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A basic protocol for functional assessment of voice pathology, especially for investigating the efficacy of (phonosurgical) treatments and evaluating new assessment techniques

Guideline elaborated by the Committee on Phoniatrics of the European Laryngological Society (ELS)

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Abstract The proposal of this basic protocol is an attempt to reach better agreement and uniformity concerning the methodology for functional assessment of pathologic voices. The purpose is to allow relevant comparisons with the literature when presenting / publishing the results of voice treatment, e.g. a phonosurgical technique, or a new / improved instrument or procedure for investigating the pathological voice. Meta-analyses of the results of voice treatments are generally limited and may even be impossible owing to the major diversity in the ways functional outcomes are assessed. A multidimensional set of minimal basic measurements suitable for all "common" dysphonias is proposed. It includes five different approaches: perception (grade, roughness, breathiness), videostroboscopy (closure, regularity, mucosal wave and symmetry), acoustics (jitter, shimmer, Fo-range and softest intensity), aerodynamics (phonation quotient), and subjective rating by the patient. The protocol is elaborated on the basis of an exhaustive review of the literature, of the experience of the Committee members, and of plenary discussions within the European Laryngological Society. Instrumentation is kept to a minimum, but it is considered essential for professionals performing phonosurgery.

Keywords Voice assessment · Dysphonia assessment · Phonosurgery · Meta-analysis · Standardisation

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Introduction

This proposal is an attempt to reach better agreement and uniformity concerning the basic methodology for functional assessment of pathological voices. The purpose is to allow relevant comparisons with the literature when presenting/publishing the results of any kind of voice treatment, e.g. a phonosurgical technique, or a new / improved instrument or procedure for investigating the pathological voice. The need for such a standardised assessment is illustrated in a recent study comparing vocal fold augmentation by Teflon injection with thyroplasty type I for unilateral vocal fold paralysis [4]: although there is abundant literature available on this topic, an adequate meta-analysis is limited by the major diversity in assessing functional outcomes.

A few basic principles served as guidelines:

1 Voice function is multidimensional [17].
2 A (minimal) set of basic requirements for presenting (publishing) results of voice treatments is necessary, in order to make comparisons and meta-analyses possible.

3 New and more sophisticated measurement or evaluation techniques and procedures are to be encouraged, but the basic set needs to be performed in all cases, for comparison.
4 The recommendations must be suited for all "common" dysphonias, but a few specific categories of voice pathology need a specific protocol for increasing sensitivity: e.g. substitution voices (= not generated by the two vocal folds) and spasmodic dysphonia.
5 In the basic set or "truncus communis" for the assessment of common dysphonias, the following components need to be considered. All of them provide quantitative data:
   a Perception
   b Videostroboscopy
   c Acoustics
   d Aerodynamics / efficiency
   e Subjective rating by patient

   When investigating substitution voices and spasmodic dysphonias, elements such as intelligibility and fluency should be added. Further, scales and algorithms should be adjusted for the dimensions 'perception', 'videostroboscopy' and 'acoustics'.

   Each of the above items has its own specific relevance when results or statistics are reported, as it provides a particular insight (multidimensionality). Combined scores or indexes [11, 43] integrating these or other data into one single value may be very useful, but optimal evaluation and understanding of the treatment effect also requires the intrinsic comparison of the scores for the different components [39]. A first implementation study pointed out that, for some patients, treatment effects can vary considerably from one dimension to another [10].

6 In the assessment of treatment outcomes, a maximal objectivity must be a constant care. However, even objective data, as audio-recordings or videolaryngostroboscopic pictures, may be subjectively rated and interpreted. Nevertheless, for research purposes, it remains possible to considerably improve the validity by (1) averaging the ratings of a panel, and (2) rating blindly, that means without knowing what is e.g. before and after treatment.

Although the present guideline only concerns basic, non-sophisticated approaches, it is not to be considered as the ultimate way to basically assess the voice function. Further implementation studies are needed, as well as further research work, and both are warmly encouraged by the Committee.

A pre-requisite: recording a voice sample

Audio recording is the most valuable basic tool for voice assessment. Once a high-quality recording has been made it can be stored, and at a later time it is possible to perform additional investigations, such as blind perceptual evaluation by a panel or sophisticated acoustic analyses. It is essential that all recordings of voice patients are filed as an archive, where it is easy to retrieve an earlier voice sample. A digital recording system should be used to store signals, unless A/D conversion and storage is directly performed by the computer. All commercially available computer systems for acoustical voice analysis record directly and store the voice samples. A sampling frequency of at least 20,000 Hz is recommended. The recordings should be made ideally in a sound-treated room, but a quiet room with ambient noise < 50 dB is acceptable. The mouth-to-microphone distance needs to be held constant at 10 cm. A (miniature) head-mounted microphone offers a clear advantage, but a harmonica holder is also effective. Off-axis positioning (45–90° from the mouth axis) reduces aerodynamic noise from the mouth in speech [26, 35].

