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ORIGINAL ARTICLE

Voice evaluation – contribution of the speech-language pathologist voice specialist – SLP-V: Part B. Acoustic analysis, physical examination and correlation of all steps with the medical diagnoses

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ABSTRACT

This article describes the contribution of the speech-language pathologist, voice specialist SLP-V in the assessment of patients with voice problems. Part B explores acoustic analysis to measure the vocal signal and to produce comprehensive documentation of the patient; the physical examination to assess the involvement of body tension, including the larynx, cervical muscles, and breathing pattern; and finally, the correlation of all previously described steps to make a clinical decision combining the patient information, tests performed, and the physical examination of the individual. Worldwide published tendencies and specific comments of each step highlight the role of the SLP-V.

KEYWORDS

Voice; voice disorder; acoustical analysis; medical diagnosis; voice specialist

Introduction

Voice evaluation is a central aspect to define a proper program of rehabilitation when this is the management of the case. This contribution, Part A and B, presents the clinical experience of a group of mature Speech-Language Pathologists specialized in the voice area, named SLP-V, in performing a voice assessment in a 40-to-60-min session. The main objective of a voice evaluation performed by the SLP-V is to understand various aspects of a patient's voice production comprehensively to contribute to the clinical reasoning to define the management.

Part A of this article [1] explored the history of the voice problem and behavioural data (particularly on the voice use), the patient self-assessment, and the auditory perceptual judgement. The history of the voice problem is crucial to understand the influence of the vocal behaviour on the voice problem. The SLP-V dos does not reproduce the medical anamneses but focus on the aspects related to the use of voice. Self-assessment of the impact of the voice problem has entered the voice field in recent decades and is widespread worldwide, making a unique contribution to understanding the patient's experience with a dysphonia. Self-assessment protocols also offer unique information of cognitive aspects required to start a rehabilitation program, such as coping strategies and self-regulation. Auditory perceptual judgement is the traditional strategy for clinical evaluation of the voice patient; it contributes to describing the degree of deviation and characterizing it according to well-defined parameters.

In Part B, we explore the following aspects: acoustic analysis, which in our proposal is carried out together with the auditory perceptual judgement, the physical examination of the patient, and the conclusion of the evaluation.

Acoustic analysis

The acoustic analysis offers the best and easiest documentation for any voice problem. It is relatively easy to perform, non-invasive, semi-objective, and allows for obtaining quantitative measures, which are sufficient reasons for use in clinical practice and research [2]. The clinical application of acoustic measurements is based on the assumption that vocal fold mass or tension changes increase voice irregularity and noise [3].

The acoustic analysis can be qualitative or quantitative. The qualitative analysis relies on the spectrographic trace. This register is a visual descriptive

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analysis of the voice signal in any voice task or speech context. It is widely used in the voice clinic, and its main advantage is that the tracing can be made from any acoustic signal regardless of its degree of deviation [4]. Spectrographic trace plays an essential role in helping the evaluator see what is heard. Moreover, patients also benefit from the fact that the voice becomes concrete, and it can be monitored. Quantitative analysis offers the advantages of including metrics on assessment to quantify the results of treatment and comparing them with reference values in addition to the reproducibility of studies [5].

Quantitative analysis is not anymore limited to university laboratories, and it is available for the average clinician. There are free or low-cost computer programs (such as PRAAT, Paul Boesrma and David Weenink, The Netherlands and VoxMetria, CTS Informatica, Brazil) that allow for conducting clinical acoustic evaluations using a standard computer with a good sound card and a microphone with a straight response curve.

One practical qualitative spectrographic analysis is the Dynamic Vocal Analysis (DVA). The DVA evaluates vocal functionality through quick and easy to perform phonatory tasks of the larynx: low versus high frequency (stretching and shortening of vocal folds), soft versus loud intensity (vocal folds adduction and subglottic pressure control), and glissandi (smooth control of frequency) [6]. As previously mentioned, functionality is a central aspect of the SLP-V assessment, and the DVA provides many insights into the voice production process. Moreover, it allows for the documentation and easy visual comparison of the main laryngeal adjustments both pre- and post-treatments.

