The Aging Voice: Influence of Respiratory and Laryngeal Changes

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Objectives. To evaluate the impact on voice quality of 2 pathogenic factors involved in age-related dysphonia: glottal gap and decline in respiratory function.

Study Design. Cross-sectional prospective.

Subjects and Methods. A total of 105 healthy patients ≥65 years old were included, with a maximum phonation time ≤15 seconds for men and ≤12 seconds for women. Laryngostroboscopy and spirometry were conducted to assess the glottal gap and respiratory function, and 4 profiles were defined according to their combination: glottal deficit, respiratory deficit, combined deficit, and no deficit. Differences across profiles in phonation times, acoustic parameters, and GRBAS scale and Voice Handicap Index–10 scores were analyzed according to Kruskal-Wallis and Mann-Whitney nonparametric tests. Multiple regression was performed to estimate the influence of each pathogenic factor.

Results. Respiratory deficit was the most frequent profile (37%). When compared to the other groups, patients with combined deficit had shorter phonation times for men (8.5 seconds; Kruskal-Wallis, \( P = .009 \)) and women (7.8 seconds; \( P = .003 \)), worse jitter (8.3%; \( P = .001 \)), GRBAS scale (5.8; \( P < .001 \)), and Voice Handicap Index–10 (7.7; \( P = .002 \)).

Conclusion. Age-related respiratory and laryngeal changes have a negative impact on vocal quality, especially when both deficits are present.

Keywords
presbyphonia, vocal aging, glottal gap, respiratory aging

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Voice symptoms in the elderly are frequent and often underdiagnosed.¹-⁴ The presence of vocal fold lesions or the consequences of other comorbidities may explain some of these disorders, but the process of aging itself is also considered an important etiologic factor for geriatric dysphonia.⁵-⁷ Although its exact prevalence has yet to be determined, age-related dysphonia is becoming a common complaint at voice clinics all over the world.⁷-⁹ Several characteristics allow listeners to differentiate elderly voices from younger ones. These changes include variations in fundamental frequency, tremor, increased noise, or a decrease in speech rate and maximum phonation times (MPTs).¹⁰-¹²

Several physiologic changes that happen with aging can affect the structures and systems involved in phonation and eventually cause dysphonia.⁵,¹³ The thinning of the superficial lamina propria of the vocal fold can interfere with its vibratory properties, and the atrophy of the thyroarytenoid muscle can lead to vocal fold bowing and incomplete glottal closure, which are common findings among patients with age-related voice symptoms.⁹,¹⁰,¹⁴ It is believed that these changes and their impact on voice production physiology may be the main pathogenic mechanisms that explain the qualitative characteristics of the aged voice.⁵,⁹,¹⁰ However, since phonation also depends on the airflow provided by the respiratory system, the aging consequences for the latter may play an important role in this subject.¹⁵-¹⁷

The objective of the present study is to assess the relevance of laryngeal and respiratory changes that occur with aging to the pathogenesis of age-related dysphonia. Four pathogenic profiles were defined from a clinical perspective and their differences on vocal quality analyzed. The primary outcome measure was the duration of MPT, and the secondary outcome measures were other objective and subjective voice quality parameters.

Materials and Methods

After receiving approval from the Hospital Ramón y Cajal Ethics Committee, we conducted a prospective study on elderly patients who consulted in our center for voice or any other ear, nose, and throat symptoms from 2010 to 2013.

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MPT was chosen as the inclusion test to provide a sample to study the influence of respiratory and laryngeal changes in the aging voice because the sustained phonation of a vowel depends on the interaction of both systems. MPT decreases with aging, progressively affecting the communication abilities of elderly people. A short MPT (≤15 seconds for men and ≤12 seconds for women) was set as the inclusion criterion for the study (normative range for healthy elderly men, 20-26 seconds; women, 18-24 seconds), which is our usual clinical limit for voice therapy referral. Subjects with a history of neurologic, laryngeal, or respiratory diseases and frail patients were excluded. Volunteers ≥65 years old were asked to perform 3 trials of MPT as a screening test at the office, and they were referred to our voice research laboratory if the best measurement complied with the inclusion criterion and they were eligible for the study. Subjects were then reevaluated at the voice clinic; their medical records were checked to ensure compliance with the selection criteria, and the MPT task was repeated at a comfortable loudness (<70 dB) at least 3 times, with the best measurement taken for analysis.

Glottic closure during phonation was evaluated using digital laryngostroboscopy. Patients were asked to phonate a sustained vowel (/e/) at the modal frequency and a comfortable loudness (below 70 dB), and the images were recorded for subsequent analysis by an experienced laryngologist. Based on the stroboscopic recordings, the glottal closure was described as complete or incomplete if a spindle-shaped gap was present. Posterior triangular gaps were not taken into consideration, as they are believed to be physiologic.

