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ORIGINAL ARTICLE

Mucosal wave measurements in the diagnosis of functional dysphonia

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 publication describes the characteristics of the glottis in FDs objectified by OQ, measured with VSK and EGG.

Aim: The aim of the study was to objectify glottal function in different types of FDs. The scope was to use open quotients gained from various mucosal wave imaging techniques for differential diagnosis of FDs.

Material and Method: The study included 204 individuals. In the study, each patient underwent otolaryngological and phoniatric examination. LVS, EGG and VSK were conducted, their results were recorded and stored using an EndoSTROB-DX--Xion GmbH (Berlin) device with DIVAS software.

Results: All patients with FDs had abnormalities in LVS. A statistical analysis showed differences in LVS characteristics according to the type of FD. The mean value of OQ_{VSK} was 0.521 in the control group and 0.565 in the study group ($P < 0.05$). Significant differences were found between patients with hypofunctional – 0.584 and hyperfunctional dysphonia – 0.55. The QOQEGG mean value in patients with FDs was 0.581 and in the control group 0.549 ($P < 0.01$). There were statistically significant differences between groups of patients with hyper- and hypofunctional dysphonias. Medians amounted to 0.574 and 0.604, respectively. Authors observed different relations of OQ with the type of FD. They decided to introduce a new parameter, illustrating the proportion of QOQ_{EGG}/OQ_{VSK}.

Conclusions: Videostrobokymographic and electroglottographic open quotients differentiate euphony from dysphony. The value of OQ_{VSK} and QOQ_{EGG} and their proportion varies depending on different types of functional dysphonias. The OQ_{VSK} and QOQ_{EGG} should be included in the diagnostic algorithm of voice.

KEYWORDS: electroglottography, functional dysphonia, mucosal wave, open quotient, videostroboscopy

ABBREVIATIONS

EGG – electroglottography
FDs – functional dysphonia
LS – laryngostroboscopy
LVS – laryngovideostroboscopy
OQ – open quotients
VFs – vocal folds
VSK – videostrobokymography

INTRODUCTION

Functional voice disorders are the result of improper voice production mechanisms [1]. Their cause is a multifactorial spectrum of pathological conditions causing pathological tension of the paralaryngeal musculature. FDs are found in 40% of patients presenting voice disorders [2]. Clinical practice guidelines on hoarsness and dysphonia published in 2018 by the American Academy of Otolaryngology-Head and Neck Surgery Foundation show that over the last several decades the percentage is stable [3]. The disorder is classified into primary and secondary forms depending on coexisting organic vocal fold pathologies or abnormal VFs movements during phonation [4]. Primary FD is associated with incorrect function of laryngeal muscles, while the morphology and mobility of the VFs remain unchanged [5]. It has the following subtypes:

- Hypofunctional dysphonia – characterized by decreased laryngeal muscle tension during phonation. LS reveals an increased amplitude. Furthermore, uneven vibrations might occur causing irregularity in LS. The open phase of the VFs is extended [6];
- Hyperfunctional dysphonia (synonymous term for muscle tension dysphonia) – characterized by excessive laryngeal muscle tension during phonation [1]. This type of voice disorder is the most common among FDs [7]. LS reveals a decreased amplitude. Mucosal wave is reduced, expiring. Vibrations occur only on the free edges of the VFs;

- Mixed-type FD combines components of hypo- and hyper-FD, or the type of voice disorder changes its character over time. Hypo-FD with the elements of hyperfunction, is a condition in which a patient compensates insufficiency of the glottis with excessive tension of the VFs. Hyperfunction of other parts of the vocal tract might be also involved. This type of dysphonia may lead to compensatory hypertrophy of vestibular folds, and an intense closing phase in the membranous part of the VFs. Another type of mixed-type FD is hyperfunctional dysphonia with elements of hypofunction. In this type, symptoms of hyperfunction are first observed. Excessive tension of the VFs causes muscle fatigue, which results in secondary hypofunction.

According to the literature laryngoscopy findings alone may not distinguish patients with FD from normal subjects and should be only a part of a diagnostic evaluation [8]. New methods are sought for objective measurements of the voice [9, 10]. The publication describes the characteristics of the glottis in FDs objectified by OQ, measured with VSK and EGG. The results obtained in FDs have not been published yet in the literature. The combination of EGG and VSK used by the authors in the voice study protocol is a unique value of the work.

