Vocal fold electromyography in patients with endoscopic features of unilateral laryngeal paralysis

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ABSTRACT:

Introduction: Electromyography (EMG) of the larynx provides information on the electrophysiological condition of laryngeal muscles and innervation. Integration of information obtained from the EMG exams with the clinical parameters as obtained by other methods for laryngeal assessment (endoscopy, perceptual and acoustic analysis, voice self-assessment) provides a multidimensional picture of dysphonia, which is of particular importance in patients with vocal fold (VF) mobility disorders accompanied by glottic insufficiency.

Aim: The aim of this study was to evaluate laryngeal EMG records acquired in subjects with unilateral vocal fold immobilization with signs of atrophy and glottic insufficiency.

Material and methods: From the available material of 74 EMG records of patients referred for the exam due to unilateral laryngeal paralysis, records of 17 patients with endoscopic features suggestive of complete laryngeal muscle denervation were selected. The EMG study of thyroarytenoid muscles of mobile and immobile VFs was evaluated qualitatively and quantitatively at rest and during volitional activity involving free phonation of vowel /e/ [ε].

Results: In all patients, the EMG records from mobile VFs were significantly different from those from immobile VFs. Despite endoscopic features of paralysis, no VF activity whatsoever was observed in as few as 2 patients so as to meet the neurophysiological definition of paralysis. In 88% of cases, electromyographic activity of the thyroarytenoid muscle was observed despite immobilization and atrophy of the vocal fold. In these patients, neurogenic type of record was observed with numerous high-amplitude mobility units. On the basis of the results, quantitative features of EMG records indicative of paralysis and residual activity of the thyroarytenoid muscle were determined.

Conclusions: Qualitative and quantitative analysis of laryngeal EMG records provides detailed information on the condition of vocal fold muscles and innervation. EMG records of mobile vs immobile VFs differ significantly from each other. Endoscopic evaluation does not provide sufficient basis for the diagnosis of complete laryngeal muscle denervation.

KEYWORDS: glottic insufficiency, laryngeal electromyography, laryngeal paralysis, thyroarytenoid muscle, vocal fold

ABBREVIATIONS
ELS – European Laryngological Society
EMG – electromyography
LCA – lateral cricoarytenoid
LEMG – laryngeal electromyography
MU – motor unit
TA – thyroarytenoid
VF – vocal fold

INTRODUCTION

Similar to the middle ear muscles and extraocular muscles, laryngeal muscles are characterized by unique electrophysiological structure [1]. Polyneuronal innervation of the motor endplates of the vocal folds translates to their lower susceptibility to damage and high resistance to vibration, ensuring long-term preservation of laryngeal function. Being adapted to high-frequency stimulation and simultaneous activation of motor endplates, the neuromuscular transmission system of the larynx is responsible for the increase in tone and speed of response, which is crucial for airway protection [2]. Laryngeal electromyography provides full information on the electrophysiological condition of laryngeal muscles and innervation. The records are interpreted on the basis of qualitative analysis. However, the importance of quantitative analysis in the evaluation of LEMG records has been increasingly raised in recent literature [3]. The development of recording technology and the development of surgical methods for the treatment of laryngeal paralysis have brought LEMG back into the basic panel of diagnostic exams in otolaryngology and phoniatrics. Integration of information obtained from the LEMG exam with the clinical parameters as obtained by other methods for...
laryngeal assessment (endoscopy, perceptual and acoustic analysis, voice self-assessment) provides a multidimensional picture of dysphonia [4]. Personalization of treatment methods so as to achieve the best possible outcome can be facilitated by the use of LEMG in the qualification of patients for surgical treatment. Because of their anatomical and physiological uniqueness, comprehensive assessment of the function of laryngeal muscles is of particular importance in patients with vocal fold (VF) mobility disorders accompanied by glottic insufficiency.

**AIM**

The aim of this study was to evaluate LEMG records acquired in subjects with unilateral vocal fold immobilization with signs of atrophy and glottic insufficiency. In addition, the study aimed at verifying the neurophysiological characteristics of LEMG records in subjects with unilateral laryngeal paralysis being suggested as the result of endoscopic examination.

**MATERIAL AND METHODS**

From the available material of 74 LEMG records of patients referred for the exam due to unilateral laryngeal paralysis, records of 17 patients were selected. The inclusion criteria were as follows: postoperative iatrogenic paralysis and endoscopic features suggestive of complete denervation of the laryngeal muscles (atrophy, position upon abduction, reduced tension, free edge deflection, and signs of glottic insufficiency).