Spirometric tests for respiratory function assessment were conducted using a Jaeger Flowscreen II office-based spirometer. Forced spirometry was performed in the sitting position at least 3 times for every patient, with the best trial results used for analysis. Respiratory function was considered to be affected if either vital capacity or peak expiratory airflow was <80% of the reference values for the subject’s characteristics.

Patients were classified into 4 pathogenic profiles according to the stroboscopy and spirometry results:

- **Glottal deficit**: patients with glottic gap and normal spirometry.
- **Respiratory deficit**: patients with complete glottal closure and altered spirometry.
- **Combined deficit**: patients with glottic gap and altered spirometry.
- **No deficit**: patients with normal spirometry and complete glottal closure.

Acoustic analysis of the voice was performed to assess voice quality. Each subject provided a sample of a sustained vowel /e/ at the modal frequency and a comfortable loudness level, which was recorded with a head-mounted microphone and further analyzed with the WPCVox program to obtain perturbation measures: jitter, shimmer, and harmonics-to-noise ratio. Maximum sound pressure was determined with a Rion NL-31 sound-level meter. For this task, patients were seated 1 m away from the device and asked to phonate with constant pitch as loudly as they could. The best measure of 3 trials was taken for analysis.

Voice quality was also perceptually assessed by the investigators using the GRBAS scale, and its impact on the patient’s quality of life was addressed using the Spanish version of the abbreviated Voice Handicap Index—10.

A chi-square test with a level of significance of $P < .05$ was used to assess the influence of sex on the distribution of the pathogenic profile. Differences in age, MPT, and voice quality parameters across the 4 profiles were assessed with a nonparametric Kruskal-Wallis test with a level of significance of $P < .05$. When significant differences were detected, nonparametric Mann-Whitney test was conducted for multiple post hoc comparisons with a level of significance of $P < .017$ after Bonferroni correction. In addition, multiple regression analysis was performed for those normally distributed variables (Kolmogerorov-Smirnov, $P > .05$), adjusting by age and sex when necessary. Data analysis was performed with SPSS 17 for Windows.

### Results

After application of the selection criteria, 105 elderly patients were included in the study. Most of the patients were women (69 vs 36 men), and the mean age was 75 years for both men and women (SD, 6.6; range, 65-93). Twenty subjects had a history of tobacco use: 17 patients had stopped smoking >15 years before; 2 subjects had stopped smoking <15 years before; and only 1 patient continued smoking actively at the time of the study (1-5 cigarettes a day).

Concerning stroboscopic findings, mucosal wave was observed in all cases, and glottal closure was found to be complete in 53% of the men and 57% of the women. Respiratory function was considered to be altered (vital capacity or peak expiratory airflow <80% of the reference values for the patient characteristics) in 50% of men and 66.6% of women, owing to mild obstructive disease in 60% of them and mild restrictive disease in 40%. With a combination of both results, patients were classified into 4 profiles, as described in Table 1. The differences in the profile distribution between sexes were not significant ($P = .28$). No significant differences in age were found across the 4 groups either (mean ages: combined deficit, 77.3 ± 6.7 years; respiratory deficit, 76.2 ± 6.9; glottal deficit, 74.3 ± 6.1; no deficit, 72.7 ± 4.9; $P = .1$).

The results of the voice quality study are listed in Tables 2 and 3. The effects of the profile on MPT and maximum sound pressure were analyzed separately for men and women, as these parameters are influenced by sex.

There were significant differences in MPT across profiles in both sexes ($P = .009$ for men, $P = .003$ for women). Patients with combined deficit had a significantly shorter MPT than did subjects with complete glottal closure. The GRBAS scale and Voice Handicap Index–10 showed the same distribution, with patients with combined deficit.
scoring significantly higher than other groups. Considering acoustic parameters, statistically significant differences across profiles were found for jitter and maximum sound pressure in women, and subjects with combined deficit performed worse in these cases.

Multiple regression analysis was conducted for MPT, sound pressure, GRBAS scale, and Voice Handicap Index–10. The results were adjusted by age and sex when necessary. The equation for each variable and its coefficient of determination \( R^2 \) can be found in Table 4.

### Discussion

Clinical manifestations of age-related dysphonia are variable and often progressive over the aging process. Increased breathiness, strain, and acoustic changes are common findings that may range from mild affectation, often considered normal in this context, to severe hoarseness.2,10-12 Another typical manifestation of this pathology is a decrease in phonation times when compared with those of younger adults.18,23 This has been associated with the loss of vocal fold pliability with aging and especially with glottal insufficiency or respiratory dysfunction,8,16 making elderly patients with short MPT an interesting population for studying the interaction of such pathogenic mechanisms in this context.

Our study suggests that subjects with age-related changes affecting both laryngeal and respiratory functions have shorter phonation times. These patients also have other vocal quality parameters that are significantly more affected, especially when compared with elderly patients without any of the studied deficits or respiratory impairment alone.

