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## The singing voice

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#### Abstract

Singing voice is a special subgroup within the field of voice. In addition to the differences in physiology between singing and speaking voice, singer patients are often regarded as a challenge for the otolaryngologist.

The reason for this is probably that the field of voice has not received as much attention as others in our speciality.

Moreover, in the case of singers, empathy is vital in the doctor-patient relationship, and, as in many other cases, it forms part of the therapeutic effect. In order to achieve this, the physician has to know what singers are and which are the main pathologies they suffer, how they are formed and how they are expressed.

This review offers an overlook of the pathological-physiology of singing voice from a double point of view, scientific and artistic, which in the case of singing are inevitably linked. © 2009 Elsevier España, S.L. All rights reserved.

## La voz cantada

#### Resumen

La voz cantada representa un subgrupo especial dentro del campo de la voz. Además de caracterizarse por aspectos diferenciales en cuanto a la fisiología, los pacientes-cantantes son con frecuencia un reto para los otorrinolaringólogos.

Esto es debido probablemente a que la formación específica en nuestra especialidad en el campo de la voz no ha tenido el protagonismo que han tenido otras áreas.

Pero además, en el caso de los cantantes, es imprescindible la existencia de una gran empatía en la relación médico-paciente que aquí, como en otras muchas ocasiones, forma parte del efecto terapéutico. Para lograrla, es imprescindible que el otorrinolaringólogo sepa qué es un cantante, cómo se forma, cómo se expresa, y qué patología le afecta.

Esta revisión pretende dar una visión general de la fisiopatología de la voz cantada desde el doble aspecto científico y artístico, que, en el caso del canto, van indefectiblemente unidos. © 2009 Esevier España, S.L. Todos los derechos reservados.

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#### Introduction

The history of voice, singing and specifically the singing voice can generally be approached in parallel fashion from either an artistic or a scientific point of view. Today it seems obvious that the approach to learning about the singing voice should include these two aspects.

In practice, it is often not like this. Consequently, we still find singing teachers and singers today who prefer to know nothing about how the voice works because they believe it can "prejudice" their art, and we also find scientific professionals who work with the singing voice (otolaryngologists, phoniatricians, and speech therapists) who are completely unaware of the artistic aspect that is inevitably linked to the singing voice.

This review presents a view of the singing voice from both aspects: scientific and artistic, both of which we cannot separate when treating singers at our surgeries.

#### History of singing and the singing voice

Claudio Galeno was the founder of laryngology and father to phoniatrics and voice science. He was the first to describe the larynx with its three main cartilages and muscles. He established that the voice was produced in the larynx, which he called *principalissimum organum vocis*, but he compared the larynx to a flute, thinking that the frequency and intensity variations were produced by modifying the narrowing of the glottis.<sup>1</sup>

We had to wait until 1741, when Antoine Ferrein described more accurately how sound in the larynx was produced through the vibration of vocal cords, with the chord tension changing to produce different tones: we owe the term vocal cords to him.

From the singing point of view, knowledge about the singing voice comes from the Italian tradition (the so-called Italian singing school), which started with the birth of opera in the 17th century. The first opera in history whose score is still kept is that of *Orfeo* by Claudio Monteverdi, which made its debut in 1607.

In fact, singing was taught in the 17th and 18th century in a totally practical and instinctive way. The teacher would teach based on example and the students would receive classes daily. The teaching method was made up from learning different "vocal exercises" occasionally designed by each singing teacher, directed at having the ability to carry out what we could call "specific singing vocal skills" that do not exist in the speaking voice and differentiate it from the singing voice. Nearly all of them are still now called after the Italian terms, such as legato, stacatto, coloratura, messa di voce, trino, etc. Specific exercises existed (and still exist) to "master" each of them. All these "skills" are then found in music arias. This teaching method has remained to the present day, and is the method that the majority of singing teachers still use  $now^2$ 

But if in the history of singing and voice as a science there is a figure uniting scientific and artistic aspects into one, it is without a doubt Manuel García, a Spanish singer and singing teacher, who explained many of the singing voice phenomena through his observations. Born in 1805 and the son of Manuel García, this Manuel was a great, internationally renowned tenor; he was the brother of María Malibrán (also a great singer) and Pauline Viardot (a singer, pianist and composer). He sang until he was 20, when he retired due to vocal problems. At the age of 24, he started teaching and by 1835 he was professor of the Paris Conservatory. In 1847 he published his renowned Traité Complet de L'Art du Chant. He went to London during the 1848 revolution together with his students. many of whom were French nobility. In 1854, while walking through the Tuileries in Paris, he saw the sun reflected on the Palais Royal windows and had an idea of how to see the vocal cords. He bought a dental mirror and managed first to see his own cords and then those of his students through the reflection of sunlight. This revolutionary invention was presented at the Royal Society of Medicine in 1855. We owe indirect laryngoscopy to him, which revolutionised voice problem diagnosis in singers. 3,4

Then in the 20th century, another Spaniard, Jorge Perelló, put forward a muco-wave theory (1962), which explained vocal cord vibration.<sup>5</sup> This, along with the histological cord structure description carried out by Minoru Hirano in 1975, allowed us to understand the physiology of the voice.

