ORIGINAL ARTICLE

Laryngeal Electromyography in Diagnosis and Treatment of Voice Disorders

Isabel García-López, a,∗ Susana Santiago-Pérez, b Julio Peñarrocha-Teres, a Antonio J. del Palacio, a Javier Gavilán a

a Servicio de Otorrinoaringología, Hospital Universitario La Paz, Madrid, Spain
b Servicio de Neurofisiología Clínica, Hospital Universitario La Paz, Madrid, Spain

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PALABRAS CLAVE
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Abstract
Introduction and objectives: Laryngeal electromyography, together with clinical evaluation, is a valuable tool for voice disorder management. It assesses the integrity of laryngeal nerves and muscles, contributing to the diagnosis of many diseases, especially laryngeal movement disorders. Our purpose was to describe the experience of the first Spanish series with laryngeal electromyography in evaluating voice disorders.

Methods: A prospective study was designed to evaluate laryngeal movement disorders with laryngeal electromyography. Both the cricothyroid and thyroarytenoid muscles were tested routinely and, in some cases, the posterior cricoarytenoid muscle. The laryngeal electromyography technique and result interpretation were performed by a laryngologist and a neurophysiologist.

Results: We included 110 patients, with the most common symptom being dysphonia. Laryngeal electromyography was performed in 85% of cases. Primary diagnosis before electromyography was laryngeal immobility. Positive predictive value for diagnosis in cases of paralysis was 88%.

Conclusions: Laryngeal electromyography is a useful adjunct, together with clinical evaluation, for diagnosis and management of motion abnormalities in the larynx in patients who present with dysphonia.

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Resumen
Introducción y objetivos: La electromiografía laringea es una herramienta útil en el diagnóstico y tratamiento de los trastornos de la voz. Proporciona información acerca del estado de los nervios y músculos laringeos completando la evaluación diagnóstica de un gran número de afecciones, fundamentalmente los trastornos del movimiento laringeo. Presentamos la primera
Laryngeal electromyography in diagnosis and treatment of voice disorders

Introduction

Electromyography (EMG) is a useful diagnostic tool in the evaluation and diagnosis of neurological diseases. This technique can be used in Neurolaryngology, which comprises the study of diseases caused by sensory and motor alterations of the larynx. The earliest works in the field of laryngeal EMG were published by Faaborg-Andersen and Buchta in the 1950s, with the technique being introduced by Weddel in 1944. However, the technique is not used routinely by most of the Spanish otolaryngologists. This is not the case in other fields of Otolaryngology, such as facial nerve examination, in which EMG is commonly employed.

Most otolaryngologists who use laryngeal EMG habitually for the evaluation of voice conditions consider it a very useful tool, especially in cases of vocal cord immobility.

The Neurolaryngology study group of the American Academy of Otolaryngology gathered a panel of experts to define the usefulness of EMG in laryngeal diseases. The conclusions of this panel were the following: EMG is important for the diagnosis of laryngeal mobility disorders, serves to guide the injection of botulinum toxin into the laryngeal muscles and is a useful tool in laryngology research.

Perhaps the most established indication, apart from its therapeutic use to guide injection of botulinum toxin, is the diagnosis of laryngeal immobility, and in particular its role in the differential diagnosis of mechanical fixation and neurogenic lesion or true vocal cord paralysis.

Although there are no prospective and double blind studies in the literature on the usefulness of EMG in neurolaryngological disorders, there are currently numerous publications which discuss its usefulness as a complementary tool in the diagnosis thereof.

To our knowledge, there is no Spanish series describing the usefulness of laryngeal EMG through a descriptive study. The aim of this work is to describe our experience with EMG in the diagnosis and treatment of laryngeal movement disorders, with the objective of developing a protocol that includes the use of laryngeal EMG and to assess its usefulness as a diagnostic tool.

Methods

We designed a prospective study by creating a study protocol for all patients referred to the Voice Pathology Unit of our hospital with a diagnosis of laryngeal mobility disorder. We present the results obtained after 2 years of work with this protocol (2010 and 2011).

We consider a laryngeal mobility disorder to be present in those cases where movement asymmetry or stillness of one or both vocal cords is observed, both in abduction–adduction and in elongation when emitting high tones, as well as the presence of spontaneous or unintentional movements.

All patients underwent the usual explorations carried out at our Unit: medical history, subjective assessment by the patient through the Vocal Disability Index, psychoacoustic evaluation through the GRABS (grading, roughness, asthenia, breathiness, strain) index, aerodynamic assessment by maximum phonation time and s/a ratio, acoustic analysis and both rigid and flexible endoscopic evaluation with both fixed and stroboscopic light.

