Objectification of vocal folds mucosal wave

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ABSTRACT: The work assessed clinical utility of open quotients measured during laryngovideostroboscopy and electroglottography. Values of the parameters were analyzed according to clinical diagnosis. An algorithm based on direct and indirect mucosal wave measurement is presented, which allows for differentiation of voice disorders. The method developed for the objectification of glottal functions in various voice pathologies is characterized by high sensitivity and specificity.

KEYWORDS: vocal folds, dysphonia, open quotient, stroboscopy, electroglottography

INTRODUCTION

Literature studies show that the voice is the subject of numerous researches all over the world in both medical and social contexts [1,2]. According to epidemiological data, the occurrence of voice disorders in the adult population reaches 15% [3]. Laryngovideostroboscopy (LVS) is a gold standard among the diagnostic tools for the larynx [4]. New technology gives the possibility to objectify LVS through open quotients (OQ) [5]. The option of LVS objectivization, currently perceived as a subjective method, provides a tool for precise diagnosis of laryngeal diseases [6]. This work describes the characteristics of the glottis in different kinds of dysphonias as measured with videostrobokymography (VSK) and electroglottography (EGG) and calculated with open quotients (OQs).

AIM

The aim of the study was to objectively measure glottal function in terms of open quotients derived from various mucosal wave imaging techniques and then use them to differentially diagnose different types of dysphonias [7].

MATERIAL AND METHOD

The material included 300 subjects (102 with various sorts of functional dysphonia, 97 with benign vocal fold lesions and 101 controls) who underwent thorough otolaryngologic and phoniatric examination. The study design was approved by the Bioethics Committee of the Institute of Physiology and Pathology of Hearing in Warsaw (IFPS:/KB/07/2013). Laryngovideostroboscopy, electroglottography, and videostrobokymography testing was conducted using an EndoSTROB-DX-Xion GmbH (Berlin) device with DIVAS software. The author analyzed regularity, amplitude, mucosal wave and glottal closure on the basis of LVS. Based on EGG recordings, QOQ_{EGG} was calculated and on VSK recordings – OQ_{VSK}. Previous studies indicate that OQ changes with the change of volume and pitch [8-12]. Individuals were recorded during prolonged, comfortable phonation of [e]. The design of this work assumes a safe range of the intensity of phonation from 70dB to 85dB, for which no significant influence on OQ has been found in literature [13].

RESULTS

Detailed characteristics of the patient groups have been published in a series of publications [4,14]. Apart from own publications, there are no reports in literature on simultaneous use of open quotients obtained from EGG and VSK methods to assess function of the larynx. Based on the results obtained from 101 healthy individuals from the control group, normative values of the OQ_{VSK} and QOQ_{EGG} opening were determined [4]. Among women, the average value of QOQ_{EGG} was 0.553 (SD = 0.04). Among men, the average value of QOQ_{EGG} was 0.537 (SD = 0.039). Women obtained higher values of averaged OQ_{VSK} than men. Respectively 0.532 (SD=0.04) and 0.51 (SD=0.039) [4]. Analysis of data obtained from the study groups

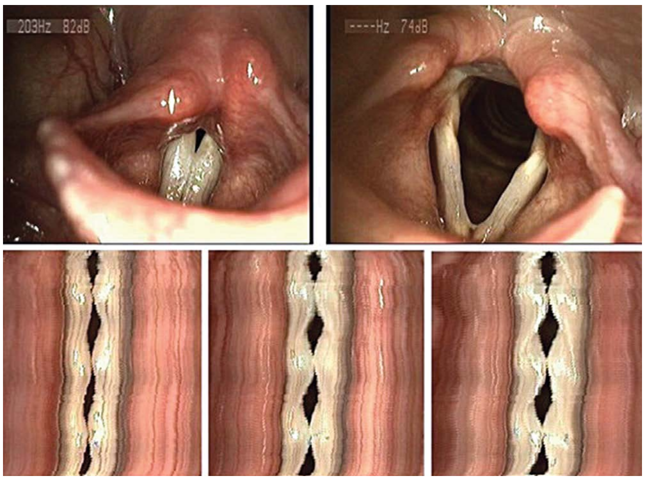

Fig. 1. Images from laryngovideostroboscopy showing phonic contraction during free phonation of vowel [e] and breathing phase of patient in the control group. Below are scanographs created at the front, middle and back (in sequence from left). OQVSK respectively 0.62; 0.55; 0.64.

Source: Institute of Physiology and Pathology of Hearing.