Patients with a history of muscle or nervous system diseases or voice disorders prior to surgery were not included in the study. All patients were followed up for more than one year, with no signs of VF mobility being restored within this period. The study group consisted of 10 women and 7 men presenting with unilateral laryngeal immobilization; the mean age of patients was 53 years (SD 8.3).

In all patients, the paralysis had been diagnosed as being due to iatrogenic complications following neck surgery, in particular thyroid surgery (14 out of 17 patients). The median time since the onset of paralysis was 20 months (6 to 72 months). In the light of current knowledge, spontaneous improvement of laryngeal function was unlikely in all patients.

Laryngeal EMG examinations of thyroarytenoid (TA) muscles of mobile and immobile VFs were carried out in line with the European Laryngological Society (ELS) guidelines by confirming anatomical reference points [5]. The records encompassed the activity of electrode insertion and the activity of the muscle upon free phonation and breathing. Patients were examined in the sitting position and under local anesthesia (2% lignocaine solution injected into the laryngeal mucosa to abolish the cough reflex, emla cream applied onto the skin over the cricothyroid space). Mobile VFs were examined first. To examine the TA muscle, after puncturing the skin within the midline at the level of the upper edge of the cartilage arch along with the puncturing of the cricothyroid membrane, the needle was guided submucosally at about 20° in the lateral and about 40° in the upward directions. The puncture was 2–2.5 cm deep. The activity of needle insertion was observed followed by observation of muscle activity at rest and upon volitional free phonation of the vowel [ε] (phonation intensity fell within the range of 75 to 80 dB). The study was carried out using 0.35 (28G) × 30 mm concentric needle electrodes. The measurements were recorded using a Neurosoft device. The recruitment of motor units (MU) was observed within a 100 ms × 100 µV window. Quantitative analysis was performed on the entire phonation record. Variables assessment included the MU potential amplitude (mean and maximum) and discharge frequency, along with the respective amplitude-to-frequency ratios. Student’s t-test was used as the statistical analysis tool to compare the parameters obtained from mobile vs. immobile VFs. The statistical significance level was defined as \( P < 0.05 \).

**RESULTS**

In all patients, the LEMG records of mobile VFs were significantly different from those of immobile VFs. As revealed by the qualitative analysis of records, 7 patients presented with extremely reduced activity of the immobile muscle.

Only 2 of these patients presented with compete absence of any activity, warranting the diagnosis of complete denervation, i.e. paralysis. In the remaining patients, neurogenic type of record was observed with numerous high-amplitude mobility units. In 88%, electromyographic activity of the thyroarytenoid muscle was observed despite immobilization and atrophy of the vocal fold. Tab. I. presents a comparison of the results of quantitative analysis of electromyographic data obtained from immobile vs. mobile VFs. The differences between the mobile and immobile sides were statistically significant for all parameters (\( P < 0.05 \)). Differences between the parameters observed in healthy vs. paralyzed VFs are presented in Tab. II. Upon free phonation, the mobile VFs presented with amplitudes and motor unit discharge frequencies amounting to approximately one half and eight times higher, respectively, than those measured at rest. These measurements were followed by the qualitative analysis of records obtained from immobile VFs. Tab. III. presents mean values of parameters within the groups of subjects with VF paralysis and signs of VF paresis. This shows that the type of muscle activity can be approximated from quantitative analysis of electromyographic results [6]. Residual activity of the muscle is indicated by LEMG records with mean amplitude of 120 µV and maximum amplitude of up to 200 µV or with the MU discharge frequency of up to 25/s and the amplitude-to-frequency ratio of > 5. Values below these means are indicative of VF paralysis.

**DISCUSSION**

According to terminological recommendations as published in 2016 by Rosen et al., only the terms “immobility” and “hypomobility” (in the case or reduced speed or range of VF motion) are warranted when vocal fold mobility abnormalities are identified in
Tab. I. Average values of parameters for mobile and immobile vocal folds.

<table>
<thead>
<tr>
<th></th>
<th>AVERAGE AMPLITUDE DURING PHONATION</th>
<th>MAXIMUM AMPLITUDE DURING PHONATION</th>
<th>MOTOR UNIT DISCHARGE FREQUENCY DURING PHONATION</th>
<th>AMPLITUDE / FREQUENCY RATIO</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mobile n = 17</td>
<td>219 SD = 72</td>
<td>1193 SD = 746</td>
<td>375 SD = 197</td>
<td>1.2 SD = 0.9</td>
</tr>
<tr>
<td>Immobile n = 17</td>
<td>144 SD = 61</td>
<td>487 SD = 539</td>
<td>63 SD = 64</td>
<td>4.8 SD = 3.3</td>
</tr>
</tbody>
</table>

Tab. II. The average difference in parameters between healthy and paralyzed vocal folds along with the relative reduction in the strength of the paralyzed fold as compared to the healthy fold (in percentage terms).

