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REVIEW ARTICLE

Stroboscopic assessment of unilateral vocal fold paralysis: a systematic review

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Abstract

Purpose To review the relevant basic stroboscopic evaluations in unilateral vocal fold paralysis (UVFP). Our aim was twofold: (1) to determine the frequency of use of stroboscopic parameters in outcome evaluation after surgical treatment of UVFP using a Pareto diagram; and (2) to select the most relevant parameters in terms of a significant difference between pre- and post-surgical intervention for UVFP.

Methods A systematic review in PUBMED includes studies on stroboscopic evaluation in combination with UVFP and surgical treatment. The review was limited to English studies published between 1990 and March 2018. The most frequently used stroboscopic parameters were identified using a Pareto diagram. Then, 'the percentage of significance' for the most frequently stroboscopic parameters was identified by comparing the number of studies that showed a statistically significant change in pre- and post-treatment results with the total number of studies using the same parameters.

Results Seven stroboscopic parameters were nominated using the Pareto diagram. In decreasing order of citation frequency, periodicity, edge bowing, mucosal wave, glottic gap, position of vocal fold, amplitude, and symmetry have respective percentages of significance of 87.5%, 83.3%, 77.7%, 64.5%, 60%, 57.1%, and 50%. Five pertinent scales were selected for the most frequent and significant stroboscopic parameters**.**

Conclusions The results indicate that periodicity, edge bowing, mucosal wave, glottic gap, and position of vocal fold represent the five most frequently used and relevant stroboscopic parameters in UVFP evaluation. The current review outlines a proposal scale of these stroboscopic parameters.

PROSPERO registration number CRD42019126786

Keywords Videolaryngostroboscopy · Unilateral vocal fold paralysis · Medialization laryngoplasty · Injection laryngoplasty · Stroboscopic parameters

Introduction

Unilateral vocal fold paralysis (UVFP) is a result of vagus nerve or recurrent laryngeal nerve injury. UVFP leads to various degrees of glottic insufficiency, which could include a weak and breathy voice and dysphagia. A wide variety of interventional options are available for the management of UVFP, including medialization thyroplasty, injection laryngoplasty, arytenoid adduction, and laryngeal reinnervation. Multiple studies show favorable outcomes, but no significant differences were found between treatment arms based on perceptual, acoustic, quality of life, and laryngoscopic outcomes [1].

Despite the fact that videolaryngostroboscopy (VLS) provides direct anatomical and functional assessment of underlining vocal disorders, it is rarely used as a treatment outcome measure in the research articles [2]. The rarity of using the VLS may be due to a lack of standardized, validated, and reliable assessment protocol of voice parameters and scales [3].

The most common laryngoscopic findings beyond vocal fold motion impairment include bowing, incomplete glottal closure, and phase asymmetry on VLS [4].

The primary aim of this review was to determine the frequency of the stroboscopic parameters utilized in evaluating

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the outcome after surgical treatment of UVFP using a Pareto diagram. The secondary aim was to select the most relevant parameters in terms of a significant difference between pre- and post-surgical intervention of UVFP.

Methods

This systematic review was completed in accordance with Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines. The methods of this review have been registered with the International Prospective Register of Systematic Reviews (PROSPERO), number CRD42019126786. We performed an electronic search on PUBMED using the following keywords in medical subject headings (MeSH): {[(stroboscopy OR laryngostroboscopy OR strobolaryngoscopy OR videostroboscopy OR videolaryngostroboscopy OR stroboscopic parameters) AND unilateral vocal fold paralysis] AND treatment OR medialization laryngoplasty OR medialization thyroplasty OR injection laryngoplasty} between 1990 and December 2018.

The assessment proceeded through examining the title, abstract and body of the paper. The two reviewers (ZB) and (LCB) independently assessed each paper. Disagreements between the reviewers were resolved through discussion. The inclusion criterion was stroboscopic outcome assessment after surgical treatment of unilateral vocal fold paralysis. The exclusion criteria were as follows: meta-analysis, case series, and studies on unspecific surgical interventions, papers not in English, and nonhuman studies. Six hundred forty-eight studies were selected after database searching. One hundred thirty-three nonhuman studies were excluded. Fifty-seven non-English studies were excluded. Abstracts of the remaining 458 studies were reviewed. One hundred fifteen of these articles were selected for extensive reading. Thirty-nine articles met the inclusion criteria and were analyzed (Fig. 1, flowchart of article selection). The assessment protocol developed by the Hawker checklist was used for evaluating the risk of bias in objectively reviewing the qualitative criteria of the research papers (Table 1).