#### Vocal-physiology technique of the singing voice

Not everyone will become a singer, but we all have the same instrument. The human voice can be trained to produce a sound that is acoustically more efficient (in terms of resulting energy/ energy expended), which has to fill a rather large sound space without the help of an amplifier.<sup>6</sup>

At any rate, not everybody has the vocal instrument that allows them to be an opera singer or soloist. This rare gift is based firstly on a physiological base structure.<sup>7</sup> Physiological differences are partly responsible for changes in the final sound produced by the voice.

The second factor is acquiring a vocal singing technique. On this note, there are many professional singers who have experienced an important change in quality, volume and tone of voice thanks to technique. It has even been demonstrated that trained singers activate different brain areas, which are larger as a response to musical stimulus compared to those of non-singers.<sup>8,9</sup> Vocal technique is therefore a tool that allows us to achieve maximum voice efficiency with minimum energy expended.

Knowledge of the singing voice technique is important to otolaryngologists, because (as we shall see later on) it is always present to a greater or lesser degree in any vocal problem that affects a singer.

On the other hand, voice technique in the singing voice is based on the physiology of the components that take part in voice production. This is true despite the fact that singers, as we have previously stated, often learn how to sing in a practical way, without really knowing what happens at a physiological level.

From the physiological point of view, we could divide sound production components into three: the source of energy: *breathing*, the sound source for speaking and singing sounds: *vocal cord vibration* and the modifiers of that "base" sound: *the vocal tract*.

The vocal singing technique is based on the same principles as those of the speaking voice and consists of the following elements:

- Body posture
- Breathing
- Emission
- Resonance
- Articulation

There are also three other characteristics of the physiology of the singing voice: Tuning, vibration and the concept of vocal registration. Below, we shall briefly describe what each of these aspects comprises.

#### Body posture

Acquiring good body posture is essential, both because it is directly related to vocal emission and because the public not only listens to singers but sees them, either at live concerts or in the media.

Singing teachers regularly use mirrors. Singers who have received technique lessons (all classical singers and quite a lot of pop singers) are consequently used to looking after and working on their body posture regularly.

The old style singing schools speak of a singer having a "noble" posture, that is, erect but without tension at the neck and at the same time well supported on the floor. Today singers trying to achieve a correct body posture have included knowledge from other schools, such as the Alexander or Feldenkrais techniques that speak more of "using the body in motion" than a specific position.

#### Breathing

Breathing techniques in singing have not varied much over history. Non-phonetic breathing is made up of active inhalation and passive exhalation. Exhalation becomes much more active than inhalation when speaking and especially when singing.

A very common mistake among singers is thinking that the diaphragm is the main muscle that controls vocal emission during exhalation. In reality the diaphragm relaxes during exhalation and the abdominal, together with the internal intercostal, muscles are responsible for exhalation. Breathing during singing tries to maintain a specific subglottic pressure that is enough to emit a certain tone and intensity, but not too much to produce damage through overload.<sup>10</sup>

#### Emission

Emission in singing refers to the larynx. The basic sound is produced, the same as for the speaking voice, according to the myoelastic-aerodynamic theory by virtue of the production known as the vocal cycle.

Vocal technique pursues correct glottic closure with a stable larynx position, which is achieved by the coordination of not only the extrinsic but also the intrinsic

muscles. Too firm a glottic closure or a larynx that is too high to sing will result in a tense and rather inflexible voice. On the contrary, a defect in glottic closure will give us an airy voice, or in singing language, one with little support.

Correct glottic closure gives the singer a clean flexible voice. It also contributes, together with resonance, to the presence in the singing voice of a projected sound that "runs" right to the back of concert halls without any apparent physical effort from the singer.