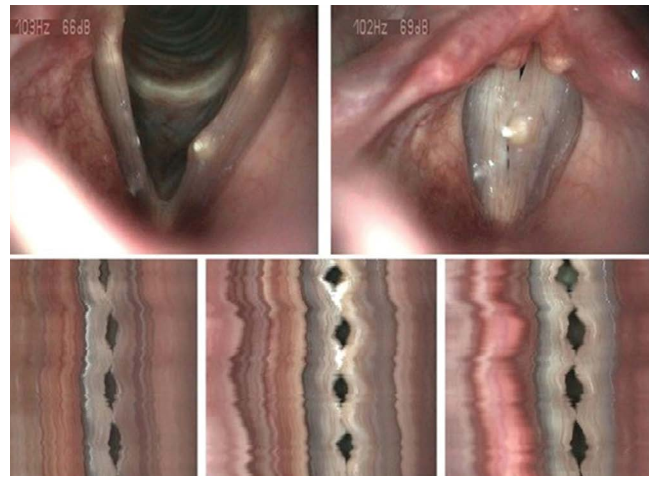

Fig. 2. Images from laryngovideostroboscopy showing breathing phase and phonic contraction during free phonation of vowel [e] of patient with cyst of the left vocal fold. Below are scanographs created at the front, middle and back (in sequence from left). OQVSK respectively 0.5; 0.46; 0.63.

Source: Institute of Physiology and Pathology of Hearing.

showed that OQ_{VSK} and QOQ_{EGG} differentiate between dysphony and euphony. Figure 1 shows LVS images and kymograms of a subject without vocal complaints. Figure 2 shows LVS and kymograms of a patient with a vocal fold cyst. Statistical analysis of data proved that the OQ_{VSK} and QOQ_{EGG} coefficients differentiate between organic and functional dysphonia [14]. Different types of dysphonia have different OQ characteristics. Figure 3 presents a comparison of mean values of the average OQ_{VSK} and QOQ_{EGG} with arrows showing statistically significant differences in relation to the control group.

Different characteristics of patients with various voice disorders were also visible in detailed OQ_{VSK} coefficients. The values measured from three parts of the vocal folds showed different tendencies depending on the type of glottal pathology. Figure 4 presents mean OQ_{VSK} values obtained from the anterior, middle and posterior part of glottis of the euphonic and dysphonic subjects. Dashed lines depict the trends of OQ_{VSK} coefficients within the glottis.

The author sought values of VSK and EGG open quotients and features of LVS examination that could distinguish voice pathologies. A decision tree algorithm classifying patients to a specific group of disorders was proposed consisting of three levels of choice (Figure 7). The first step concerned the distinction between people with euphonic voice and people with dysphonia. The second step divided subjects in terms of the nature of dysphonia - organic or functional. Step three and four attributed specific recognition to individual groups of dysphonia (Table I).

Step 1 correctly assigned 80 healthy individuals to the group of people without voice disorders and 182 dysphonic individuals to a group of people with voice disorders. Therefore, the share of correct classification for the entire analyzed material was 87.3%. Sensitivity of the above test was 91.4% and specificity was 79.2%. The sensitivity of step 2, tested only on the population of patients with dysphonia, assuming that the test indicates an organic dysphonia, was 81.9% and specificity was 85.2%. Results of the classification are presented in figure 6. OQ_{VSK} values measured from the anterior and middle part of glottis most accurately differentiated functional and organic dysphonia. Figure 7 illustrates the distribution of OQ_{VSK} values measured from the anterior and middle part of glottis in the two types of dysphonia. While determining the conditions of the above algorithm, it was observed that opening coefficients obtained on the basis of VSK constitute the most significant differentiating condition. The ROC curve was used to assess correctness of the classifier [15]. The author applied AUC statistic to show if OQs can reliably distinguish the dysphonic groups. Values of the area under the ROC curve (AUC) for mucosal wave open quotients are shown in Table II.

DISCUSSION

Knowledge of normative values is a key element that allows not only to characterize the physiologic voice, but also to detect its disorder. According to the literature, the duration of vocal fold contact in euphonic people should be close to 50% of the glottal cycle [16, 17]. Normative values developed in the stu-

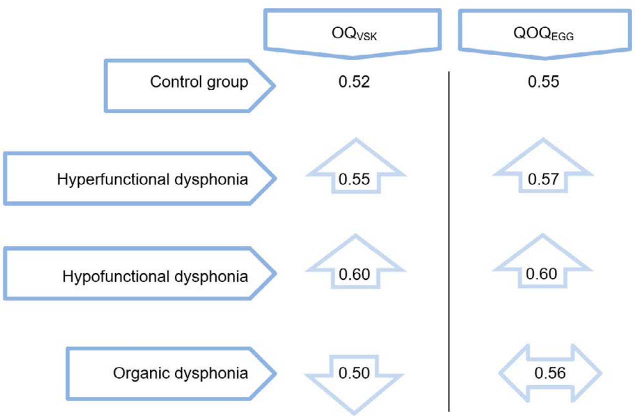

Fig. 3. Mean values of averaged OQ_{VSK} and QOQ_{EGG} in the group of people with voice standard and dysphony.