Analysis

The total frequency of use of each stroboscopic parameter was classified in descending order (Table 2). A Pareto diagram (Fig. 2) that combines bars showing individual values in descending order and a line graph showing the cumulative percentage of data was drawn. Using the Pareto diagram, the most frequently used stroboscopic parameters, accounting for 80% of the total stroboscopic signs, were identified. For these most frequently stroboscopic signs, the number of studies that showed a

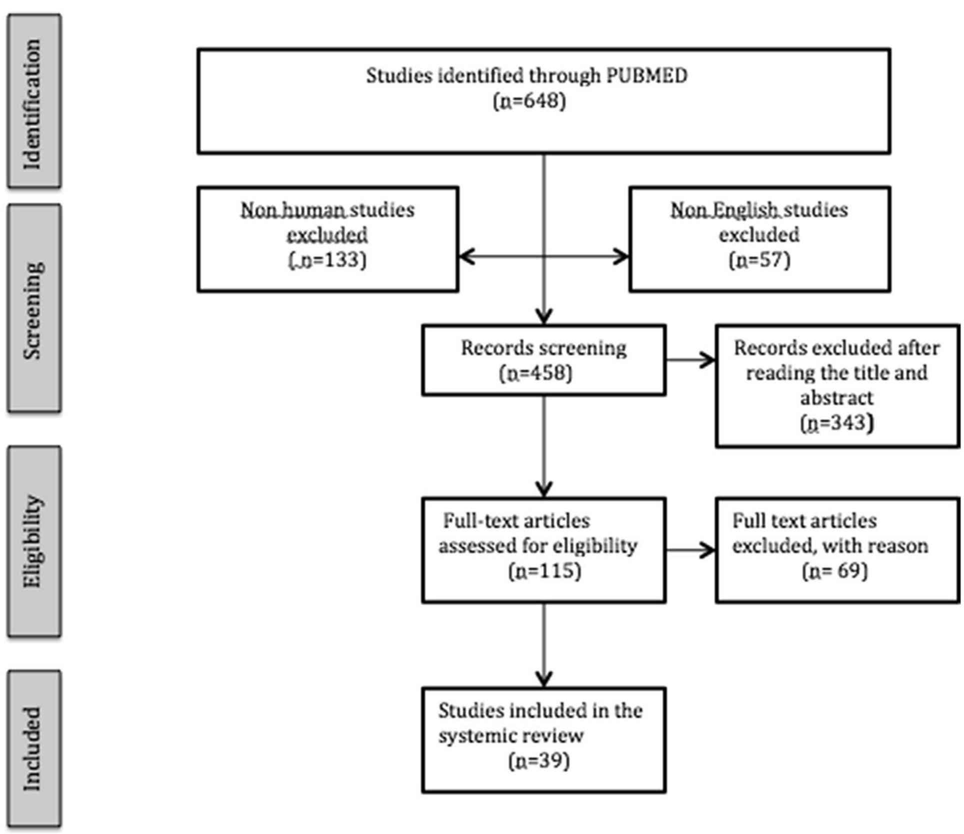

Fig. 1 Flowchart of article selection

Table 1 Evaluating the risk of bias in included studies using the Hawker checklist