Pespiratory activity is related to laryngeal activity in one of the basic characteristics that differentiate speaking voices from singing voices: the production of different tones and frequencies. The increase in tone (or the emission of high notes, in singing language) can be carried out by increasing subglottic pressure and thus muscle tension in the vocal muscle (this is how pop singers generally do it), or through elongating the vocal cords (relaxing the vocal muscle and contracting the cricothyroid muscle)<sup>11</sup> with less variation in subglottic pressure. The latter is the mechanism most used by lyrical singers, especially experienced ones.<sup>12</sup>

#### Resonance

The sound produced in the larynx is similar to a buzz that is very different to the wonderful voice of some singers. This laryngeal sound is made up of a main tone and tones called harmonics in musical terms or overtones in English literature.

Any sounding board of any instrument boosts some of these harmonic tones and deadens others. In the case of the human voice, the sounding board is the supraglottic tract, which goes from the vocal cords to the mouth (or up to the nose when we emit nasal consonants).

Voice formants are precisely those harmonics or group of harmonics that are boosted, which are emitted with greater energy, and finally have greater intensity. There can be up to 6 formants in the human voice, although not all of them always appear. It seems that the first two formants (the deepest) are responsible for vocal definition or understanding, while formants from the third onwards are related more to the vocal tone (this allows us to differentiate different voices).

The singer learns through technique to voluntarily change the form and position of the mobile components in the vocal tract (larynx, soft palate, tongue). The aim of these changes is firstly, to achieve maximum vocal potential with minimum muscle effort (with less subglottic pressure), that is, to amplify the sound emitted by boosting natural resonance to the maximum. As we have previously stated, for this to be produced there must firstly be good breathing control and efficient glottic closure. Secondly, singers are capable of voluntarily changing their tone. Although an individual might be able to recognise Maria Callas or Elvis Presley in the first line, neither of them would sing an aria or love-song the same way as a song speaking of betrayal. In these two cases, there would be a change in what in singing language we call voice "colour" and this is always up to interpretation.13

In the case of classical singers, there is another aspect that differentiates them from the rest. Classical

singers must make themselves heard without a microphone in a rather large hall and above the instrument that accompanies them.<sup>14</sup> At first glance, it does not seem that difficult to compete in volume with a guitar or a harpsichord, but what happens when we have to sing with a symphonic orchestra? Obviously, if it were a question of decibels, it would be completely impossible for any singer to be heard. The trick is not in the quantity but in the quality: a voice that projects itself or that "passes" or "runs" (in singing language), that is, that is heard in the final row of the theatre, does not have to be a very powerful voice at a "short distance".

Consequently, in singing we talk about big or small voices according to the volume that they are able to achieve over a short distance (we could classify them with a sound level metre at the surgery). But all classical singers, whether they have big or small voices, must project their voice if they want to sing in a concert hall.<sup>15</sup>

Going back to technique, vocal projection in a singer is achieved through boosting energy to around 2,500-3,000 Hz in the spectrogram. This boost is given the name of singer formant, and is more or less constant in lyrical voices.<sup>16</sup> It is this sound energy concentration that makes the singer's voice go over a large symphonic orchestra<sup>17</sup> as for example in Wagner operas, in which any of the brass instruments have a lot more "volume" than any voice in the history of singing.<sup>18</sup> This is how, for example, you can hear Birgit Nilsson singing a Tristan and Isolda aria from Wagner, and she can be heard perfectly over the orchestra with no apparent effort. www.youtube.com/ watch?v=\_mOA8pZ\_ I4M

#### Articulation

The existence of music over text is what differentiates singing from the speaking voice and the existence of text over music is what differentiates it from the rest of musical instruments. In fact, this is what makes singing superior to any other artistic expression, whether theatrical or instrumental.

Understanding the text in singing is therefore essential for the message to reach the listener. We have already said that this depends on the height of the first two formants. These formants have a rather constant frequency in each of the vocals.

However, in lyrical voices, and especially in the soprano voice (the one that emits the highest sounds), a sound is emitted that is in fact higher that the frequency of the first formant. This means that the latter cannot exist, which consequently produces a reduction in understanding the text because it is phonetically impossible to emit some of the vocals. For this reason, sopranos change the dimensions of their vocal tracts in such a way that the first formant of each phoneme rises to be above the main frequency.<sup>19-21</sup>

#### Tuning

An aspect that does not properly form part of vocal technique but that is probably the most essential to be able to sing is the ability to sing in tune or with precise emission

of a frequency. To do this, it is necessary to have a correct perception of sound (tone or frequency that is heard), which in music is known as an ear for music, followed by a correct emission of the tone that one is trying to emit.

In reality, this essential singing aspect is only seen by the public in live music performances, as sound technicians in studios are currently able to substantially change the tuning of the voice recorded onto a record. This explains why some singers who sound fantastically in tune on records leave a lot to be desired during live shows.