AIM

The aim of the study was to objectify glottal function in different types of FDs. The scope was to use open quotients gained from various mucosal wave imaging techniques for differential diagnosis of FDs.

MATERIAL AND METHOD

The material of the work included 204 individuals aged 20–60 years. The study group comprised 103 patients with functional voice disorders treated in the Audiology and Phoniatric Clinic. The group included patients with hypo-, hyper- and mixed-type FD. There were 65 individuals (60 women, 5 men) with hyper-FD, 29 individuals (19 women, 10 men) with hypo-FD and 9 individuals (6 women, 3 men) diagnosed with mixed-type FD. Fig. 1. shows the percentage of patients with different types of FD in the study group. It was observed that in the population of patients with FD there were significantly more women than men. The control group included 101 healthy volunteers who signed a consent to participate in the research. The subjects were non-smokers, non-professional voice users, without vocal complaints. The group was balanced in terms of gender and age in relation to the study group. The study design was approved by the Bioethics Committee.

In the study, each patient underwent otolaryngological and phoniatric examination. LVS and EGG were conducted, their results were recorded and stored using an EndoSTROB-DX-Xion GmbH (Berlin) device with DIVAS software. Patients were recorded during prolonged, comfortable phonation of [e]. DIVAS software calculated OQ on the basis of kymograms and electroglottograms. The coefficients describing the behavior of the glottis as a function of time were introduced by Sonesson and published in 1960

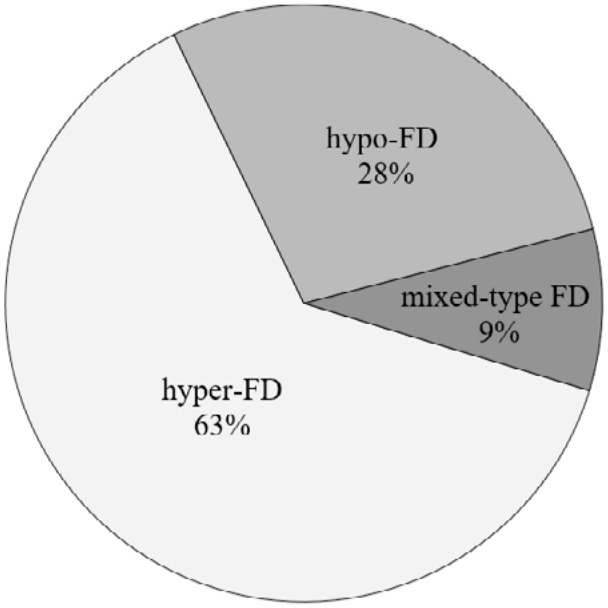

Fig. 1. The percentage of patients with different types of FD in the study group.

Tab. I. Mean values and medians of OQ_{VSK} in patients with normal voice and functional dysphonia.

	ANTERIOR ⅓		MIDDLE ⅓		POSTERIOR ⅓		AVERAGED	
Control Group	Mean value OQ_{VSK}							
	0.507		0.524		0.533		0.521	
	SD = 0.047		SD = 0.051		SD = 0.075		SD = 0.045	
	Median OQ_{VSK}							
	0.51		0.52		0.53		0.52	
	Min	Max	Min	Max	Min	Max	Min	Max
	0.38	0.66	0.41	0.64	0.35	0.77	0.43	0.63
Study Group	Mean value OQ_{VSK}							
	0.542		0.562		0.591		0.565	
	SD = 0.082		SD = 0.067		SD = 0.07		SD = 0.055	
	Median OQ_{VSK}							
	0.54		0.58		0.605		0.57	
	Min	Max	Min	Max	Min	Max	Min	Max
	0.33	0.71	0.37	0.7	0.4	0.72	0.42	0.67

[11]. The OQ is defined as the time the VFs are separated from each other divided by the duration of the whole glottal cycle. Kymograms were made from LVS recordings (VSK) from the anterior, middle and posterior third of the membranous portion of the glottis (Fig. 2., 3.) [12]. The grade of EGG regularity was assessed according to the 3-degree Titze scale [13].