Some common clinical parameters, such as maximum phonation time, *s*/*z* relation, vocal registers, resonance, and articulatory patterns, can be evaluated *via* the recording of selected tasks using the spectrographic trace. In addition, this is when the speech or singing tasks indicated as difficult by the patient will be produced for analysis, such as reaching a high pitch, having stability in the low pitch, speaking at a low intensity, or projecting the voice. A spectrographic trace can provide valuable data for vocal production in these situations and visual feedback to the patient, also serving as a comparison at the end of the treatment.

The quantitative analysis is centred on the extraction of acoustic measurements. Traditional acoustic parameters are based on the source-filter model, while modern acoustic parameters rely on nonlinear dynamics measures based on voice as a chaotic system [7].

Traditional acoustic measures are usually monoparametric and give objective data of different aspects of the voice signal, usually a sustained vowel, such as fundamental frequency, jitter, shimmer, and noise measurements [8]. Some of them proved to be clinically relevant, such as Glottal to Noise Excitation (GNE), which measures the additional noise in the audible signal and is capable of discriminating the predominant type of voice and the intensity of the deviation [9]. Yet, the extraction of these traditional measures presupposes a certain periodicity of the vocal signal and requires predicting the fundamental frequency values; thus, this can be performed only on quasi-periodic voice signals [10], the minority of the clinical voice samples. Moreover, traditional acoustic measures, such as jitter and shimmer, have a weak or negligible correlation with the auditory-perceptual analysis of the voice [11]. Although the sustained vowels used in traditional acoustic measures are suitable for analyzing vocal disorders, they do not mirror voice quality during speech.

The limitation of traditional measures has been recently overcome using modern acoustic measures, which consider both a sustained vowel and speech samples. These new measures optimize the quantification of a dysphonia, even in cases of higher aperiodicity. Cepstral measures, which do not rely on the fundamental frequency, are new procedures with a good correlation to some auditory perceptual classifications, such as breathiness [12]. Specifically, the Smooth Cepstral Peak Prominence – CPPS was shown to be related to the overall degree of vocal deviation [13] and offers a high accuracy to discriminate normal from altered voices [14].

Another alternative of an acoustical analysis is to use multiparametric models as they consider the multidimensionality of the voice. The two most studied multiparametric indicators are the Cepstral Spectral Index of Dysphonia – CSID and the Acoustic Vocal Quality Index – AVQi. The CSID [15] includes cepstral and spectral measures (cepstral peak prominence, low-frequency/high-frequency, and sex information through weighted multiple regressions). The Acoustic Vocal Quality Index – AVQI includes six acoustic parameters (the smoothed cepstral peak prominence, harmonics-to-noise ratio, shimmer per cent, shimmer dB, general slope of the spectrum, and tilt of the regression line through the spectrum) [5,16,17]. Multiparametric indexes provide one single

score to reflect the overall voice quality for clinical purposes.

The current tendency is to abandon the traditional single measures in favour of multiparametric ones, representing voice functionality more accurately. The use of combined classifiers and measures has shown encouraging results for identifying vocal deviations, becoming a contemporary trend for the analysis of vocal signals. They are more consistent in classifying normal versus deviate samples with a wide range of deviation than the isolated monoparametric measures; however, these indexes need to be submitted to validation studies in different languages to be adequately used [17].

Even if we consider the questionable correlation of the traditional acoustic measures with the perceptual auditory analysis and the need for more studies using the modern multiparametric ones, the acoustic analysis has value in assisting with differential diagnoses to evaluate treatment outcomes, and as mentioned, for patient documentation [11].

Physical examination of the patient

Another critical aspect of the voice assessment made by a SLP-V is to observe all the signals that the body reveals about the various elements involved in voice production, from laryngeal aspects to body movement.

Voice disorders can be caused by misuse or can also indirectly impact the use of the voluntary muscles of phonation. The clinician must identify a deviated use of muscles of the larynx, pharynx, jaw, tongue, face, neck, and respiratory system. Some dysphonias can be attributed primarily to incorrect vocal techniques, such as poor coordination among phonation, breathing, resonance, and articulation; excessive or inadequate laryngeal valving; improper resonance focus; and improper control of pitch and loudness dynamics [18].