		1	2	3	4	5	6	7	8	9	Total	Quality
1	Wang et al. [4]	4	4	4	3	4	4	4	4	3	34	High
2	Lee and Park [14]	4	4	4	3	4	4	4	4	4	35	High
3	Li et al. [16]	4	4	4	3	3	4	4	4	4	34	High
4	Lim et al. [17]	3	4	4	3	3	4	3	4	4	32	High
5	Kodama et al. [18]	4	4	4	3	4	4	4	3	3	33	High
6	Pagano et al. [19]	3	4	4	3	4	2	4	3	3	30	Moderate
7	Rudolf and Sibylle [20]	3	4	4	3	3	4	4	4	2	31	High
8	Hagemann and Seifert [21]	3	3	4	3	3	4	4	4	2	30	Moderate
9	Bergamini et al. [22]	3	3	4	3	3	1	4	3	2	26	Moderate
10	Reijonen et al. [23]	3	4	4	3	4	4	3	3	2	30	Moderate
11	Cheng et al. [24]	3	2	4	3	4	1	4	3	4	28	Moderate
12	Storck et al. [25]	4	3	4	3	4	4	4	3	2	31	High
13	Li et al. [26]	4	4	4	3	4	1	4	3	3	30	Moderate
14	Van Ardenne et al. [27]	4	4	4	3	4	4	4	3	3	33	High
15	Vinson et al. [28]	4	4	4	3	4	4	4	4	2	33	High
16	Arviso et al. [29]	4	4	4	3	4	4	4	4	2	33	High
17	Schwarz et al. [30]	4	4	4	3	4	4	3	3	2	31	High
18	Wang et al. [31]	4	4	4	4	4	4	4	4	2	34	High
19	Thompson et al. [32]	3	4	3	3	3	2	4	3	2	27	Moderate
20	Pearl et al. [33]	3	4	4	3	4	3	4	3	2	30	Moderate
21	Rihkanen et al. [34]	4	4	4	4	4	4	4	3	2	33	High
22	Uloza et al. [35]	4	3	3	2	4	1	4	3	3	27	Moderate
23	Milstein et al. [36]	4	4	4	3	4	4	4	4	4	35	High
24	Morgan et al. [37]	4	4	4	3	4	4	4	4	3	34	High
25	Lu et al. [38]	3	3	4	3	4	1	4	3	4	29	Moderate
26	Lundy et al. [39]	4	3	4	4	4	1	4	4	2	30	Moderate
27	Karpenko et al. [11]	4	4	4	3	4	4	4	4	4	35	High
28	Lee et al. [40]	4	4	4	3	4	4	4	3	2	32	High
29	Su et al. [12]	4	4	4	4	4	4	4	3	3	34	High
30	Halderman et al. [41]	4	4	4	4	4	4	4	3	2	33	High
31	Lorenz et al. [42]	4	3	4	3	4	4	4	4	2	32	High
32	Chhetri et al. [43]	3	3	4	3	4	2	4	4	3	30	Moderate
33	Woo et al. [44]	4	3	4	4	4	4	4	3	3	33	High
34	Malik et al. [45]	4	2	3	3	4	4	3	3	2	28	Moderate
35	Su et al. [46]	4	4	4	3	4	4	4	3	2	32	High
36	Wang et al. [47]	4	4	4	4	4	4	4	3	3	33	High
37	Storck et al. [48]	4	4	4	3	4	2	4	3	2	30	Moderate
38	Schneider et al. [49]	4	4	4	3	4	2	4	3	3	31	High
39	Li et al. [50]	4	4	4	4	4	4	4	4	2	34	High
	Questions scores:	Values of the scores: 1–4	Quality of the scores:									
	Abstract and title											
	Introduction and aims		> 30: high quality									
	Method and data											
	Sampling	Total: maximum 36, minimum 9	18–30: moderate quality									
	Data analysis											
	Ethics and bias		< 18: low quality									
	Findings/results											
	Transferability/generalizability											
	Implications and usefulness											

Table 2 The most frequent stroboscopic parameters used in the literature, their percentage of use, and the cumulative percentage

Stroboscopic parameters	Frequency	Percentage	Cumulative percentage
Glottic gap	31	32.63	32.63
Symmetry	10	10.53	43.16
Mucosal wave	9	9.47	52.63
Regularity	8	8.42	61.05
Amplitude	7	7.37	68.42
Edge bowing	6	6.36	74.74
Position of VF	5	5.26	80
Open phase duration	3	3.16	83.16
VF vibration	2	2.11	85.26
Arytenoid position	2	2.11	87.37
Glottic vertical	2	2.11	89.47
Nonvibratory location	2	2.11	91.58
Glottic shape	1	1.05	92.63
VF motility	1	1.05	93.68
MTP	1	1.05	94.74
Glottic gap mean	1	1.05	95.79
Vestibular fold	1	1.05	96.84
Supraglottic effort	1	1.05	97.89
Reaction	1	1.05	98.95
Scarring	1	1.05	100
Granuloma	1	1.05	101.05
	95	100	

VF vocal fold, *NGGA* normalized glottal gap area

statistically significant change in pre- and post-treatment results ($p \leq 0.05$) was compared to the total number of studies using the same stroboscopic signs; this portion was expressed in a percentage. This percentage was identified as 'percentage of significance' and used to assess changes of each stroboscopic parameter as shown in Table 3.

The most frequently used scale of each parameter was assessed by measuring the number of the studies that showed the percentage of significance between pre- and post-surgical management with the total number of studies using the same stroboscopic scale.