#### Vibrato

Vibrato is a quality that is characteristic of the singing voice, especially in lyrical voices, but it is also present in other singing styles. It consists of an oscillation not only in the main tone or frequency but in the intensity of the sound, providing a great tonal richness.<sup>22</sup> Vibrato can be characterised by two parameters: amplitude (measured in hertz or oscillation semitones) and frequency<sup>23</sup> (number of cycles or oscillations per second).<sup>24</sup> It is developed in parallel to the vocal technique.<sup>25</sup>

#### Registers

For singers to be able to emit all the range of sounds that they are capable of, certain adjustments must be made to the organs that make them, to allow them to cover all the vocal extension.

The registers are different "areas" in the vocal range whose tone is similar and that are emitted with a similar "mechanism" (which is how Manuel Garcia defined them). However, the term "register" can sometimes be misleading, as it is not always used in publications with the same meaning. These different meanings depend on the observation source from which the phenomenon is studied: the singer's own proprioceptive view (chest voice, head voice, falsetto voice), that of the auditorium, acoustic (bass, medium or high register), or laryngoscopic (mechanisms I and II are terms commonly used by phoniatricians and speech therapists). Some have more of a bearing on the mechanism on which the larynx works, and some more on the resonance cavities and the sensations as to "where" the sound vibrates.<sup>26,17</sup>

With respect to the laryngeal mechanism, differences can be established through electroglottography or videokymography,<sup>27</sup> which relate vocal signal to glottic contact. It is thus observed that, on going up the scale through a glissando (going through all frequencies with the voice without interruption from bass to high), there is a point where the signal amplitude is brusquely reduced. This corresponds to a reduction in cord contact surface, which is the same as a thinning of the vocal cord: this finding is a characteristic of the step from mechanism I to mechanism II. This phenomenon does not depend on gender or on vocal training level.<sup>28</sup>

#### Examination of the singer

In the same way as in all other medical disciplines, it is essential for a medical history to be carried out. Adhering to specific aspects of the singer's history, we should know that the individual usually comes to consult on quite a specific voice-related problem. The type of consultations that are not unusual are: "I notice that my voice has less shine from high G, it is more opaque" or "when I sing Baroque music, with a flatter voice, I notice something strange in the pace". In these cases, instead of starting to examine the singer without having any idea of what he or she has said, it is worth wasting a little more time and encouraging the patient to explain it in other words to try and understand what exactly is happening.<sup>29</sup>

Another important aspect that we have to take into account is the high level of anxiety that these patients sometimes have when they come to our surgeries. They are conscious that their problems are to a certain extent "different" to the rest of patients and they are often afraid *a priori* of not being understood by the doctor, which can make symptom description become even more difficult. It can consequently be very useful to use guides to carry out a medical history on singers (perhaps the most thorough is that published by Sataloff).<sup>30</sup>

Other times consultations do not refer to a problem in the voice itself, but to a different proprioceptive feeling that the singer does not recognise even though they are normally very precise: "I notice an inflammation behind the right cord" or "I notice a lack of support on the bass notes".

To understand the detailed nature of the sensory symptom description, one has to understand that singers every day, over years and years of classes and practice, are used to singing with two references: auditory and proprioceptive. Auditory reference or self-listening is developed by educating the ear to know when the sound is correct or not. Proprioceptive reference is continuously used in teaching singing, instructing the singer on the "right" sensations that accompany the right emission. It is therefore normal singers, being used to being observed so carefully, are so precise in describing symptoms.

In the medical history, or even better before carrying out this history, it is good to go through a subjective symptom rating scale (questionnaire on quality of life relating to the voice) as well as a vocal incapacity index adapted for singers.<sup>31,32</sup>

Within the personal history, as well as asking about illnesses or previous surgery (always taking into account what sort of trauma endotracheal or nasotracheal intubation would mean to the vocal cords), we should not stop placing an emphasis on drug use. This is important as the side effects of a lot of medications (antihistamines, antidepressants, inhaled corticosteroids, antihypertensive medicines, contraceptives) can affect the voice.<sup>33,34</sup>

The following step in consultation assessment is to listen to the voice. If the complaint is in a singing voice, then patients must be heard singing so that they can show us in practice what is happening. Listening to what is happening often helps to guide us on the problem.