General postural misalignment is common, particularly in behavioural dysphonia patients. The cervical spine has a direct implication on the configuration of the whole vocal tract and deserves attention. Compensatory strategies due to faulty laryngeal adduction or due to the presence of a mass lesion may result in inadequate respiratory dynamics or excessively focussed or generalized muscle tension. These body signs are identified during the history taking step or when using speech and reading tasks. Abusive behaviours, such as yelling, screaming, and/or talking too loudly, a lack of or improper training, and/or emotional reactions stemming from one's daily lifestyle stress can be evident [19]; however, visual impressions must be confirmed with a direct assessment of posture, vertical laryngeal positioning, cervical muscles, and breathing patterns.

The main topics of the clinical examination are posture, vertical laryngeal positioning, neck and cervical muscles, and breathing pattern.

Posture

There is widespread understanding that postural alignment benefits voice function. Therefore, the traditional recommendation of keeping the spine aligned seems obvious. Posture and voice are coordinated in communication behaviours, and each body segment plays its specific role in the vocal effort behaviour; however, the interaction among voice, posture, and body muscle tension is neither direct nor simple.

A good posture allows for an easier shift in tension between muscles and offers free movement of the larynx, benefiting voice production. Therefore, clinicians usually consider correct posture the basis for cost-effective voice production. Nevertheless, a recent systematic review revealed that the relation between dysphonia and posture seems contradictory [20], and scientific evidence regarding voice quality, voice disorders, and body posture is lacking.

Despite this limitation, for clinical purposes, two observations have importance: posture, particularly of the cervical spine, is directly related to vocal resonance and pitch control [21]; on the other hand, vocal effort caused by any laryngeal imbalance may produce changes in posture, such as forward bending of the trunk and backward rotation of the head [22]. Body posture, and more directly, cervical spine alignment, may impair the freedom of the laryngeal intrinsic and extrinsic muscles. Postural correlates of vocal effort are extensively dealt with in voice rehabilitation but are rarely described in the literature [23]. As an example of how posture can influence the voice, hyperlordosis of the cervical spine with an extended head and kyphotic hump in the upper thoracic vertebrae can cause poor laryngeal posture, increased vocal effort, and muscular tension in and around the larynx during phonation [24].

The SLP-V should address the agonist/antagonist relationships, the biomechanics of stretching, postural assessment, and the relationship between muscle tension and muscle weakness [21]. The treatment of postural problems is usually multidisciplinary and beyond the scope of the SLP-V intervention, but the

identification of deviations and some general recommendations can be made.

Vertical laryngeal positioning (VLP)

VLP is relevant to voice function [25]. The resting level of the larynx is evaluated after a deglutition, and it is most often directly related to the activity of the thyrohyoid and sternothyroid muscles. The clinician visually and manually checks laryngeal displacement during tasks of high frequencies (upper movement) and low frequencies (lower positioning) [25]. Vertical freedom is important, and the tendency of high or low positioning is directly related to the patient's voice quality. Individuals with classical training learn to maintain a lower larynx during singing, which is not observed in popular singing or untrained singers [25]; however, the larynx is not fixed when singing, and there might be a healthy displacement throughout the music. A higher hyoid bone and larynx is typical in muscle tension dysphonia patients [26] and can be triggered by asking individuals to count numbers in a low and loud voice. Moreover, high lung volume is associated with a lower larynx position and is stronger in males than in females, which indicates that the lung volume is a factor that is highly relevant to larynx height, at least in untrained subjects [25].

The auditory perceptual impression of the VLP and vocal tract length is the so-called vocal focus, i.e. the effect of the vocal tract length on the perceived sound of the voice [27]. A forward focus results from a shortened vocal tract with a raised larynx and a reduced pharyngeal space. The resulting sound is described as flat and bright. A backward focus results from a lengthened vocal tract with a lowered larynx and a widened pharyngeal space. The resulting sound is described as throaty and dark [28].

