootologie 2008; 87(5): 323–330 (in German).
10. Yamauchi A, Imagawa H, Yokonishi H, Nito T, Yamasoba T, Goto T, et al. Evaluation of vocal fold vibration with an assessment form for high-speed digital imaging: comparative study between healthy young and elderly subjects. J Voice. 2012; 26(6): 742–750.
11. Chodara AM, Krausert CR, Jiang JJ. Kymographic characterization of vibration in human vocal folds with nodules and polyps. Laryngoscope 2012; 122(1): 58–65.
12. Patel R, Dailey S, Bless D. Comparison of high-speed digital imaging with stroboscopy for laryngeal imaging of glottal disorders. Ann Otol Rhinol Laryngol. 2008; 117(6):413–424.
13. Patel RR, Liu L, Galatsanos N, Bless DM. Differential vibratory characteristics of adductor spasmodic dysphonia and muscle tension dysphonia on high-speed digital imaging. Ann Otol Rhinol Laryngol. 2011; 120(1): 21–32.
14. Colton RH, Woo P. Measuring Vocal Fold Function. In: Rubin JS, Sataloff RT, Korovin GS (eds.). Diagnosis and Treatment of Voice Disorders. 3th ed. San Diego, Oxford: Plural Publishing, Inc., 2006. p. 221–247.
15. Deliyski DD, Hillman RE. State of the art laryngeal imaging: research and clinical implications. Curr Opin Otolaryngol Head Neck Surg. 2010; 18(3): 147–152.
16. Hertegard S. What have we learned about laryngeal physiology from high-speed digital videoendoscopy? Curr Opin Otolaryngol Head Neck Surg. 2005; 13(3): 152–156.
17. Svec JG, Schutte HK. Kymographic imaging of laryngeal vibrations. Curr Opin Otolaryngol Head Neck Surg. 2012; 20(6): 458–465.
18. Schade G, Muller F. Hochgeschwindigkeitsglottographische Diagnostik in der Laryngologie. HNO. 2005; 53(12): 1085–1086, 1088–1091 (in German).
19. Yan Y, Damrose E, Bless D. Functional analysis of voice using simultaneous high-speed imaging and acoustic recordings. J Voice. 2007; 21(5): 604–616.
20. Miyaji M, Iwamoto Y, Oda M, Niimi S. Relation between voice quality and pathological vibratory patterns using high-speed digital imaging. Nihon Jibiinkoka Gakkai Kaiho. 1999; 102(3): 354–367 (in Japanese).
21. Miyaji M. Analysis of pathological vocal fold vibrations using high-speed digital imaging. Nihon Jibiinkoka Gakkai Kaiho. 1998; 101(9): 1099–111 (in Japanese).
22. Kendall KA. High-speed laryngeal imaging compared with videostroboscopy in healthy subjects. Arch Otolaryngol Head Neck Surg. 2009; 135(3): 274–281.