DIVAS software calculated OQ_{VSK} and EGG quasi open quotient – QOQ_{EGG} from a selected cycle on a kymogram. In the software the VSK cycles are marked manually by the researcher. OQ_{VSK} and QOQ_{EGG} are calculated automatically. The EGG module calculates also the sound pressure level in dB (dB SPL) for each cycle.

For a statistical analysis of parameters obtained in the work, the following tests were used: Chi-square test, Mann-Whitney test, Significance test, Pearson correlation and Spearman correlation. The level of statistical significance was set at $P < 0.05$.

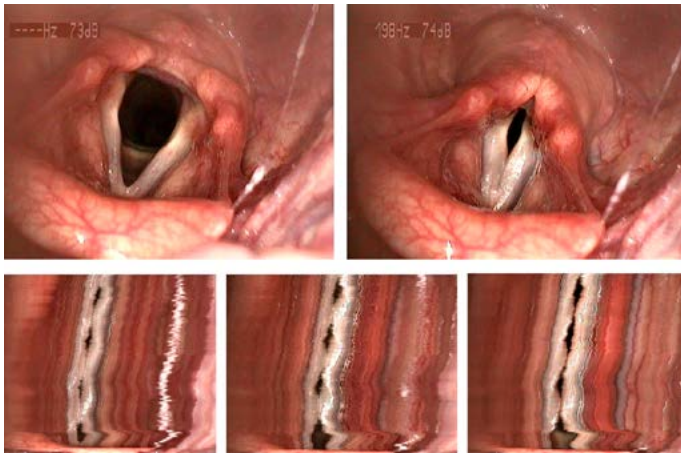

Fig. 2. LVS view of an open and fully closed glottis and kimograms made from the anterior middle and posterior part of the glottis in a patient with hiper-FD. OQ_{VSK} was respectively 0.44; 0.5; 0.72.

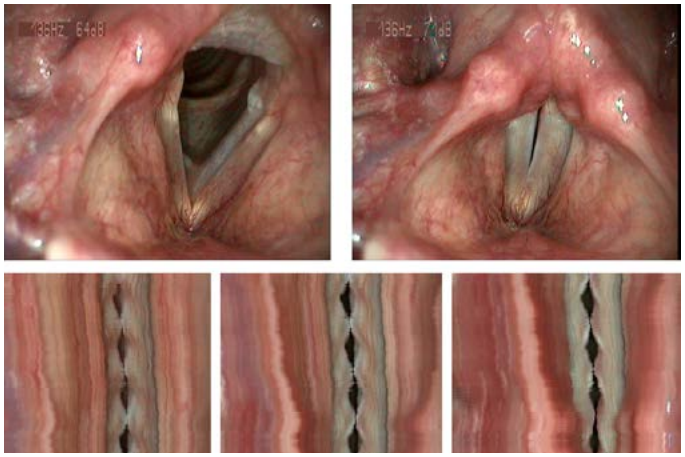

Fig. 3. The LVS view of an open and fully closed glottis and kimograms made from the anterior middle and posterior part of the glottis in a patient with hypo-FD. The OQ_{VSK} was respectively 0.59; 0.62; 0.65.

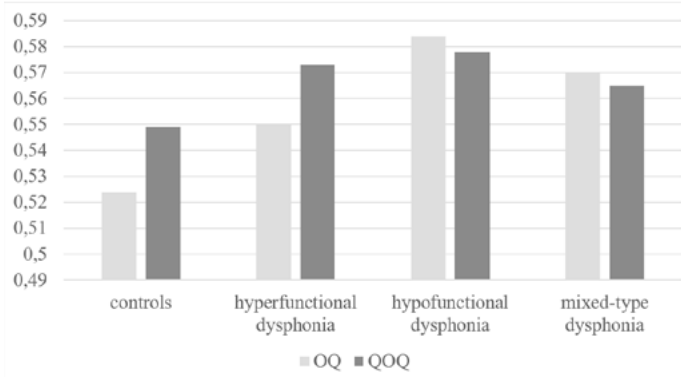

Fig. 4. The QOQ_{EGG} and averaged OQ_{VSK} mean values in the control group and patients with different types of functional dysphonia.