Of these, the most important examination to decide the indication for EMG is flexible fibroscopy, which enables an assessment of the larynx under physiological conditions. Firstly, we conducted an observation of the larynx at rest while the patient breathed, designed to measure the tone and position of the cords, as well as the eventual presence of their paradoxical movement, with adduction in inspiration and abduction in expiration. We also assessed the presence of abnormal movements, such as tremor or myoclonus.

Secondly, we conducted an evaluation during phonation, both with a sustained vowel and with a conversational voice and singing voice. In the case of laryngeal dystonia we observed abnormal spastic movements during phonation activity, which typically diminished or disappeared in the singing voice. By contrast, in muscle tension dysphonia, sometimes very difficult to distinguish from spasmodic dysphonia, there were no variations between conversational and singing voice. In order to assess fatigability and asymmetries in adduction–abduction we requested patients to repeatedly emit the phoneme /i/ with a deep inspiration between repetitions.
Following this assessment and after confirming the presence or suspicion of a laryngeal mobility disorder, we offered patients the possibility of conducting a laryngeal EMG with diagnostic or therapeutic purposes.

The EMG was performed in the operating room, while patients rested in the supine position with an extended head. Patients were awake and in no case was it necessary to use local anaesthesia. All procedures were performed in the presence of an ENT specialist, who performed the insertion of electrodes into the laryngeal muscles, and a specialist in Clinical Neurophysiology, who conducted the registration with the electromyography apparatus. Interpretation of results was performed jointly by both professionals. We also accounted for the collaboration of other specialists in our unit for the definitive diagnosis and treatment of these patients: a phoniatrician, a neurologist, and a speech therapist.

The muscles studied were both cricothyroids and thyroarytenoids in all cases and the posterior cricoarytenoid muscle in some subjects in whom abduction spasmodic dysphonia was suspected. We used coaxial needle electrodes (bipolar), which were introduced by an anterior transcervical route, according to techniques described in the literature.9,12–14

In order to reach the cricothyroid muscle, the needle pierced the skin at the midline from the superior edge of the cricoid cartilage and progressed laterally, at approximately 45°, towards the outer side of the thyroid wing until electrical activity was observed.

The thyroarytenoid muscle can be reached by several methods: through the skin and cricothyroid membrane at the midline to enter the laryngeal lumen and from there advancing upwards and laterally to reach the muscle, or directly crossing the thyroid wing from lateral to medial at the level of the vocal cord. The first technique has the drawback of causing coughing and the second case is very complicated in cases of cartilage calcification. Therefore, we preferred to employ a third route, which involved crossing the skin in the midline at the level of the superior edge of the cricoid cartilage, and then moving through the subcutaneous cellular tissue with a lateral inclination of 45° towards the inferior edge of the thyroid cartilage. Once this was reached, the needle was passed under it to the vocal muscle through the elastic cone without entering the glottis, thus preventing stimulation of the sensory receptors in the laryngeal mucosa. In our experience, this approach produced minimal discomfort for patients and did not require the use of anaesthesia.

There are 2 approach routes for the posterior cricoarytenoid muscle: the first, crossing through the cricothyroid membrane at the midline and the glottic lumen to reach the muscle through the lamina of the cricoid cartilage on either side, and the second, which is the one we used, rotating the larynx and crossing the skin at the level of the posterior edge of the thyroid wing in its inferior half and then progressing towards the cricoid seal until the muscle is reached.

Confirmation of the correct positioning of the electrodes was done using the following protocol:

- For the cricothyroid muscle: electrical silence with breathing and prelaryngeal muscle contraction against resistance and presence of recruitment of motor unit potential (MUP) with the emission of high tones.
- For the thyroarytenoid muscle: silence during breathing and motor activity (MUP activation) with phonation.
- For the posterior cricoarytenoid muscle: motor activity during breathing and silence during phonation.

The electromyographic parameters evaluated were:

- At rest:
  - Presence or absence of spontaneous denervation activity (fibrillations, positive waves).
  - With voluntary motor activation:
    - Presence or absence of MUP.
    - MUP parameters (amplitude, duration, morphology).
    - Presence of synkinesias.