Results

Our search identified 648 articles, and 39 studies met our inclusion criteria [4, 11, 12, 14, 16–50]. According to the Hawker checklist for the assessment of relevance and risk of bias, 69.2% of studies were rated as high quality and 30.7% as moderate quality (Table 1). The mean follow-up period was 14 months, and the median was 6 months. In the different articles, the sample size ranged from 10 to 349 participants, with an average of 45 participants (median = 27) recruited for the studies. The most frequent etiology of UVFP was iatrogenic (64%), followed by idiopathic (20.5%) and oncological (5.1%) causes (4 studies did not mention the causes). Only 6 of 39 studies mentioned the position of the vocal fold before medialization intervention. The most frequent position was paramedian (64.77%), followed by intermediate (34.33%), lateral (16.90%), and median (4.96%). In terms of surgical treatment, 4 main categories of interventions emerged from the included articles. The most common intervention categories were injection laryngoplasty (13 studies), thyroplasty (5 articles), and re-innervation (8 studies); 5 studies were included combined techniques, and 8 studies compared multiple types of interventions.

Concerning the stroboscopic examination, the rigid endoscope was used in 20 studies, while the flexible fiberscope was used in 3 studies. Three studies had mixed use of either a rigid or flexible fiberscope, and 13 studies did not mention the type of endoscope.

Stroboscopic examination was performed before and after surgery. The mean follow-up period between pre- and postoperative stroboscopic examinations was 5 months, and the median was 3 months.

The stroboscopic protocol was mentioned in 20 studies (51.2%). Fourteen studies used sustained /i/ or /e/ with comfortable pitch and loudness. Three studies used /i/, /e/, and /u/ with a variety of phonatory conditions, including low, comfortable, and high pitches and intensities. Two studies used conversational speech with habitual pitch and intensity. One study used sustained phonation produced at various frequencies and intensities with pseudo-phonatory tasks, including whispering and laughing, to evaluate the non-speech motility of the glottis.

Table 2 shows the 21 most reported stroboscopic parameters in descending order of frequency in the review of the 39 studies. The selection of 7 out of 21 parameters depends on the Pareto diagram, which is a simple bar chart that ranks related measures in decreasing order of occurrence. The basic underlying rule behind the Pareto principle (80/20 rule) is that 80% of the effects come from 20% of the causes. The seven parameters selected are located below the cross point of the graphic line of 80% cumulative percentage and the bar chart of the frequency of stroboscopic parameters.

Figure 2 demonstrates the seven stroboscopic parameters that were identified using the Pareto diagram. In decreasing order of frequency of citation, these were periodicity, edge bowing, mucosal wave, glottic gap or glottic closure, position of vocal fold, amplitude, and symmetry, which have respective percentages of significance of 87.5%, 83.3%, 77.7%, 64.5%, 60%, 57.1%, and 50%.

Table 4 represents the frequency and percentage of significance of various scales utilized for the assessment of