Voice / speech material

An example of protocol for standard recording:

– /a:/ at (spontaneous) comfortable pitch/loudness, recorded three times to evaluate variability of quality
– /a:/ slightly louder, to evaluate the possible change in quality and the slope of the regression line: frequency / sound pressure level [3].
– a single sentence or a short standard passage

Phonetical selection can be useful, e.g. a sentence with

– Constant voicing
– No fricatives

Such a sentence can be analysed by the computer program for sustained vowels, and as it contains no articulation noise there is no biasing of harmonics-to-noise computations. In addition, it allows easy computation of the mean habitual fundamental speaking frequency. Another example of a criterion for phonetical selection could be a multiplication of voice onsets. Such criteria are not language-linked.

(1) Perception

Current research does not support the substitution of instrumental measures for auditory–perceptual assessment. However, it is well known that semantics regarding definition of dysphonia and hoarseness are a critical matter: social and cultural aspects have a great importance for what is considered breathy or harsh voice quality [13].

It is proposed that the term 'dysphonia' be used for any kind of perceived voice pathology: the deviation may concern pitch or loudness, as well as timbre or rhythmic and prosodic features. 'Hoarseness' is limited to deviant voice 'quality' (or timbre), and excludes pitch, loudness and rhythm factors. A limited number of voice pathology categories, such as those related to mutation or transsexuality, are specifically concerned with pitch. Rhinophonia is a specific abnormality of resonance – and needs to be reported separately, if present. However, the assessment of treatments for rhinophonia (aperta or clausa) does not fall in this scope. Tremor is a characteristic temporal feature, and must also be reported separately, when present.

The rating is made on current conversational speech (anamnesis of patient). The severity of hoarseness is quantified under the parameter G (grade) from the GRBAS scale proposed by Hirano [16]: it means the overall voice quality, integrating all deviant components.

Two main components of hoarseness have been identified, as shown by principal component analysis [5]:

(1) Breathiness (B): audible impression of turbulent air leakage through an insufficient glottic closure may include short aphonic moments (unvoiced segments).
(2) Roughness or harshness: audible impression of irregular glottic pulses, abnormal fluctuations in Fo, and separately perceived acoustic impulses (as in vocal fry), including diplophonia and register breaks. When present, diplophonia can be additionally recorded as ‘d’.

These parameters have shown sufficient reliability (inter- and intraobserver reproducibility) when used in a current clinical setting [2, 7]. The behavioural parameters ‘asthenicity’ and ‘strain’ are currently less reliable and have been omitted from the basic protocol. The remaining simplified scale, GRB, then becomes similar to the RBH scale (*Rauhigkeit* for roughness, *Behauchtheit* for breathiness, and *Heiserkeit* for hoarseness) used in German-speaking clinics [24].

For reporting purposes, a four-point grading scale is convenient (0, normal or absence of deviance; 1, slight deviance; 2, moderate deviance; 3, severe deviance), but it is also possible to score on a visual analogue scale (VAS) of 10 cm, with anchoring points [7, 44].

(2) Videolaryngostroboscopy

Videolaryngostroboscopy is the main clinical tool for the aetiological diagnosis of voice disorders. It can also be used for assessing the quality of vocal fold vibration, and thus the effectiveness of treatments, medical or surgical.

The pertinence of stroboscopic parameters is based on a combination of reliability (inter- and intraobserver reproducibility), nonredundancy (from the factor analysis), and clinical sense (relation to physiological concepts).

Basic parameters are:

(1) Glottal closure: quantitative rating using a four-point grading scale, or a visual analogue scale of 10 cm (see above). It is recommended that the type of insufficient closure also be recorded and categorised:
   - Longitudinal: over the whole length of the glottis and without sufficient adduction
   - Dorsal (posterior triangular chink): it is, however, important to consider that a slight dorsal insufficiency – even reaching into the membranous portion of the glottis – occurs in about 60% of middle-aged healthy women during normal voice effort. In 50% of women the glottis is completely closed when they are speaking in a loud voice
   - Ventral
   - Irregular
   - Oval: over the whole length of the glottis, but with a dorsal closure
   - Hour-glass shaped [31, 32]

Rating of glottal closure has been found very reliable [31]

(2) Regularity: quantitative rating of the degree of irregular slow motion, as perceived with stroboscopy [6].
(3) Mucosal wave: quantitative rating of the quality of the mucosal wave, accounting for the physiology of the layered structure of the vocal folds [16].
(4) Symmetry: quantitative rating of the ‘mirror’ motion of both vocal folds. Usually asymmetry is caused by the limited vibratory quality of a lesion (e.g. diffuse scar, or localised cyst or leucoplakia) [18].