A strobovideolaryngoscopy, fundamental in evaluating voice pathology in any patient, is even more important in

the diagnostic assessment of singers, who are able to symptomatically perceive small changes (such as free edge irregularities) that could not be seen without this examination method. In the case of the singing voice, it is also especially important to assess the patients through a flexible fibrescope, as then we shall see the larynx in a physiological position and we can explore the vocal tract during singing.<sup>35,36</sup>

As far as acoustic analysis, some of the parameters normally used in acoustic voice assessment (such as jitter or shimmer) are not applicable to the singing voice. In the case of the lyrical voice, these values are normally found to be higher.<sup>37</sup>

In recent years, there has been an avalanche of work regarding the acoustics of the singing voice. This is partly due to the existence of computers that allow easy acoustic analysis,<sup>38</sup> together with videokymography development, functional magnetic resonance, etc.<sup>19,8,9,37,27,17,21</sup> All this new knowledge has converted the singing voice into a multidisciplinary area where professionals from medicine and from basic sciences, together with artists, should converge, which would produce a lot more opportunities for creative thinking.

#### Pathology of the singing voice

Professional singers are perhaps, among the voice professionals that go to otolaryngologist consultations, those that are most affected by vocal problems, although these may only be small. The truth is that the public always expect interpretations to be perfect, with the singer's best voice, but singers are generally even more demanding and perfectionist than the public themselves. For this reason, any vocal problem, however small, leads to not only vocal, but also psychological consequences.

On this note, a singer's assessment should be individualised to the maximum, as the consequences of the pathology will be different depending on the musical style, the singer's experience, their professional career, the moment it happens (just before an important concert...).

Actually, we could summarise saying that there are no rules to cover a singer's pathology. However, as well as the knowledge available from being otolaryngologists, it is essential to have great empathy (ability to put ourselves in their place) to understand these patients.<sup>39</sup>

On the other hand, singers are generally very grateful patients, when complying with medical treatment. We could thus consider them as voice athletes. The majority are singers because they are passionate about singing, and they are prepared to strictly adhere to their doctor's orders as long as they can continue singing.

Problems for which singers consult are generally the same as for other patients regarding their voice. There are some diagnoses, such as vocal cord microvascular lesions, for example, that are more prevalent in singers than in the general population. However, what really differentiates the vocal pathology in singers above all is the impact and repercussion this pathology has on these patients' lives.<sup>40</sup>

On a career level, small alterations in voice quality that in other people would hardly be noticed can be a real disaster in a singer that could simply oblige them not to work.<sup>35</sup> Not being able to work also means not only not being able to do a specific concert, but (especially for younger self-employed singers) cancelling a concert could endanger future contracts.

Another important aspect to take into account is the love that the majority of singers have for their profession. Many of them openly reflect it at the surgery: "if I didn't sing I don't know what I would do." It is consequently understandable that any circumstance that prevents such a vocational profession is more frustrating for these patients than for any other, and that the anxiety and fear of not knowing what is happening is greater in a singer than in any other person who suffers from dysphonia.

Vocal problems in a singer can basically have two origins:

- 1. Problems in technique: which we can likewise subdivide into two sections:
  - There can be an *incorrect base technique* (young singers, students, singers who have never received instruction on technique), but it is also possible for singers who have been correctly trained in the technical aspect to develop bad habits during their careers. In this way, singing is like medicine; you never stop learning, and you continue studying all your life. In fact, nearly all the greatest singers continue having classes or following advice from their maestros throughout their career. This section corresponds to what we know as *bad use of the voice*.
  - In second place would be problems due to *vocal abuse*. All voices have a limit, and when this is overdone, it invariably culminates in a vocal pathology. This limit depends on two conditions:
  - The singer's "Anatomical" conditions: in the singing world, there are singers with "stainless steel" cords, and others with larynges that develop a strain pathology more easily. Elastine fibre density as well as hyaluronic acid and collagen in the superficial lamina propria influence the capacity to absorb trauma in the vocal cords (phonotrauma).<sup>41</sup>
  - On a *technical level*, in the singer again: one of the things that technique achieves is the capability to sing without "overloading" the anatomical structures that take part in the voice emission process: laryngeal muscle and the vocal cords themselves. Thanks to a good technique, there are singers who are able to keep their voices "intact" for many years (as an example I recommend that you listen to the bass Mark Reizen singing at 90 years old (www.youtube.com/watch?v=B0hVOpCGAD4), In contrast, others start to develop problems at a specific moment of their professional career.
- 2. Problems completely external to technique:

Collateral illnesses, infections, etc.: Here again the singer's technical level comes into play: the older singers are, the easier it is for them to sing in unfavourable conditions (having a cold, etc.) without lesions developing in their vocal cords.

Therefore, vocal technique is really always present, to a greater or lesser extent, in any vocal problem that affects a singer.