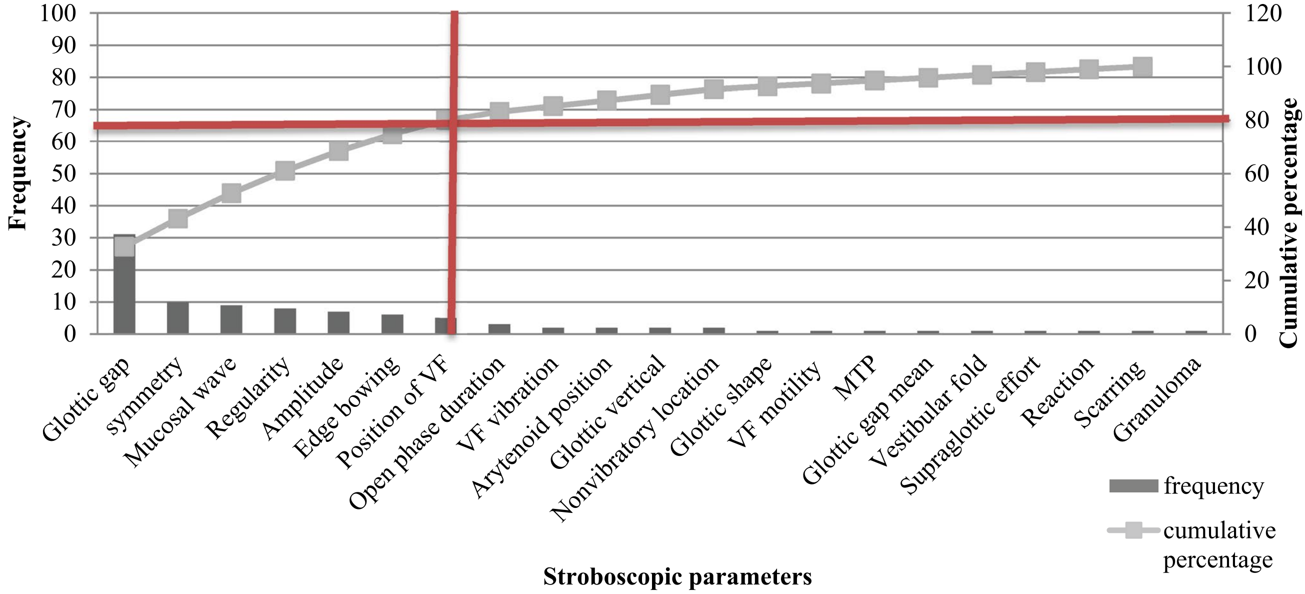

Fig. 2 The Pareto diagram of all stroboscopic parameters. VF: vocal fold, NGGA: normalized glottal gap area, MTP: muscle tension dysphonia

Table 3 Proportion of the studies showing significant results ($p \leq 0.05$) between the preoperative and postoperative assessment for the stroboscopic parameter selected by the Pareto diagram

Stroboscopic sign	*P* value ≤ 0.05	% Significance
1-Periodicity	7/8 (1NS; 0 NA)	87.5%
2-Edge bowing	5/6 (1NS; 0 NA)	83.33%
3-Mucosal wave	7/9 (2NS;0NA)	77.7%
4-Glottic closure or gap	20/31 (11NS; 0NA)	64.51%
5-Position of vocal fold	3/5 (2NS; 0 NA)	60%
6-Amplitude	4/7 (2NS; 1 NA)	57.14%
7-Symmetry	5/10 (3NS; 2NA)	50%

NS not significant, *NA* not available

each of the five stroboscopic parameters that were selected by the Pareto diagram and shows significant differences after medialization surgeries.

The result of the current literature review outlines a proposal protocol scale of the most frequent and significant stroboscopic parameter measures that reveal significant differences after medialization surgeries as listed in (Table 5).

Discussion

Videolaryngostroboscopy

This study is a review of the literature on the stroboscopic evaluation in UVFP. For voice evaluation, several agreements and consensuses have been published on voice measures, such as perception, acoustics, aerodynamics, and self-evaluation [5, 6]. Although videolaryngostroboscopy is part of the usual laryngeal examination for anatomical and functional assessment, it is still rarely described in the literature due to difficulties in the comparison of outcomes and interpretation of results across studies, probably because of a lack of standardized parameters with equivocal definitions of the VLS parameters and the unclear correlation of changes in these parameters and the clinically meaningful improvement [5]. In addition, voice treatment studies do not commonly use VLS to evaluate post-intervention outcome, even though an initial stroboscopic evaluation is usually performed on the participants before their enrolment in the study [3]. Our study intended to focus on the parameters used for describing the videolaryngostroboscopic evaluation before and after surgical management of UVFP. VLS remains a valuable diagnostic technique that provides information about the nature of the glottic vibration and the visual images that facilitate the diagnostic analysis and enables a comparative study [2]. VLS findings were considered useful in 92% of cases as reported by Remacle [7] in his study of 732 patients. Some of the limitations of using VLS are directly linked to the training and skills of the operator that relay visual judgment with a lack of rigor in methodology and low inter-rater reliability in evaluating the stroboscopic parameters [2].

Videolaryngostroboscopy is a valuable evaluation tool in the assessment of vocal fold vibration. Production of the voice requires glottal competence to facilitate the vibration of the vocal fold mucosa. Several mechanisms contribute to

Table 4 The frequency and percentage of the significance of various scales utilized for the assessment of each of the five stroboscopic parameters selected by the Pareto diagram