We used the criteria established in the literature for the electromyographic diagnosis of movement disorders.12–23

In cases of acute laryngeal paralysis with a known onset, the EMG was performed at least 3 or 4 weeks after the onset of symptoms, as described in the literature.9

We assessed the presence of denervation at rest and decreased recruitment for the diagnosis of acute lesions. Chronic injuries showed a reduced recruitment with polyphasic MUP of increased amplitude and without denervation at rest.24

Lesions were divided into mild, moderate, severe, and very severe according to reduction in recruitment of MUP activated during voluntary contraction with maximal effort: mild-moderate, if the deficit was small, severe if activation was very deficient and very severe if there was no activation of MUP (complete lesion). The difference between acute and chronic lesions was that denervation at rest was present in the acute. Synkinesias were diagnosed when there was laryngeal muscle contraction (thyroarytenoid muscle) of greater intensity during breathing than during phonation.15,26

The presence of dystonia was established by the existence of normal activity at rest and a spastic recruitment pattern during phonation (adductor dystonia when the pattern appeared in the thyroarytenoid muscle and abductor dystonia when it appeared in the posterior cricoarytenoid).15,20,21

Tremor was diagnosed by observing a rhythmic recruitment pattern at rest and/or during phonation.27

Muscle tension dysphonia (MTD) was characterised by the presence of sustained, non-rhythmic electrical activity both at rest and during activity, with difficulty or impossibility for relaxation.13

MTD was considered primary when its aetiology was a purely functional problem (there was no organic lesion), characterised by a hyperkinetic behaviour with excessive supraglottic contraction, both anteroposterior and lateral. Secondary MTD is caused by a compensator mechanism underlying an organic problem, a failure or defect in glottic closure.28

Botulinum toxin injection employed monopolar needle electrodes, with a toxin injection system through the cannula. The insertion technique was similar to that described previously. The toxin was injected once it had been
confirmed that the target muscle had been reached through the previously described manoeuvres.\textsuperscript{29}

**Results**

A total of 110 patients (66 females: 60\% and 44 males: 40\%) were referred to the Voice Pathology Unit of our service with a diagnosis of laryngeal movement disorder.

The age range was between 14 and 86 years, with a mean value of 57 years. A total of 40 patients (36\%) used their voice as a fundamental tool in their work.

Regarding personal history related to diagnosis (Table 1), the largest group was that which reported no history of interest, followed by those who had undergone thyroidectomy.

The most common presentation symptom was dysphonia (79\%), followed by dyspnoea (14\%) and dysphagia and/or choking (10\%).

The primary diagnosis leading to the indication of laryngeal EMG was vocal cord immobility (Table 2).

Of the total 110 patients, 94 underwent laryngeal EMG (85\% of cases). The 16 cases in which it was not conducted all belonged to the group suffering laryngeal immobility/hypomobility. In 5 cases (5\%), the reason was rejection by the patient. The remaining 11 cases (10\%) were due to laryngeal paralysis post-thyroidectomy and were resolved within the period elapsed between the assessment in consultation and performance of the EMG.

<table>
<thead>
<tr>
<th>Table 1 Personal History Related With the Diagnosis.</th>
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<td>History</td>
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</tr>
<tr>
<td>Idiopathic</td>
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<tr>
<td>Thyroidectomy</td>
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<tr>
<td>Laryngeal surgery</td>
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<tr>
<td>Other H and N surgeries</td>
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<td>Neurological disease</td>
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<td>Thoracic surgery</td>
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<td>Thyroid involvement</td>
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<td>H and N, head and neck.</td>
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</table>

Among the group of patients with vocal cord immobility or hypomobility, 82\% (47 cases) presented an abnormal result. The EMG revealed that 26 patients suffered injury of 1 nerve, 17 of 2 nerves, 2 of 3 nerves and 2 of 4 nerves.

A total of 14 cases suffered neurogenic lesion of the left superior laryngeal nerve (registry in the left cricothyroid muscle), 10 of the right superior laryngeal nerve (registry in the right cricothyroid muscle), 31 of the left recurrent laryngeal nerve (registry in the left thyroarytenoid muscle), and 19 of the right recurrent laryngeal nerve (registry in the right thyroarytenoid muscle).

The positive predictive value of the EMG for diagnosis was 88\% in the case of paralysis.

In the group of abnormal vocal cord movement, laryngeal EMG contributed to the differential diagnosis between spasmodic dysphonia and vocal tremor, as well as the differential diagnosis between abductor and adductor spasmodic dysphonia in doubtful cases judging from symptoms. The EMG record enabled us to observe whether there was dysphonia/spasm or tremor, specify its frequency and verify which intrinsic muscles were affected.