Cervical muscles

All cervical, anterior, and posterior muscles play a role during vocalization and may interfere in spectral characteristics of the voice [29] and articulatory [30] and prosodic aspects [31].

Palpation reveals essential elements of the involvement of extrinsic muscles in vocal production. Some protocols are available to assess this region, but none has been validated; however, they guide what to look for in the cervical muscle assessment [32].

Cervical muscle tension could be linked to muscle misuse dysphonia [33,34]. The main muscles engaged during vocalization tasks are the sternocleidomastoideus (STM), scalenus (SC), and upper trapezius (TR). Their action is usually evidenced by a variation in vocal frequency and intensity. STM/SC and TR mutually influence upper thorax movement in the precise adjustments needed to produce the appropriate subglottal pressure for the intended phonation [34]. Thus, their involvement in phonation is constant.

The clinician must palpate and observe the larynx and the cervical muscles at rest and during different voice tasks, such as speaking, singing, high and low frequency, and intensity. Increased tension in the suprahyoid muscles results in an excessive larynx elevation, which reduces the possibility of a balanced voice. The contraction of the thyrohyoid muscles pulls the hyoid bone and thyroid cartilage together, and, in severe cases, firmly closes the thyrohyoid space. As a result, an anteroposterior supraglottic contraction is observed on a laryngoscopy [33].

A laryngeal palpation should be done before any intraoral or laryngoscopic examination to avoid changes in muscle tension due to the manipulation. Some soreness may be found in these muscle groups and should be noted. Th examination is best done from the side, with the head, neck, and shoulders in a neutral position [33].

Cervical muscles are accessory inspiratory muscles whose activity is also related to respiratory pattern modulation during vocal effort, such as the activation of the sternocleidomastoid [35]. Patients with muscle tension dysphonia may show a contraction of this muscle even when speaking with reduced volume, which impacts the breathing pattern.

Breathing pattern

The evaluation of breathing behaviour begins at the history taking step, and it is considered an important component of the clinical process when dealing with clients with speech and voice disorders [36]. The behaviour of the breathing apparatus differs substantially depending on body position (supine or upright) and performance activity (resting tidal breathing or speech breathing). Thus, it follows the approaches used in clinical evaluations, and treatment should be sensitive to these differences [36].

During the evaluation, the clinician must initially observe the patient's breathing pattern, which can be nasal or oral with or without tension of the cervical musculature. Oral breathing is usual during speech, and nasal breathing is the norm during rest. It is also interesting to observe abdominal movements during inspiration and expiration at rest and while speaking.

Table 1. Steps of the proposed SLP-V assessment with main goals and comments.

Steps of the assessment	Main goal	Comments
History	To understand the vocal problem and particularly the influence of vocal behaviour on the case	It takes time, but it is crucial to define the selection of phonatory and communication tasks and referrals
Self-assessment of impact of voice problem	To verify the patient experience in living and coping with the voice problem	It is fast and gives unique information; validated protocols in the patient's language and culture must be used; it is of great value when symptoms are difficult to measure objectively, such as vocal fatigue and vocal tract discomfort; in the case of the absence of negative impact of the voice problem, it can compromise adherence to treatment
Auditory analysis	To describe type and degree of deviation of vocal quality	It requires training and experience; structured scales help in exchanging information among clinicians; in the case of vocal fatigue, this analysis may be not sensitive
Acoustic analysis	To document and compare pre- and post-treatment data	This is the best way to document the characteristics of voice; it gives information about the use of glottic source and filters; spectrographic trace can be used in any type and degree of deviation; instrumentation necessary is minimal
Physical examination	To comprehend involvement of body tension, including larynx, cervical muscles, and breathing pattern	It provides information on how adjacent structures, and particularly the head, neck, and shoulders, are engaged in voice production
Correlation of all steps	To favour the cognitive process by which a clinical decision is reached combining the patient information, tests performed, and the physical examination of the individual	It requires clinical reasoning to analyze the many variables contributing to the individual limitations (on the physical capacity to use voice) and performance (at the several contexts of voice usage); in case of not enough data for a logical sequence leading to a clinical decision, referrals or another consultation to conclude the assessment are needed

The rib cage and shoulder movements must also be observed while breathing and during different vocal tasks.