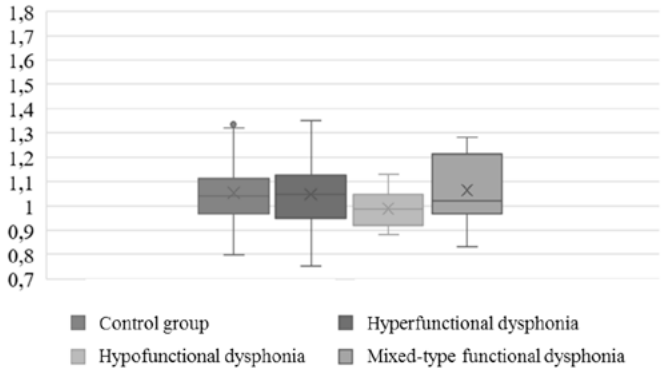

Fig. 5. Distribution ratio of QOQ_{EEC}/OQ_{VSK} in patients from the control group and different kinds of FD.

RESULTS

Detailed characteristics of the control group were published in a previous publication [14]. The mean age in the study group was 46.4 years (standard deviation SD = 13.1), for women 46 years (SD = 14) and for men 48 years (SD =11.8). Median age was 46 years (min 20, max 60), for women 46 years (min 20, max 60) and for men 50 years (min 21, max 60). The mean sound pressure level in the study group was 78.2 dB (SD = 3.3 dB), which did not differ the study group from the control group.

Mean age in case of patients with hyperfunctional dysphonia was 43.1 years (SD = 8.5), in patients with hypofunctional dysphonia 51.7 years (SD = 7.1) and in patients with mixed-type dysphonia 54 years (SD = 10). Median age in case of patients with hyperfunctional dysphonia was 46 years (min 21, max 60), in patients with hypofunctional dysphonia 53 years (min 45, max 60) and in patients with mixed-type dysphonia 54.5 years (min 49, max 60).

LVS RESULTS

All patients with FDs had abnormalities in LVS. In patients with hyperfunctional dysphonia irregular vibrations were found in 4 subjects, reduced amplitude in 61, reduced mucosal wave in 61 and incomplete glottal closure in 49 patients. In patients with hypofunctional dysphonia irregular vibrations were found in 3 subjects, increased amplitude in 26 and incomplete glottal closure in 26 patients. In patients with mixed-type FD irregular vibrations were not found, reduced amplitude was found in 4 patients, increased amplitude in 5, reduced mucosal wave in 4 and incomplete glottal closure in 6 patients.

The statistical analysis showed differences in LVS characteristics according to the type of FD. The Chi-square test showed differences between hyperfunctional and hypofunctional dysphonia in terms of amplitude and mucosal wave size. Increased amplitude appeared only in patients with hypofunctional dysphonias. Reduced mucosal wave was more frequently found in patients with hyperfunction. No statistically significant differences were found in patients with the mixed type compared to other types of FDs.

VSK RESULTS

Two patients were excluded from further analysis because of conditions that did allow for the calculation of OQ_{VSK} (due to incomplete glottal closure of the parameter and irregular vibrations). Further 6 were excluded due to irregularities in EGG making the calculation of QOQ_{EGG} impossible.

Tab. II. OQ_{VSK} results in different types of functional dysphonia's.

	ANTERIOR ⅓		MIDDLE ⅓		POSTERIOR ⅓		AVERAGED	
Hyperfunctional dysphonia	OQ_{VSK} mean value							
	0.513		**0.544**		0.592		**0.55**	
	SD = 0.078		SD = 0.066		SD = 0.065		SD = 0.051	
	OQ_{VSK} median							
	0.52		**0.55**		0.6		**0.55**	
	Min 0.33	Max 0.71	Min 0.37	Max 0.7	Min 0.4	Max 0.72	Min 0.42	Max 0.67
Hypofunctional dysphonia	OQ_{VSK} mean value							
	0.577		**0.586**		0.568		**0.584**	
	SD = 0.059		SD = 0.044		SD = 0.062		SD = 0.041	
	OQ_{VSK} median							
	0.59		**0.61**		0.63		**0.613**	
	Min 0.47	Max 0.68	Min 0.51	Max 0.68	Min 0.45	Max 0.72	Min 0.53	Max 0.67
Mixed-type functional dysphonia	OQ_{VSK} mean value							
	0.582		**0.552**		0.507		0.547	
	SD = 0.064		SD = 0.074		SD = 0.083		SD = 0.058	
	OQ_{VSK} median							
	0.59		**0.575**		0.505		0.553	
	Min 0.5	Max 0.68	Min 0.4	Max 0.63	Min 0.5	Max 0.68	Min 0.4	Max 0.63