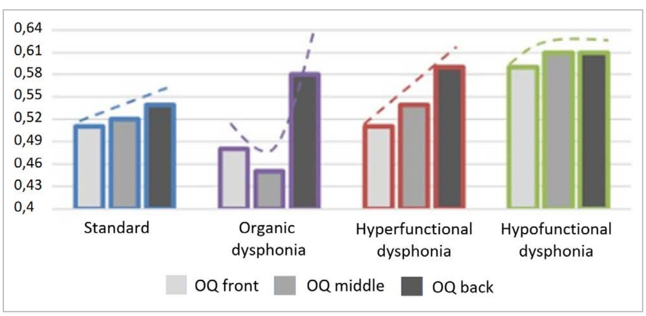

Fig. 4. Values for OQ_{VSK} from three parts in the control group and various types of dysphonia.

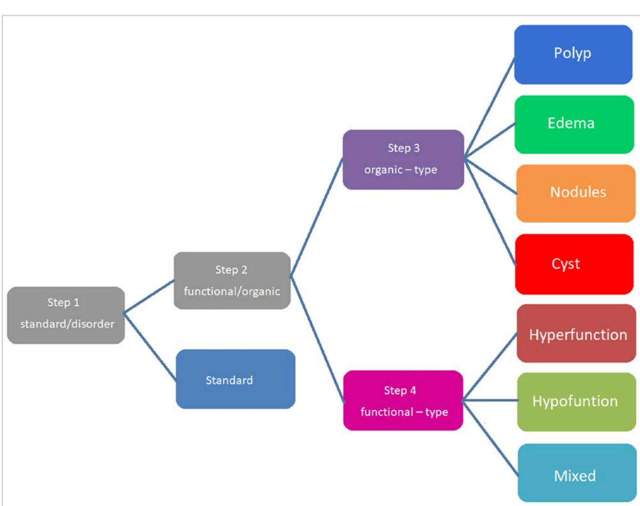

Fig. 5. Diagram of classification algorithm.

dy obtained so far for the most numerous material are close to the assumptions published by other authors.

Fig. 6. Results of classification with quantification of subjects studied and percentage share of correct classifications using an algorithm.

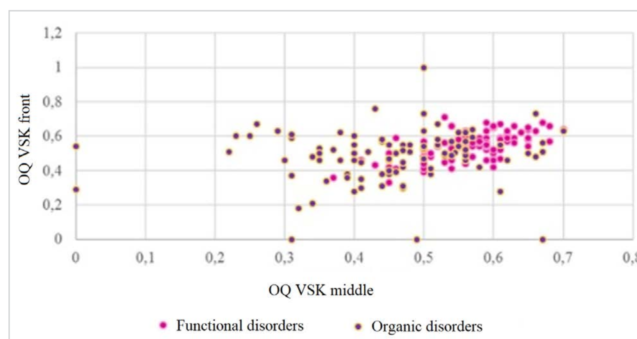

Fig 7. Distribution of values for OQ_{VSK} in the front and middle in patients with organic and functional voice disorders.

Results of the work show significant differences in OQ_{VSK} and QOQ_{EGG} coefficients not only between patients with functional dysphonia and euphonic patients, but also between different types of functional dysphonia. Subjects with hypofunctional dysphonia achieved significantly higher values of coefficients in relation to patients with hyperfunctional dysphonia.

Moreover, OQ_{VSK} and QOQ_{EGG} coefficients in organic dysphonias showed a different character from previously described functional dysphonias. In patients with vocal fold polyp, Reinke edema or cyst, a decrease in OQ_{VSK} was recorded relative to the control group. The decrease was most visible in the anterior and middle part of the vocal folds. QOQ_{EGG} values in these patients were not statistically different compared to the control group. An interesting result of the study are different tendencies of OQs in patients with vocal nodules in relation to other organic dysphonias [14].

Glottic characteristics in this group of patients resembled hy-

Tab. I. Steps of classification algorithm.