Coordination between breathing and the phonatory and swallowing functions of the larynx is needed for normal voice production during speech. Dyscoordination may contribute to several voice problems. For breathing, non-professional speakers need more coordination than volume; professional speakers or singers need coordination and volume. Well-trained classical singers can present any of the two polar inhalatory behaviours, the so-called 'belly in' or 'belly out', with a large intrasubject variability [37]. The critical point is to verify the subject's comfort in mastering the inhalation behaviour for professional purposes.

Aerodynamic assessment strategies can be used in a clinical setting. Maximum phonation time and *s*/*z* ratios are popular measures that estimate the balance between glottic adduction and control of airflow [38]. A person's respiratory capacity can be measured using a low-cost spirometer device with reliable results [39]. Spirometry takes measurements of the quantity of air inhaled and exhaled by the lungs during a specific time to determine the individual pulmonary capacity. In cases of chronic obstructive pulmonary disease and in the elderly, these measures can be of value; however, in the clinical routine for average patients, deviating values are seldomly observed. An observation of the coordination between breathing and phonation during speaking or singing is the most important clinical information to obtain.

Correlation of all steps and with the medical diagnoses

The foundation of the correlation for all steps is the clinical reasoning, a complex cognitive ability to logically analyze the available data and reach a conclusion about the case. Also called professional expertise, clinical reasoning is acquired with training and experience. Both should be used in all actions, whether diagnostic or treatment actions [40].

Specifically, regarding voice cases, this expertise is a combination of theoretical knowledge concerning healthy voice production with perceptual and cognitive skills to generate hypotheses from the collected data. Clinicians should apply these hypotheses to classify the dysphonia to support the required decisions, taking into account the course of the disorder or disease.

Communication of clinical reasoning to the patient improves adherence, and it is an essential attitude to conclude the assessment. Cases of behavioural dysphonia require changes in vocal habits and can be quite challenging for both clinicians and patients.

This is particularly true for recalcitrant dysphonia, for which patients have already submitted to previous treatments without satisfactory results. Cases of organic dysphonia may have the challenge of developing adaptations of structures and recovery of lost functionality due to anatomofunctional limitations; however, they do not require behavioural changes in speech or singing.

The articulation of knowledge resulting from theory, practice, and experience through analysis, synthesis, data evaluation, information processing, and an understanding of the patient's demands and their problem should be confronted with reflexive self-awareness to identify limitations in the quality of the information obtained. In some cases, the lack of correlation of the data obtained in the analyses made by the SLP-V with the laryngological evaluation does not favour a logical understanding of the case. It may require a review of diagnostic hypotheses, additional tests, or a referral to other professionals. Table 1 presents the proposed steps of the SLP-V assessment, the main goals and some comments.

Conclusion

Patients with vocal disorders pose complex clinical questions. The evaluation of these individuals may require the analysis of several professional perspectives. In the present article, all SLP-V authors present a proposal for clinical vocal evaluation to be developed between 40 and 60 min, on a single session. This proposal is present on a 2-part article. This assessment consists of five steps: history of the problem to understand the participation of vocal behaviour in the aetiology of the condition; self-assessment of the impact of the complaint to comprehend the individual's perception of living with the voice problem; auditory analysis to define the type and degree of vocal alteration (presented in Part A); acoustic analysis for the documentation and observation of diverse aspects of voice production in the context of sustained vowels, speech, and singing; the patient's body evaluation to observe deviations directly or indirectly related to the production of the voice, mainly in the muscles of the neck and the breathing pattern; an finally, the correlation of all steps with the medical diagnosis to take a treatment decision (presented here).

The SLP-V evaluation defines and describes the problem, characterize the perception of impact of a voice problem and assesses the patient's vocal functionality. These are essential factors in proposing a rehabilitation program. We also reinforce the suggestion of retrieving the laryngological medical evaluation after the end of the voice assessment to avoid bias. Understanding the limits and intersections between professionals who care for this patient and an explicit sharing of information are essential to the best possible clinical decision.

Disclosure statement

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