The Mann-Whitney test showed no relations between the values of OQ_{VSK} and LVS parameters, apart from the amplitude size in patients with hypo-FD. Patients with hypofunction, who had an increased VF amplitude, gained higher OQ_{VSK} values from each part of the glottis. The OQ_{VSK} and QOQ_{EGG} differed patients with different types of functional dysphonias (Fig. 4.). Mean values and medians of OQ_{VSK} in the control and study group are shown in Tab. I. There were statistically significant differences ($P < 0.05$) between the control and the study group in OQ_{VSK} measured from all parts of the vocal folds and averaged results. The OQ_{VSK} values in different types of FD are shown in detail in Tab. II. Significant differences were found between patients with hypofunctional and hyperfunctional dysphonia for parameters measured from the anterior and middle third and averaged values. No differences were found between patients with hyper- and hypo-FD and patients with mixed-type FD. The parts of VF in which statistically significant differences were found in comparison to the control group are bolded in Tab. II.

EGG RESULTS

Unreadable EGG (third degree according to the Titze classification) was found in 4 patients with hyperfunctional dysphonia, 2 patients with hypofunctional dysphonia and 2 patients with mixed-type dysphonia. The second type according to Titze was found in 13 patients with hyperfunctional dysphonia, 6 patients with hypofunctional dysphonia and 2 patients with mixed-type dysphonia. No relation existed between the amount and type of abnormal findings in LVS and the degree of EGG regularity according to Titze.

The QOQ_{EGG} mean value in patients with FDs was 0.581 (SD = 0.051), median 0.585 (min 0.31; max 0.85). There was a statistically significant difference between the control and the whole study group in QOQ_{EGG} ($P < 0.001$). A corelation was observed between incomplete glottal closure and QOQ_{EGG} value. The corelation was not significant ($P = 0.07$). Higher values of QOQ_{EGG} were observed in patients having incomplete glottal closure. Mean values and medians of QOQ_{EGG} in different types of dysphonias are shown in Tab. III. There were statistically significant differences between groups of patients with hyper- and hypofunctional dysphonias in terms of QOQ_{EGG} values ($P < 0.05$). QOQ_{EGG} parameters measured in the groups differed significantly from those obtained from the control group. The level of statistical significance was $P < 0.05$ for hyperfunction and $P < 0.01$ for hypofunction. Authors observed different correlations between OQ and the type of FD. As shown in Fig. 4., in cases of hyper- and mixed-type FDs, parameters grow proportionally in comparison to the control group. Patients with hypo-FD show a higher increase of OQ_{VSK}. Authors decided to introduce a new parameter, illustrating the proportion of QOQ_{EEG}/OQ_{VSK}. The results of the proportion were 1.03 in the control group, 1.05 in hyper-FD, 0.99 in hypo-FD, 1.06 in mixed-type FD. Fig. 5. shows a distribution ratio of QOQ_{EEG}/OQ_{VSK}. The analysis of the QOQ_{EGG} and OQ_{VSK} proportion (QOQ_{EEG}/OQ_{VSK}) showed significant differences between the control group and patients with hypofunction. The results of the work have proven that the coefficients QOQ_{EGG}, OQ_{VSK} and their proportion $-QOQ_{EEG}/OQ_{VSK}$ give an accurate, objective characteristics of FDs. Moreover, the parameters differentiate patients with FD from those with normal voice, as well as patients with various types of FDs.

DISCUSSION

There are no data in the literature on the application of QOQ_{EGG} and OQ_{VSK} in the diagnostics of FD. As shown in the results of this

work, OQ_{VSK} and QOQ present accurate characteristics of FD. Higher values of OQ_{VSK} (measured from the anterior and middle third and averaged values) and QOQ_{EGG} were found in patients with hypofunctional dysphonia, as compared to patients with hyperfunctional dysphonia. Furthermore, the increase of was signifficantly higher in patients with hypo-FD. The results of the LVS performed in this research confirmed previous observations published by other authors [15]. The assessment of the mucosal wave and amplitude constitute LVS features describing best the differences in the type of FD. Reduced mucosal wave was more often found in subjects with hyperfunctional dysphonia. The increased vocal fold amplitude was observed only in patients with hypofunctional dysphonia.