In the MTD group, it enabled the differential diagnosis between primary and secondary MTD, with signs of underlying neurogenic lesion being found in 1 patient (8\%).

In cases of vocal cord dysfunction, it enabled us to rule out the presence of an underlying phenomenon of synkinesis which could be the cause of paradoxical movement.

Furthermore, laryngeal EMG was used to guide injection of botulinum toxin in all patients requiring this treatment (22 cases).

**Discussion**

The results obtained confirm that laryngeal EMG contributes to the diagnosis and treatment of patients with laryngeal movement disorders.

EMG may be useful in diagnosing a considerable number of diseases affecting the laryngeal muscles and their innervation.\textsuperscript{24}

These include the assessment of the recurrent laryngeal and superior laryngeal nerves in cases of vocal cord immobility or hypomobility, the prognosis of laryngeal paralysis, differentiation between paralysis and arytenoid fixation, the differential diagnosis between paralysis of the first or second motor neuron, diseases caused by alterations in neuromuscular transmission, myopathies, laryngeal dystonia, and tremor, the assessment of patients with psychogenic dysphonia or those with MTD who do not respond to rehabilitation treatment, assessment of paradoxical movement of the vocal cords and the presence of laryngeal synkinesias in cases of previous paralysis. Regarding treatment, it enables monitoring of botulinum toxin injection into the intrinsic muscles of the larynx.

It is sometimes difficult to differentiate spasmodic dysphonia from vocal tremor, and either entity from MTD. The diagnosis is usually obtained by clinical examination, but sometimes, the hyperfunctional compensatory mechanisms occurring mainly at the supraglottic muscle level can make the diagnosis extremely difficult.\textsuperscript{27} The therapeutic approach for each of these 3 entities is completely different. EMG can be of great aid\textsuperscript{13} by enabling each set of

<table>
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<th>Table 2 Diagnoses Indicating Laryngeal EMG.</th>
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<td>Diagnosis</td>
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<td>VC immobility-hypomobility</td>
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<tr>
<td>Left VC</td>
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<tr>
<td>Right VC</td>
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<tr>
<td>Bilateral</td>
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<td>VC spasms or tremor</td>
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<td>MTD</td>
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<td>VC dysfunction</td>
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<td>Laryngeal granuloma</td>
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MTD, muscle tension dysphonia; VC, vocal cords.
symptoms to be differentiated from the others, even specifying the frequency of tremor, which can guide us towards the underlying neurological disease, or documenting which intrinsic muscles are involved. In the case of treatment with botulinum toxin, this allows us to be much more selective during its injection, thus minimising side effects. In the case of spasmodic dysphonia, whose diagnosis is mainly clinical, laryngeal EMG is useful to differentiate cases in addition from abductor spasmodic dysphonia, in addition to guiding the injection of botulinum toxin.14

Another aspect to be taken into consideration in the diagnosis of MTD involves secondary MTD cases, that is, those in which MTD is a compensating mechanism. This group would include all diagnostic entities which are based on a defect of glottal closure, such as paralysis or paresis, presbyphonia or vocal scars.10,30 Thus, patients with "hypokinetic" dysphonia may present apparently "hyperkinetic" findings. In our series, this occurred in 8% of cases. Moreover, some organic lesions, such as vocal nodules which do not respond to rehabilitation treatment or laryngeal granulomas, can be caused by a compensating hyperkinetic component.30,31 In these cases, the EMG can rule out the presence of an underlying neurogenic lesion, both in the recurrent and the superior laryngeal nerves, the latter being more frequent in the case of granulomas.32

A close collaboration with phoniatricians and speech therapists is crucial in order to obtain a correct indication in this group of patients. These specialists should suspect the lesion in cases which do not improve with adequate treatment.

In the case of vocal cord dysfunction, the typical symptoms are dyspnoea with stridor triggered by various stimuli. The EMG allows a differential diagnosis with the existence of a neurogenic lesion that has evolved with aberrant reinnervation, thus causing synkinesias.33

Laryngeal EMG can also be useful in the study of dysphonia and dysphagia in patients suffering from neurological diseases of the second motor neuron, such as amyotrophic lateral sclerosis, Guillain-Barre syndrome, polymyelitis, and other degenerative disorders of the anterior horn, nerve root or peripheral nerve.2

In patients with laryngeal immobility, EMG is widely considered as the key to establishing the presence of a neurogenic lesion. It is the only diagnostic method capable of establishing whether an asymmetry in vocal cord or arytenoid mobility is due to laryngeal nerve injury. These asymmetries are common in the laryngoscopic assessment of dysphonia.30,34