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<thead>
<tr>
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<th>AVERAGE AMPLITUDE DURING PHONATION</th>
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<th>AMPLITUDE / FREQUENCY RATIO</th>
</tr>
</thead>
<tbody>
<tr>
<td>Healthy – paralyzed</td>
<td>75.18 SD = 93.20</td>
<td>706.18 SD = 811.26</td>
<td>211.59 SD = 201.46</td>
<td>–3.29 SD = 3.26</td>
</tr>
<tr>
<td>(Healthy – paralyzed)/paralyzed</td>
<td>52% SD = 59%</td>
<td>385% SD = 541%</td>
<td>778% SD = 983%</td>
<td>–57% SD = 62%</td>
</tr>
</tbody>
</table>

Tab. III. Mean parametric values as established in groups of subjects with neurogenic VF immobilization. Subjects with complete paralysis and subjects with trace electromyographic activity were separated on the basis of qualitative evaluation of LEMG records.

As shown by the results of our study, distinguishing the features of complete denervation is not possible on the basis of endoscopic evaluation alone. According to the literature, the tone of the immobilized vocal fold depends largely on the innervation of the lateral cricoarythenoid (LCA) and TA muscles [8]. Recently, increasing number of literature reports have been published on the analysis of records obtained following a deeper (3–3.5 cm) puncture of the vocal fold, where a common response of the LCA and TA muscles can be measured due to the intertwining of respective muscle fibers. In this study, the analysis was carried out on the records obtained from the TA muscles after the needle electrode had been inserted to a depth of about 0.5 cm beyond the level of puncture activity being recorded, i.e., to the total depth of 2–2.5 cm (facilitating evaluation of TA muscle activity). In this study, we focused on the analysis of the activity of muscles directly determining the shape of the glottis, which meant that included in the study material were subjects with atrophy and deflection of the free edge of the immobile fold. Despite these endoscopic features, features of complete paralysis were found in only about 12% of subjects while signs of severe paresis could be observed in another 29%. Results of animal research confirm the low level of complete denervation following recurrent laryngeal nerve injuries [9]. More and more authors present LEMG examination results showing that the level of electrophysiological activity (either preserved or presenting in the course of reinnervation) within the immobile vocal folds is very high and reaches as much as 90% [8, 10–13]. This percentage, however, does not mean that the fold mobility will be regained. In the opinion of the authors, the standard procedure for the LEMG evaluation of patients with laryngeal mobility disorders should include the analysis of both sides of the larynx. Thanks to this algorithm, responses from both recurrent laryngeal nerves can be obtained for individual comparison of electrophysiological recordings [4].

The term “paresis” empirically suggests reduced muscle strength and partially preserved VF mobility. The term may be somewhat misleading when referring to an immobile vocal fold with preserved electrophysiological activity. On the other hand, concerns are also raised by the use of the term “paralysis” in relation to partially preserved MU activity. In the light of the requirements of the ICD-10 classification, in the cases of electromyographically verified activity within an immobilized, previously paralyzed vocal fold, the diagnosis of J38.0 (Paralysis of vocal cords and larynx) should be extended to include additional description. The use of the code G52.2 (disorders of the vagus nerve) is also warranted when referring to laryngeal nerve disorders. Further research comparing endoscopic and electromyographic features of neurogenic laryngeal injuries would be advisable to the classification of these injuries. This would lead to simplification and standardization of nomenclature while simultaneously bringing practical benefits with regard to surgical treatment decisions being made in the management of patients’ vocal fold mobility disorders.
CONCLUSIONS

Qualitative and quantitative analysis of laryngeal EMG records provides detailed information on the condition of vocal fold musculature and innervation. EMG records of mobile vs immobile VFs differ significantly from each other. Endoscopic evaluation does not provide sufficient basis for the diagnosis of complete laryngeal muscle denervation.

ETHICAL APPROVAL

All procedures performed as part of this study were carried out in accordance with the ethical standards of the local bioethics committee and in accordance with the Declaration of Helsinki as adopted in 1964. The study was approved by the local Bioethics Committee, decision no. KB.1FPS 1/2021.

REFERENCES