For each stroboscopic parameter, a four-point grading scale (0, no deviance; 3, severe deviance), or a visual analogue scale can be used [8, 9, 18].

Videostroboscopy can be documented on a hard copy, and thus be archived.

Rating ‘a posteriori’ is possible.

It is classically recommended videostroboscopic pictures be observed and recorded in different voicing conditions. For example, the degree of glottal closure usually increases with increasing loudness [31, 32]. However, this basic rating concerns the comfortable pitch and loudness.

For comparisons (pre-/posttreatment), it is advisable to use the same kind of endoscope (rigid or flexible, if rigid: same angle) at each examination.

(3) Aerodynamics

The simplest aerodynamic parameter of voicing is the maximum phonation time (MPT) in seconds. It consists of the prolongation of a/a:/, for as long as possible after maximal inspiration, and at a spontaneous, comfortable pitch and loudness. It is one of the most widely used clinical measures in voice assessment, worldwide [16]. A prior demonstration is necessary, and three trials are required, the longest time being selected [25]. As it concerns an ‘extreme’ performance, it has been shown to be very sensitive to learning and fatigue effects. Furthermore, in the case of good voices the duration of ‘apnoea’ can become the limiting factor, rather than the available air. Children show significantly lower values of MPT, as their lung volume is smaller [21]. A reduction of possible bias – e.g. supportive respiratory capabilities compensating for poor membranous vocal fold closure – is possible if the following ratio is computed:

Averaged phonation air flow or Phonation Quotient (PQ) = Vital Capacity (ml)/MPT (s)

Vital capacity (VC) is defined as 'the volume change at the mouth between the position of full inspiration and complete expiration'. It can be measured in a reliable way by using a hand-held spirometer [27]. In normal subjects, VC depends on anthropometric factors, and it is quite strongly correlated with height, for example [22]. It is also sensitive to lung disease, especially for patients with carcinoma. As VC is not directly related to voice quality, it is sensible to take it into account, certainly when children are being investigated.

The mean air flow rate can also be measured by using a pneumotachograph. This device provides a direct measurement of the mean airflow rate (ml/s) for sustained phonation over a comfortable duration, usually 2–3 s, at the habitual pitch and intensity level and following inspiration of a habitual kind. A pneumotachograph consists of a (hand-held) mouth tube (possibly connected to a mask) within which a fine-mesh wire screen is placed in order to create a (small) resistance to airflow. This resistance results in a pressure difference across the screen, which can be measured with a differential pressure transducer: the pressure difference increases with the flow.

Pathophysiological backgrounds and normative values have been reported by Hirano [16, 17], Verdolini [38], Colton and Casper [1], and Woo and al. [41, 42].

The variation of averaged phonation airflow varies considerably among normal subjects, and there is a large overlapping range of values in normal and dysphonic subjects. This limits its value for diagnostic purposes [29]. Nevertheless, when glottal function before and after surgical intervention or nonsurgical voice training techniques is compared, airflow measurement may be useful for monitoring therapeutic effects [30], for example in the case of paralytic dysphonia [12, 19, 23] or when microlaryngeal phonosurgery is performed [42]. The method is especially useful for demonstrating changes in a single test subject over time.

For comparisons (pre-/posttreatment), it is advisable to use the same kind of technique (PQ or mean airflow rate measured by pneumotachography) on each occasion.

(4) Acoustics

Acoustic parameters provide objective and noninvasive measures of vocal function. Increasingly, these measures have become available at affordable cost, and they appear to have been very successful for monitoring changes in voice quality over time. Perturbation measures (in period and amplitude) and harmonics-to-noise computations have emerged as the most robust measures, and seem to determine the basic perceptual elements of voice quality: Grade, Roughness and Breathiness [7, 40]. A general limitation is that the systems employed for acoustic analysis cannot (or not in a reliable way) analyse strongly aperiodic acoustic signals. Perturbation measures become unreliable if the voice signal contains intermittency, strong subharmonics or modulations. Perturbation measures less than about 5% have been found to be reliable [36]. Therefore, a visual control of the period definition on the microphone signal or of the spectrogram is always necessary: even in regular voices, a strong harmonic or subharmonic may account for erratic values [35].