Another important premise when facing a singer patient is that often a symptom or a group of symptoms are not due to a single problem but various ones. We must therefore avoid the tendency of trying to find only a single diagnosis to which we can blame all the symptoms, as it is probable that, for example, as well as a varices, there may be signs of laryngopharyngeal reflux and of vocal overload with a concomitant functional problem.

Below we shall go through the problems that affect singers more often, especially referring to those aspects of diagnoses or treatments that are specific to the singing voice.

#### Laryngopharyngeal reflux

Laryngopharyngeal reflux is produced by a retrograde movement of stomach acid to the hypopharynx. It a problem in the upper oesophageal sphincter that is different to gastroesophageal reflux, whose origin is in the lower oesophageal sphincter.

The symptoms that patients generally refer to include: dysphonia, sensation of a foreign body in the throat, presence of phlegm and a chronic cough. It is calculated that only 35%have dyspepsia symptoms.<sup>39</sup>

In the case of singers, they can also report a loss of voice extension (especially with the loss of high notes), a change in tone that can be expressed as loss of "crystal" or voice opaqueness, vocal fatigue and the presence of non-controllable trills and breaks, with an inability to sing *legato* (that is, without interruptions in the sound).<sup>42</sup>

The appearance of symptoms is usually gradual, although they can appear more or less suddenly after a cold or a period of great vocal activity.

Singers may only have dysphonia; it will be the otolaryngologist who will specifically ask for any other symptoms, which can also be assessed by a self-administered questionnaire<sup>43</sup> (validated in English).

Endoscopic findings of retrocrycoid and arytenoid oedema, vocal cord oedema, interarytenoid pachydermia, the presence of mucous and pseudosulcus can also be objectively assessed through a rating that has shown high intra- and inter-observer reproducibility.<sup>44,45</sup>

The 24 hr dual channel pH-metry/ manometry is considered by many as the fundamental test for diagnosis. However, response to inhibitors in the proton pump with an improvement of signs and symptoms is considered a diagnostic test.

For the purpose of treatment, dietary changes are recommended that include avoiding alcohol abuse, fatty foods, chocolate, caffeine, fizzy drinks and spicy foods, which favour stomach acid production. The stomach's own distension also favours the increase in acid production, so it is convenient to space out the diet, avoiding the supine position and increase in abdominal pressure for 2 hours after eating.<sup>46</sup> Singers are recommended not to sing just after eating due to the increase in intra-abdominal pressure. Proton pump inhibitors should also be prescribed in high doses twice a day for at least 6 months<sup>47</sup>; anti-H2 antihistamines (ranitidine 300 mg) can be added at night in case of persistent night reflux symptoms (dyspepsia or night cough) or morning dysphonia.

If the patient does not respond to treatment, the individual should be sent to the gastroenterology and general surgery department to assess surgical treatment (endoscopic fundoplication).

#### Muscle tension dysphonia

Muscle tension dysphonia (MTD) can be considered to be a form of bad use of or vocal abuse as is characterised by the excessive use of muscle effort to produce a voice, consequently producing a tense voice.

In the majority of MTD cases, it is not an isolated diagnosis, but it accompanies other concomitants, such as laryngitis through laryngopharyngeal reflux, nodules, polyps, cysts, etc. In all these cases MTD consists of the compensating factor of another problem.

Another aspect to take into account is that we sometimes can find MTD patterns without dysphonia<sup>48,49</sup>; therefore, we must be careful in giving a diagnosis such as this to a singer, as here we are talking about his vocal technique, that is to say, that his singing style is wrong.

Therefore, on finding a MTD pattern in a singer, we should do two things: firstly: carry out a thorough assessment that rules out the presence of other factors that could be contributing to dysphonia; secondly, make the singer see that although at the moment this is not the main dysphonia cause (or even if there is no dysphonia now), the hyperfunctional laryngeal mechanism will probably end up turning into a vocal problem.

With regards to treatment, in the case of singing, rehabilitation vocal treatment means a change in vocal technique, although sometimes what is incorrect is the speaking technique, not that of the singing voice. Singers frequently spend many hours of their life dedicated to their singing voice technique and few to the speaking one. In any case, the best way is to make singers see that part of their problems could be a consequence of this fact, and they are generally the ones who know better than anyone else that the main cause is the way they sing. In this case, they must be sent to their singing teacher or it might even be suggested that they change teachers. If it is due to speaking, then we can recommend speech therapy.<sup>50</sup>

In cases where MTD is a consequence of a compensatory mechanism, the underlying cause must be corrected.