	Scales	% of frequency	% significant
Glottic gap			
1-glottic gap	0 = no gap 1 = small gap 2 = one-third glottic gap 3 = two-thirds glottic gap 4 = gap along the whole glottic	50	100
2-glottic gap	0 = severe 1 = moderate 2 = mild 3 = absent	12.5	100
3-glottic gap	Improved No change Disappeared	12.5	0
4-glottic gap	No scale	25	50
Glottic closure			
1-glottic closure	1 = complete closure 2 = mildly incomplete 3 = moderately incomplete 4 = severely incomplete	43	80
2-glottic closure	No closure Anterior third Anterior two-thirds complete	8.69	50
3-glottic closure	Complete Partial No contact	13	0
4-glottic closure	Complete Incomplete	13	33.3
5-glottic closure	1 = predominantly closed 2 = closed or open 3 = predominantly open 4 = always open	4.34	100
6-glottis closure	100 scale	8.69	100
7-glottis closure	Scale of 5 1 = normal 5 = abnormal	4.34	100
8-glottis closure	Scale of 6	4.34	0
Vocal fold bowing			
1-vocal fold bowing	Liner Bowed	16.6	100
2-vocal fold bowing	1 = straight vocal fold edge 2 = mildly bowed 3 = moderately bowed 4 = severely bowed	83.3	100
Vocal fold position			
1-vocal fold position	0 = midline 1 = paramedian 2 = intermediate 3 = lateral	100	100
Periodicity of mucosal wave			
1-periodicity	1 = normal 2 = mild 3 = moderate 4 = severe	44.4	75
2-periodicity	Severely aperiodic Normal	11.1	100
3-periodicity	Periodical and symmetry Periodical and asymmetry Not periodical	11.1	100

Table 4 (continued)

	Scales	% of frequency	% significant
4-periodicity	Synchrony in all of the cycle Synchrony in most of the cycle Out of synchrony	11.1	100
5-periodicity	100 scale	11.1	100
Mucosal wave			
1-mucosal wave	0 = absent 1 = severely reduced 2 = mildly reduces 3 = intact	11.11	100
2-mucosal wave	Presence Or absence	44.44	75
3-mucosal wave	Improved Or not	11.11	100
4-mucosal wave	Scale of 5 Unrestricted-to-absent	11.11	100
5-mucosal wave	Absent Small Normal Great	11.11	0
6-mucosal wave	Scale of 100	11.11	100

Table 5 Our protocol proposal from the review based on the most frequent and significant stroboscopic parameter scales

Parameters	Scales	% frequency	% significant
Glottic gap	0 = no gap 1 = small gap 2 = one-third glottic gap 3 = two-thirds glottic gap 4 = gap along the whole glottic	50	100
Vocal fold bowing	1 = straight vocal fold edge 2 = mildly bowed 3 = moderately bowed 4 = severely bowed	83	100
Vocal fold position	0 = midline 1 = paramedian 2 = intermediate 3 = lateral	83	100
Periodicity	1 = normal 2 = mild 3 = moderate 4 = severe	50	75
Mucosal wave	Presence Or absence	44	75

the vibration; e.g., the Bernoulli effect, which is the negative pressure created perpendicular to the airflow, is essential for the closing phase of the mucosal cycle or undulation of the vocal folds, with the requirement of airflow from the lungs to initiate the process. The loss of voice quality in patients with vocal fold paralysis is caused by inadequate closure of the vocal folds and loss of vocal fold tone, resulting in bowing, flaccidity, and weakness of the paralyzed vocal fold. The reliability of the stroboscopic description is controversial as it relies on the visual evaluation to assess the quality of the mucosal wave during phonation, comparing the bilateral vocal fold vibration. VLS depends on pitch tracking and temporal resolution; therefore, previous studies reported that between 17 and 63% of patients could not be assessed due to the inability of the strobe to synchronize to the fundamental frequency (F0) of the acoustic signal. This is considered a common limitation of stroboscopy in evaluating patients with moderate-to-severe disturbances of voice quality due to motion alteration introduced by stroboscopic tracking errors, resulting in a non-interpretive vibratory function [8].

The stroboscopic evaluation is used to assess the vibrant quality of the vocal folds via a strobe light source sent at a frequency slightly slower than the vibration frequency (i.e., mucosal wave), which gives an impression of slow motion of the mucosal wave [9]. The stroboscopic evaluation in the present study includes the following parameters: periodicity, edge bowing, glottis gap, mucosal wave, position of the vocal fold, amplitude, and symmetry. In the review, the patient was asked to sustain a vowel, i.e., /e/, at a comfortable loudness and pitch for as long as possible, and videographs with regular halogen and stroboscopic light were recorded on a video system of 25 images/s.

A rigid endoscope was used more frequently in the current review. Hosbach-Cannon et al. [10] found no significant differences between rigid and flexible endoscopy methods in the assessment of vibration amplitude, while controlling for certain voice parameters that may affect vibratory amplitude, which include a constant F0 range between the two endoscopic conditions, and the mean voice intensity level was allowed to vary so that typical phonatory patterns would be represented and compared [10]. However, flexible videostroboscopy is better tolerated with less supraglottic contraction during phonation and is considered more physiologic. Laryngologists use flexible endoscopes as a routine examination tool, and it is important to keep the accessibility of the examination to encourage their standardization.