There is still insufficient standardisation of the optimal algorithm(s), e.g. for signal-to-noise ratio computations (NNE normalised noise energy, HNR harmonics-to-noise ratio, cepstrum peak, etc.). Thus, at present, percent jitter and percent shimmer are proposed as the basic acoustic measures, to be computed on a sustained /a:/, at comfortable frequency and intensity. Jitter is computed as the mean difference between the periods of adjacent cycles divided by the mean period. It is thus a Fo (fundamental frequency)-related measurement. For shimmer, a similar computation is made on peak-to-peak amplitudes. Voice breaks must always be excluded. If any other algorithms are used they need to be clearly specified. Obviously, comparisons of pre-/posttreatment voice qualities require similar techniques and material.

Also included in the basic acoustic measures are three critical points of the phonetogram (VRP: voice range profile) [14, 28]. The highest frequency and the softest intensity (dB A at 30 cm) seem to be the most sensitive for changes in voice quality [15, 37, 43], the latter being related to phonation threshold pressure [33, 34]. The measurement of the lowest frequency makes it possible to compute the fundamental frequency range. Such a 'three-point phonetogram' can be obtained without completing a (time-consuming) whole voice range profile. However, as these three points represent 'extreme' performances, they, like MPT and CV, are very sensitive to learning and fatigue effects.

(5) Subjective (self-)evaluation by patient

This evaluation of voice, although subjective by definition, is of growing importance in daily clinical practice. It is the patient who has to live with his/her voice. Also, social and cultural aspects may be relevant in consideration of voice quality [13]. This evaluation needs careful quantification, as it is paramount and needs to be compared and correlated with the data of the objective assessment. The basic aim is to differentiate the deviance of voice quality in the strictest sense, and the severity of disability / handicap in daily social and/or professional life. A voice handicap index can be computed on the basis of a patient's responses to a carefully selected list of questions [20]: besides the aspects already mentioned, it also investigates the possible emotional repercussion of the dysphonia. However, for the basic protocol, a minimal subjective evaluation can be provided by the patient him- or herself on a double visual analogue scale of 100 mm: the impression of the voice quality in the strict sense, and the impression of what repercussions the voice problem has on everyday social and, if relevant, professional life and activities. A score of '0' (extreme left) means normal voice (no deviance) on the first scale and no disability or handicap (related to voice) in daily life on the second scale, while ‘100’ (extreme right) means extreme voice deviance on the first scale and extreme disability or handicap in daily social (and, when relevant, professional) activities, as rated by the patient him-/herself.

Example of a report for the proposed basic protocol

Woman of 26, diagnosed with vocal fold nodules,
before treatment.

Perception: G34 B52 R18d
Stroboscopy: Clo 40hs Reg10 MW25 Sym0
Aerodynamics: PQ 285 ml/s (MPT 13 s).
Acoustics: Ji 1.2%, Shi 6.1%, Fo-range: c–g1, softest intensity: 53 dB(A) 30 cm.
Subjective evaluation: Vo30 Dis50

Explanation

Perception is rated on three visual analogue scales, each 100 mm long. Grade is scored 34/100, etc., where 0 always means normality (no deviance) and 100 extremely deviant. Diplophonia is present.

Stroboscopy is rated on four visual analogue scales, each 100 mm long: closure, regularity, quality of mucosal wave, and symmetry. For closure, if abnormal, a categorical choice is also recommended: in this case an hourglass-shaped pattern. Symmetry is normal in this case.

Aerodynamics: both phonation quotient (ml/s) and maximal phonation time (s).VC was 3705 ml in this example.

Acoustics: Percent ‘jitter’ and percent ‘shimmer’ on a sustained /a:/, at comfortable pitch and loudness; c corresponds to 131 Hz and g1 to 392 Hz. As for phonetography, distance of microphone needs to be 30 cm.

Subjective evaluation: provided by the patient him- or herself on a double visual analogue scale 100 mm long. The first scale concerns the impression of voice quality in the strict sense (i.e. 30/100: slight to moderate), while the second one concerns the impression of what repercussions the voice problem has on everyday social and, if relevant, professional life and activities (i.e. 50/100: moderate to severe).

Concluding remarks

Instrumentation is kept to a minimum, but is considered essential for professionals performing phonosurgery. The ENT surgeon can be assisted in performing this basic set of measurements by a qualified and trained speech therapist.

In summary, two of the dimensions must be considered objective (insofar as the subject is cooperating normally): aerodynamics and acoustics; two other dimensions are objective but rated subjectively by the examiner (however, ratings can be made blindly by a panel): recording of a voice sample and videostroboscopy; and one dimension remains totally subjective (self-rating by the patient).

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