According to the literature, the diagnosis of FD based only on the LVS is insufficient [14]. Moreover, the LVS interpretation depends on the experience of the researcher [16]. Undeniably the LVS is a standard procedure used in the diagnostics of FD, as it excludes the organic cause of the disease.

Cohen et al. analyzed the medical history of 55 million individuals diagnosed by primary care physicians [17]. The prevalence of dysphonia in the studied population was 1%. Roy showed that nearly 30% of people experienced problems with their voice [18]. More than 20% of the group reported chronic dysphonia. Among the diagnostic tools of the larynx, LVS is considered to be a gold standard. Due to the wide availability of LVS, it is necessary to seek measures objectifying the examination [16]. The existing correlation between the type of FD and the value of OQ_{VSK} proved in this work, reinforces the LVS position as the most powerful diagnostic tool in clinical practice.

As previously mentioned, there are no reports in the literature on the combination of EGG and VSK in FD diagnostics. Wendler observed similar tendencies of parameter value change during LS and EGG [19]. The range of OQ_{LS} values was smaller than the range of OQ_{EGG}. Wendler also observed changes in OQ_{LS} with different levels of voice intensity. In hyperfunctional dysphonias the OQ_{LS} were low during comfortable phonation and decreased during forced phonation. The author did not observe changes in OQLS in patients with hypofunctional dysphonias. The ability to differentiate the nature of FD on the basis of EGG has also been described by Hacki [20]. The author observed decreasing values of QOQ_{EGG} with the increase of the sound pressure level in euphonic people and patients with hyperfunctional dysphonia. He observed an inverse relationship in patients with hypofunctional dysphonia – the QOQ_{EGG} increased with the increase of sound pressure level [21]. In the results of our work, we observed no differences in the level of comfortable phonation between the control and the study group or between patients with different types of FDs.

Difficulties in interpretation involved the group of patients with mixed-type FD. The group consisted of only 9 people. The small size of the group stemmed from a low occurrence of this type of dysphonia in the general population. What is more, the group is heterogenic. No statistically significant differences were found in the group, as compared to patients with hyper- or hypo-FD. It is necessary to analyze a larger group of people with this type of voice disorder, distinguishing the subtypes of dysphonia.

Tab. III. Mean values and medians of QOQ_{EGG} in different types of dysphonia's.

Control group	QOQ_{EGG} mean value	
	0.549	
	SD = 0.044	
	QOQ_{EGG} median	
	0.545	
	Min 0.35	Max 0.71
Hyperfunctional dysphonia	QOQ_{EGG} mean value	
	0.573	
	SD = 0.056	
	QOQ_{EGG} median	
	0.574	
	Min 0.31	Max 0.85
Hypofunctional dysphonia	QOQ_{EGG} mean value	
	0.578	
	SD = 0.035	
	QOQ_{EGG} median	
	0.604	
	Min 0.47	Max 0.81
Mixed-type functional dysphonia	QOQ_{EGG} mean value	
	0.565	
	SD = 0.057	
	QOQ_{EGG} median	
	0.59	
	Min 0.41	Max 0.57

There are no reports in the literature concerning vocal fold mucosal wave characteristics using the VSK, VLS and EGG. There are also no publications using OQ parameters from the mentioned methods, to objectify glottal function.

The results of the work prove a relationship between the type of FD and objective parameters gained from LVS, VSK and EGG. Further research should be undertaken to create a module of vocal fold evaluation, using OQ parameters, that could be used in the diagnostics and monitoring of dysphonias.

CONCLUSIONS

1. VSK and EGG open quotients differentiate euphony from dysphony;
2. The value of OQ_{VSK} and QOQ_{EGG} and their proportion varies depending on different types of functional dysphonias;
3. The OQ_{VSK} and QOQ_{EGG} should be included in the diagnostic algorithm of voice.

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