STEP 1	STEP 2	STEP 3	STEP 4
Differentiation of voice standard from dysphonia	Differentiation between organic and functional dysphonia	Differentiation of organic dysphonia type	Differentiation of functional dysphonia type
We recognize a disorder when at least one of the following conditions is met:	We recognize organic voice disorder when at least one of the following conditions is met:	We recognize the type of organic disorder based on the following conditions:	We recognize the type of functional disorder based on the conditions:
– OQ_{VSK} front, middle or back < 0.4 – OQ_{VSK} front, middle or back > 0.65 – QOQ_{EGG} > 0.6 – finding abnormality in LVS regarding regularity, amplitude or marginal shift	– OQ_{VSK} middle < 0.5 – OQ_{VSK} front < 0.4 – finding in LVS an increased amplitude and OQ_{VSK} front< 0.5	– increased amplitude -» Reinke's edema – OQ_{VSK} front, middle or back> 0.7 -» nodules – OQ_{VSK} front, middle or back <0.3 -» polyp – in women, when regularity of vibration is found in LVS -» nodules – In other cases -» polyp	– OQ_{VSK} front < 0.53 -» hyperfunction – increased amplitude -» hypofunction – OQ_{VSK} back> 0.6 and difference between max and min OQ_{VSK} front, middle or back < 0.1 -» hypofunction – In other cases -» hyperfunction
Sensitivity 91.4% specificity 79.2%.	Sensitivity 81.9% specificity 85.2%.		

Tab. II. AUC values for individual mucosal opening coefficients.

		OQ_{VSK}				QOQ_{EGG}
		FRONT	MIDDLE	BACK	AVERAGED	
Polyp	Classified from group of organic dysphonia	0,51	0,59	0,64	0,52	0,54
Edema		0,69	0,62	0,76	0,62	0,54
Nodules		0,64	0,53	0,63	0,62	0,53
Cyst		0,61	0,50	0,55	0,54	0,58
Hyperfunction	Classified from group of functional dysphonia	0,80	0,74	0,51	0,73	0,55
Hypofunction		0,78	0,78	0,62	0,79	0,62
Mixed		0,67	0,52	0,80	0,59	0,65
Standard	Classified from whole group	0,55	0,50	0,69	0,58	0,55

perfunctional dysphonia rather than other types of organic dysphonias. This fact is consistent with the belief that the cause of vocal fold nodules occurrence is chronic glottal hyperfunction [18]. In this pathology, organic and functional changes coexist with each other. The coexistence of different types of dysphonia is an issue requiring further careful analysis. The example of patients with vocal fold nodules shows that OQs in cases of coexisting types of dysphonia may suggest dominance of one of the components. This property may have a particularly practical application in choosing the right therapeutic process and monitoring the progress of rehabilitation [19,20].

The algorithm developed in this work shows that EGG and VSK may not only be a tool for monitoring the course of treatment, but also a valuable element in differential diagnosis. Own research comparing different types of software available for the analysis of VSK on the Polish market did not show any significant differences in the calculated OQ parameters [6]. The author tested DIVAS software (Xion Medical) and DiagnoScope Specialist software (Diagnova technologies). The average values of OQ measurements were comparable, despite the use of different measurement software.

The author believes that the use of modern software in processing LVS and EGG examinations gives the opportunity to objectify glottal function. A parametric description of the glottis should contain OQ_{VSK} results from at least three parts of the vocal folds (anterior, middle, posterior third), not as an average. Analysis of AUC showed that a single OQ cannot alone be a classification criterion.

The analysis of the results within dysphonia groups indicates that the coefficients measured from three parts of glottis have a much better classification value. According to the authors, OQ_{VSK} can be used in more complex classification algorithms.

In the algorithm presented in the paper, the QOQ_{EGG} value over 0.6 was one of the conditions differentiating euphony from dysphony. The literature shows that EGG – a simple and non-invasive test, can also be used in detecting risk groups of voice disorders [21]. In Jiang and Titze's opinion, the occurrence of increased contact of vocal folds in electroplottography suggests development of hyperfunctional disorders, which may become the basis for organic changes [21]. Observation of EGG features enables implementation of preventive actions. The results of this research indicate that numerical values of OQ obtained on the basis of LVS and EGG not only facilitate and improve the diagnosis of voice disorders but can also become a tool in everyday medical practice for monitoring voice disorders. Another benefit offered by parametrization of techniques for mucosal wave visualization is visual feedback. De Faria emphasized the importance of visualization of the patient's progress in the therapeutic process [22].

CONCLUSIONS

Combined with modern computer software, LVS and EGG offer the opportunity of objective analysis of glottal function. Apart from own studies, there are no data in the literature describing the use of QOQ_{EGG} and OQ_{VSK} to diagnose glottal function. As shown in the results of this work, OQ_{VSK} may constitute determinants of dysphonia type. VSK and EGG complement the existing tools of visual, acoustic and perceptual assessment used by voice scientists [18,23,24].

Further research might lead to a new protocol that employs OQ parameters to evaluate vocal fold status - a procedure that could facilitate the diagnosis and monitoring of voice disorders, and also provide a benchmark for comparing results between research centers.

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