At present, thanks to the experience with EMG, we know that laryngeal paralysis is not an all-or-nothing phenomenon, but rather a continuum of neurogenic dysfunction which can range from total to partial denervation, as well as including varying degrees of reinnervation.35

The presence of denervation and reinnervation patterns suggests the existence of paralysis, whereas a normal EMG would point towards arytenoid fixation. A denervation pattern is characterised by fibrillation potentials, complex repetitive discharges, and positive waves. A reinnervation pattern would show polyphasic potentials with increased parameters.36

In cases of normal EMG in the presence of immobility or hypomobility evidenced by clinical examination, the cause of immobility must be sought in a fixation of the cricoarytenoid joint due to luxation, cricoarytenoid arthritis or else a scar or synchiae in the posterior commissure,9,37 in most cases due to trauma or prior intubation.37

Laryngeal EMG also provides information about the anatomical location of a lesion.9 In the case of lesions of the first motor neuron there is no spontaneous activity and the MUP present normal characteristics. In lesions of the second motor neuron-peripheral nerve there is reduced recruitment with abnormal MUP and there may also be denervation at rest.14

EMG findings can help us to decide which radiological tests are indicated in the case of idiopathic paralysis. If only the recurrent laryngeal nerve is affected, it will be necessary to assess the route of the vagus nerve from the skull base to the mediastinum by computed tomography (CT). However, in case of involvement of both nerves, the superior laryngeal and recurrent laryngeal, we will opt for a cerebral and skull base magnetic resonance imaging (MRI) scan along with a cervical CT.37

Furthermore, EMG is useful in determining whether a lesion is acute or chronic, thus allowing us to classify it according to its severity, which is undoubtedly useful in providing a more or less definitive treatment for patients. Another aspect that is clear from the above is the usefulness of EMG as a prognostic tool in the case of laryngeal paralysis.7,9,10,37-39

In a recent meta-analysis, the absence of spontaneous activity, normal or near-normal MUP morphology and recruitment were the most important findings associated with a good prognosis. By contrast, the presence of spontaneous activity or absence or decrease of MUP recruitment indicated a poor prognosis. The statistically significant conclusion was that those patients with a poor prognosis in the initial EMG had a low probability of their paralysis being resolved. According to our work, this was not the case in terms of EMG as a predictor of good prognosis or complete recovery, probably due to the complexity of the laryngeal reinnervation phenomenon,39 which has the main problem of existing adductor and abductor fibres travelling alongside each other within the recurrent laryngeal nerve. This can lead to paradoxical or ineffective reinnervation when this nerve is injured.25,36,40

The choice of treatment in patients with laryngeal paralysis should be influenced by the prognosis of the lesion, the severity of symptoms and the vocal needs of each patient. In cases where the EMG indicates a favourable prognosis, we can opt for conservative treatment or a temporary surgical procedure with more confidence. On the other hand, in patients with severe symptoms or with high professional vocal needs where the laryngeal EMG shows a poor prognosis, we will opt for a more definitive surgical procedure with minimal delay.37

In our series, we observed a tendency towards better evolution by patients with lower grade lesions in laryngeal EMG, although the number of cases was too small for the results to be statistically significant.

In our opinion, a key aspect for EMG to become a useful tool in clinical practice is a close collaboration between Otolaryngology specialists and Clinical Neurophysiology specialists. In our case, both professionals were involved in conducting the test and, above all, in interpreting the results.
together, thus helping to make the most of the data obtained and optimise the results.

Conclusions

Laryngeal EMG is a test that can be performed with minimal risk and minimal discomfort for patients. It can be used in combination with clinical examination for the diagnosis and treatment of laryngeal movement disorders which commonly appear with dysphonia. Moreover, it enables us to assess the neuromuscular condition of the larynx and provides information about the location of the lesion, the time of evolution and the prognosis for recovery of laryngeal paralysis, distinguishing it from arytenoid fixation. The results aid in the selection of other diagnostic tests and in decisions about the timing and type of treatment.

The indication to perform a laryngeal EMG should be based on clinical history and examination of patients. The data obtained should be interpreted in a clinical context and with the collaboration of a multidisciplinary team, formed at least by an otolaryngologist and a neurophysiologist. Close collaboration between these 2 professionals is essential to include laryngeal EMG in the study protocol for voice problems.

Its use is likely to increase in the future, in parallel with a growing interest in laryngeal neurophysiology.

Conflict of Interests

The authors have no conflict of interests to declare.

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