The characteristics of stroboscopic parameters such as the periodicity, mucosal wave, and amplitude are highly dependent on pitch frequency (vocal fold tension) and loudness (subglottal lung pressure). In the current review, the voice task of stroboscopic evaluation was mentioned in 51.2% of the studies. The vast majority of the studies (35%) used sustained /i/ or /e/ with comfortable pitch and loudness, 10% of the studies used /i/, /e/, and /u/ with a variety of phonatory conditions, including low, comfortable, and high pitches and intensities. The assessment of glottic gap was done on the modal pitch and loudness and the various frequencies and loudness were used to evaluate the compensatory activity of contralateral vocal fold and the supraglottic activity, as mentioned in studies [11, 12]. Patel et al. [5] recommended in stroboscopic parameters' ratings to report at a minimum, the normal phonation /i:/ (typical pitch and loudness) for at least three consecutive glottal cycles. This is in addition to any other voice production tasks that help to elucidate the patient's problem, a sustained phonation at varied pitches, different loudness, and glissando (slowly ascending and descending pitch) to demonstrate maximum range parameters and all registration transitions [5].

Stroboscopic parameters

Using the Pareto diagram, the current study demonstrates that "periodicity", which means regularity of successive vibrations in period and phase, is the most relevant parameter in the evaluation of UVFP (87.5%), followed by "edge bowing", which corresponds to the smoothness of the free edge of the paralyzed vocal fold (83.3%); "mucosal wave", which is independent lateral movement of the mucosa over the body of the vocal fold (77.7%); "glottic closure", which is complete or partial glottic closure (64.5%); "position of vocal fold" (60%); "amplitude" or lateral distance of movement from the midline of each vocal fold (57.1%); and "phase symmetry", which corresponds to the opening and closing of each fold mirroring the other (50%).

The stroboscopic parameter review demonstrates variant inter-rater reliability. Nawka et al. [13] reported that the inter-rater reliabilities for vertical level, glottal closure, phase closure, phase symmetry, and regularity are so low that these variables should not be assessed via stroboscopy. The remaining variables, such as amplitude, mucosal wave, non-vibrating portion, supraglottic activity, and vocal fold edge smoothness, reveal adequate reliability by aggregating evaluations from at least two raters [13]. Bonilha et al. [2] indicated that rating of anatomical (stationary) features was more reliable than ratings of functional (temporally)-dependent features that involve a movement pattern, with the poorest rater reliability for the phase symmetry [2]. In our study, the five most relevant parameters that show a high percentage of significance and reliability in evaluating the effect of surgical interventions in UVFP by VLS are periodicity, edge bowing, mucosal wave, glottis closure, and position of the vocal fold. It includes the functional parameters periodicity and mucosal wave in addition to the anatomical parameters edge bowing, glottic closure, and position of the vocal fold.

A comparison of stroboscopic signs between the subgroups of the different types of medialization surgeries was not conducted due to a small and unbalanced sample size between the subgroups that would not yield a valid result. However, in the comparison groups of different types of medialization surgeries that included eight studies, four studies showed equal results between the different medialization techniques [14, 16–18]. Three of 11 studies showed that titanium implants provide better results than silicon thyroplasty [19–21]. One study showed that both injection and reinnervation surgeries have equal results, but reinnervation has longer effects after 3 years [14].

Rating of stroboscopic parameters

There is a lack of standardized scales published for evaluating stroboscopic parameters. The majority of the scales that were used in the studies were ordinal scales instead of interval scales [3]. This means that the intervals between the levels of the scales are inconsistent. In addition, the nominal scale included named variables that were dichotomous, for example, improvement or no improvement or present or absent. Several studies have been conducted to improve the reliability of the stroboscopic rating form. The Stroboscopy Evaluation Rating Form (SERF) was developed to resolve various challenges with stroboscopy rating. The SERF uses a graphics-based approach to facilitate the rating of selected parameters. The form has been revised and renamed to reflect new features. It includes the following nine parameters: glottal closure, amplitude, mucosal wave, non-vibrating portion, supraglottic activity, vocal fold edge smoothness, vertical plane, regularity, phase closure and phase symmetry. The new form is called Voice-Vibratory Assessment with Laryngeal Imaging (VALI); it expands the use of graphics-based rating and includes parameters to be assessed with high-speed imaging (HIS) that includes four parameters, which are regularity, phase closure, phase symmetry, and other voice-vibratory patterns (e.g., fry, breathy, and pressed.) [15]. In the current study, the proposal scales of the stroboscopic parameters in evaluating treatment improvement of unilateral vocal fold paralysis were selected based on the percentage of significance of the most frequent scale utilized for each of the five stroboscopic parameters identified by the Pareto diagram, which include three parameters of the SERF scale (periodicity, mucosal wave, and glottic gap) in addition to edge bowing and position of the vocal fold. Our scale implies a simple, accessible, and reliable scale of the stroboscopic examination in evaluating the unilateral vocal fold paralysis based on the percentage of significance.