#### Laryngeal paralysis

In recent years more attention has been paid to laryngeal paralysis as a possible cause of dysphonia.

The symptoms through which paresis can manifest are the need for a greater vocal effort, vocal fatigue, diplophonia, odynophonia and loss of the vocal range and voice dynamics.

Endoscopic findings range from hypomobility or bending of one or both vocal cords to there being a laryngeal axis rotation.<sup>51,52</sup> A MTD compensatory pattern can be found because of a defective glottic closure. Before diagnosing laryngeal paresis, and before recommending treatment (especially in a singer), confirmation of the diagnosis by laryngeal electromyography should be evaluated, <sup>53</sup> as small asymmetries are described in arytenoid mobility that do not correspond to paralysis.<sup>54-56</sup>

A subgroup especially relevant to the singing voice is upper laryngeal nerve paresis. Affectation of this nerve often produces no appreciable symptoms in the spoken voice, but in a singer this translates into loss of vocal extension at the expense of the high register, which can be dramatic. In these cases, as well as recommending vocal re-education, one must also assess whether to recommend that the singer to change his or her repertoire. Laryngeal electromyography can also give us important prognostic information on resolving the paresis.

#### Vocal nodules

Nodules constitute the most frequent common lesion in vocal cords. If conditions of free edge pre-oedema (also called vocal overload,<sup>57</sup> pseudocyst or fusiform oedema) are included in vocal nodules, then these are also frequent in singers. The appearance of these lesions generally occurs during a time with the greatest work, with lots of rehearsals and concerts without rest periods.

The symptoms generally produced in the singing voice are hoarseness, presence of air in the voice, vocal fatigue and loss of vocal range.

In the stroboscopy, we can see a bulge on the bilateral free edge, quite symmetrical between the anterior third and half of both vocal cords, which produces an hourglass defect in the glottic closure. Laryngopharyngeal reflux signs or a MTD are frequently associated.

Initial treatment should always be advice on vocal hygiene, <sup>58</sup> including the recommendation to warm up the voice<sup>59</sup> (which is not common, especially in pop singers). These recommendations on their own can make small oedemas disappear. A short cycle of oral corticosteroids can also be given.

Changes in vocal technique can be assessed according to the age of the lesions. If it is deduced through medical history that the lesion was produced by vocal abuse (excess work of the singing voice, which is common in musical theatre singers, for example, or in pop singers while on tour). We must emphasise the need for a vocal rest to the patient. Many singers think that they can sing indefinitely, while others are obliged by their contracts to sing for several hours a day without rest. In all these cases, we must make our patients see that singers are like athletes, that they need periods of rest so that the anatomical structures that take part in vocal production can recover, and if they do not do so then there is little chance that they will be able to continue singing on a medium to long term basis.

A very important aspect to bear in mind in singers, especially in pop singers, is that an endoscopic nodule image can still persist even though dysphonia has disappeared. In this case, it must be remembered that treatment is always based on symptoms and function, not on the presence of the lesion. If there is a need for surgical treatment (lack of response to drug treatment), it should be as conservative as possible in preserving the superficial lamina propria to avoid scarring.

#### Vocal polyps

Polyps are unilateral lesions that usually present with the same symptoms as nodules, with the addition of diplophonia. Stroboscopically, they can cause an asymmetry in the vibration by a different mass in the cords together with a closure defect (of the same type as in the nodules). Small polyps (pseudocysts, unilateral fusiform oedemas) are frequently found in singers; faced with the condition, we should initially carry out the same recommendations as for nodules. However, in this case it is best to warn the singer from the start that he or she will probably require surgical treatment.

#### Vocal cysts

Intracordal cysts can be congenital (epidermoid) or acquired (mucous). The presenting symptoms are usually the same as for polyps.

In the stroboscopic examination, there will be asymmetry in the vibration with greater rigidity and a reduction in the amplitude of the mucous wave in the affected vocal cords. Stroboscopy often gives us only a clue in suspecting an intracordal cyst and we have to put the patient to sleep to explore the larynx under general anaesthetic and confirm the existence of the lesion.

The treatment of these lesions is always surgical through cordotomy and cyst removal, taking into account that there can be associated factors that require another type of approach (reflux, MTD). In addition, whether to perform laryngeal phonomicrosurgery or not should always be decided considering the functional vocal result, especially in the case of singers, by explaining in detail the risks that scarring represents to vocal production.<sup>60</sup>

#### Scarring and sulcus

Scarring is the replacement of normal tissue by fibrous tissue that can occur due to different reasons: inflammation, cancer or iatrogenic. Sulcus can be the congenital absence of the superficial lamina propria in the case of type II sulcus, or stretch marks or the scar produced by opening an intracordal cyst in the case of type III sulcus. They are therefore lesions that physiopathalogically can have different origins, but functionally behave in a similar manner.