The present study has several differences from the basic protocol of voice evaluation (Dejonckere et al. [6]) of the European Laryngological Society. First, Dejonckere et al. [6] provided a protocol for all laryngeal examinations, not specific to UVFP. Second, it included all phonetic examinations of perception, VSL, acoustics, aerodynamic and subjective rating by the patient, while the current study focuses on the VLS parameters. Third, the present study includes the same VLS parameters of Dejonckere et al. [6]; that is, glottic closure, regularity and mucosal wave, in addition to edge bowing to measure the tone and the position of the vocal fold. Finally, Dejonckere et al. [6] provided four-point grading scale (0, no deviance; 3, severe deviance), while our grading scales of either four points or two points are specific to each parameter scale.

The current review has distinct differences from the recent systematic review published by Bonilha et al. [3] on the parameters and scales of stroboscopy. First, Bonilha et al. [3] included all voice disorders and UVFP accounted for 40% while our study focused entirely on UVFP. Second, they included several treatment modalities of surgeries (64%), voice therapy, pharmaceutical intervention, and combination intervention methods. In contrast, the scope of our study was on the stroboscopic evaluation of surgical interventions of UVFP, which included injection laryngoplasty, thyroplasty, and re-innervation. Third, Bonilha et al. [3] reported that glottal gap was the most frequent parameter (50%) succeeded by mucosal wave and amplitude (27%), regularity of vibration (19%), and phase symmetry (18%). Our study found that the glottic gap was likewise the most common stroboscopic parameter (32%) followed by symmetry (10.5%), mucosal wave (9.4%), regularity (8.4%), and amplitude (7.3%). Fourth, they did not mention the phonatory task protocol used for assessment. However, our study stated that the voice task of the stroboscopic evaluation was noted in 51.2% of the studies. Finally, they concluded that there is a lack of agreement in the literature regarding which parameters and scales should be assessed to measure voice treatment outcomes [3]. The current review provides an additional contribution because the articles' inclusion criteria were according to the Hawker checklist, the computation of stroboscopic parameters was by Pareto diagram, and the selection of parameters based on their percentage of significance, and accordingly we outline a proposed protocol of stroboscopic parameter scales to evaluate the surgical treatment outcome of UVFP.

Limitations

This review contains limitations that may have influenced our findings. It did not include a robust statistical analysis combining results of eligible studies because of the variability of the parameters and scales reported. It is possible that the search terms may not have detected all relevant studies related to the topic; i.e., the search included only articles that were published in English. We considered only the stroboscopic parameters and did not compare or correlate them with acoustic and perceptual data. In addition, we admit there is a limitation of stroboscopic images, namely, the inability to detect the aperiodic mucosal wave in the severe breathy voice of UVFP. The studies used different pitch and loudness protocols that may affect the comparison of stroboscopic parameters among the studies.

We recommend conducting future studies to evaluate the inter-rater reliability for the proposed scale to enable comparative studies.

Conclusion

We attempted to provide a simple method in the reporting of the stroboscopic parameters and scales that are used frequently in UVFP and that report a relevant significant difference after surgical treatment. The aim was to encourage the use of VLS routinely in the treatment outcome of UVFP. Furthermore, the examination can be performed with a fiberscope, a tool currently used by all laryngologists.

The results indicate that periodicity, edge bowing, mucosal wave, glottic gap, and position of vocal fold represent the five most frequently used and relevant stroboscopic parameters. The current review outlines a proposal protocol of the most frequent and significant stroboscopic parameter scales.

Compliance with ethical standards

Conflict of interest The authors declare that they have no competing interests.

Ethical approval This article does not contain any studies with human participants or animals performed by any of the authors.

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