The mechanism by which these lesions cause dysphonia is two-fold: on the one hand, they produce a glottic closure defect and, on the other, an absence of vibration in the vocal cord area where they are located.

Therefore, the severity of the symptoms that they produce depends on lesion extension and location in the vocal cords (for example, a lesion on the free edge would be far more symptomatic than one on the upper surface). It is consequently not rare to find singers with a small sulcus that does not prevent them from carrying out their job. The best scarring treatment is prevention. It is best to be conservative, especially with singers, when carrying out laryngeal phonomicrosurgery, by preserving the superficial lamina propria to the maximum.

Rehabilitation treatment is always initially recommended to improve vocal efficiency and try and free the scarred tissue. If surgical treatment is considered after rehabilitation, the patient's functional assessment is even more important in this case, explaining expectations on a vocal level.<sup>61</sup>

#### Microvascular lesions. Vocal haemorrhage

The term microvascular lesion refers to two types of lesions on the vocal cords: varices (longitudinal vascular dilations) and ectasias (which have a round aspect). Both are more frequent in singers than in the general population. This is perhaps due, on the one hand, to the greater frequency with which singers go to otolaryngologist and, on the other, to the mechanism that produces these lesions, vocal abuse. They are also more frequent in females than males, which is probably related to hormonal factors.<sup>62-64</sup>

The majority of patients with microvascular lesions in their vocal cords are asymptomatic Sometimes the varices or ectasias can be very large or be at the free edge and alter the vocal cord' vibration, which can be seen in a singer as hoarseness, reduction in the vocal range or vocal fatigue. In these cases, anti-reflux treatment is recommended initially, together with vocal hygiene measures and assessment of a vocal technique change to minimise the trauma in the cords during singing and speaking. If the symptoms persist, then surgical removal of the lesion must be considered.

However, the most common surgical recommendation for these lesions is recurrent vocal haemorrhage, which is a true catastrophe in a singer. Vocal haemorrhage is produced by a phonotrauma<sup>65</sup> and has a very characteristic presentation: after a period of intense vocal activity and frequently due to an infection in the upper respiratory tracts, generally while the singer is singing, there is a sudden change in the voice, which ranges from slight dysphonia to complete dysphonia. Singers are greater risk if they are taking NSAIDs and especially aspirin. Generally singers go to the surgery quickly with serious symptoms, so we can normally see the haemorrhage with an endoscopic exploration.

Upon finding a vocal haemorrhage, strict rest for at least a week should be prescribed for a singing voice, also reducing the speaking voice to the maximum. The use of corticosteroids has not been shown to be efficient in accelerating haematoma absorption. In the case of a tension haematoma that does not improve after a few days of vocal rest, its removal through a cordotomy under general anaesthetic may be considered.<sup>66</sup>

With regards to microvascular lesion removal, this can be carried out with a cold instrument or by coagulating the vessel with laser or bipolar tweezers.<sup>67</sup>

With respect to the general treatment of vocal pathology in singers, we have already mentioned that they are normally good at carrying out prescribed treatment, not only regarding oral hygiene but also with drug treatments. However, in the case of surgery, singers generally believe that if they undergoe surgical treatment on the larynx, their voice will never be the same. This can mean that some singers actually end their careers prematurely due to the fear of losing their voice.<sup>68</sup> When informing our singerpatients, we should be clear that surgery correctly indicated in the first place and correctly performed in the second place, together with proper follow-up and rehabilitation after surgery in the third place, leads to patients recovering their previous voice in the majority of cases.

#### Conclusion

Singing is a synthesis of various aspects: anatomical, physiological, aesthetic, acoustical, psychological, and so on. All of these are present in the singing voice, and

knowledge about them on the part of otolaryngologists who see singers every day in their surgeries will improve the attention to these patients.

In addition, there are two things we can do to broaden our knowledge in this field and better understand the pathology. The first is to receive some lessons on vocal technique, to experience first-hand, at least once, the voice physiology that we have studied so many times.

The second is to go to live concerts; I recommend seeing good lyrical artists above all. Listening to vocal music will help us to educate our ear to later interpret the small deviations from normality in the voices heard at our surgery. Listening will also help us to develop a better understanding of singers with their peculiarities and love for the art that they do. These are essential requirements not only to do our job better, but also to transmit singers a trust based on knowledge and on respect for their job.

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