An efficient glottal valve has an essential role in voice production. Incompetent glottal closure, as associated with age-related changes, can result in air escape and shorter MPT, as well as acoustic perturbations, which will eventually mean a variable degree of deterioration in vocal quality.11,24 Logically, the combination of an incompetent glottis with impaired pulmonary function that cannot compensate the escape of air will lead to serious negative effects on speech production and voice quality in these cases.17

The division of elderly patients with age-related shortage of MPT into the 4 profiles provides a clinical perspective of its pathogenesis that facilitates its management, allowing for specific treatment of the contributing factors from the moment of diagnosis. Patients with a glottal gap are most likely to benefit from voice therapy, and vocal fold injections or surgery can be used for cases that do not respond to therapy alone.5,7,13 Patients with a respiratory impairment could also benefit from voice therapy and respiratory exercises, as well as bronchodilators or other medical treatments if necessary.5 Referral to a respiratory physician for further examination and therapy could be advisable in some of these cases.

Some limitations of the present study are related to the sample selection. As we conducted the research on patients consulting at our general ear, nose, and throat clinic, it is possible that our sample was somehow different from the general population. We also included subjects with a history of tobacco use, although most of them had stopped smoking a long time before. However, to avoid the effects of these concerns on the results, selection criteria were aimed to exclude patients suffering from any interfering condition. Thus, a sample more representative of the general elderly population was studied.

### Table 2. Voice Quality Parameters among Profiles, Mean ± SD.

<table>
<thead>
<tr>
<th>Parameter (Normative)</th>
<th>GD</th>
<th>RD</th>
<th>CD</th>
<th>ND</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>Maximum phonation time, s</td>
<td>9.9 ± 2.6</td>
<td>11.7 ± 2</td>
<td>8.5 ± 2.5</td>
<td>13.3 ± 1.4</td>
<td>.009</td>
</tr>
<tr>
<td>Males (20-26)</td>
<td>10.2 ± 1.5</td>
<td>9.8 ± 2</td>
<td>7.8 ± 1.9</td>
<td>10.7 ± 1</td>
<td>.003</td>
</tr>
<tr>
<td>Jitter, % (0.2-1.6)</td>
<td>3.1 ± 2</td>
<td>1.8 ± 1</td>
<td>8.3 ± 19</td>
<td>2.3 ± 2</td>
<td>.001</td>
</tr>
<tr>
<td>Shimmer, % (1.6-4.8)</td>
<td>5.8 ± 6</td>
<td>3.7 ± 2</td>
<td>10.4 ± 13</td>
<td>5.3 ± 5</td>
<td>.1</td>
</tr>
<tr>
<td>HNR, dB (28.3-29.9)</td>
<td>24.8 ± 5.9</td>
<td>26.9 ± 4.8</td>
<td>22 ± 8.8</td>
<td>26.9 ± 6.6</td>
<td>.11</td>
</tr>
<tr>
<td>Maximum sound pressure, dB</td>
<td>88.9 ± 7.2</td>
<td>91.1 ± 5.8</td>
<td>82.7 ± 10.3</td>
<td>92.3 ± 9.4</td>
<td>.31</td>
</tr>
<tr>
<td>Males (100-110)</td>
<td>84.2 ± 8.2</td>
<td>85 ± 6.7</td>
<td>79.3 ± 8.2</td>
<td>88.7 ± 5.7</td>
<td>.007</td>
</tr>
<tr>
<td>GRBAS scale</td>
<td>4 ± 1.7</td>
<td>3.5 ± 1.8</td>
<td>5.8 ± 2.5</td>
<td>2.7 ± 1.8</td>
<td>&lt;.001</td>
</tr>
<tr>
<td>Voice Handicap Index–10</td>
<td>5.2 ± 3.7</td>
<td>3.3 ± 3.1</td>
<td>7.7 ± 6.1</td>
<td>3.3 ± 2.5</td>
<td>.002</td>
</tr>
</tbody>
</table>

Abbreviations: CD, combined deficit; GD, glottal deficit; HNR, harmonics to noise ratio; ND, no deficit; RD, respiratory deficit.

*Bolded values are statistically significant (Kruskal-Wallis, \( P < .05 \)).
Table 3. Results of Post Hoc Multiple Comparisons, P Values.a

<table>
<thead>
<tr>
<th></th>
<th>CD vs ND</th>
<th>CD vs GD</th>
<th>CD vs RD</th>
</tr>
</thead>
<tbody>
<tr>
<td>MPT /e/</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Males</td>
<td>.005</td>
<td>.271</td>
<td>.015</td>
</tr>
<tr>
<td>Females</td>
<td>.001</td>
<td>.001</td>
<td>.002</td>
</tr>
<tr>
<td>Jitter</td>
<td>.016</td>
<td>.099</td>
<td>&lt;.001</td>
</tr>
<tr>
<td>MSP females</td>
<td>.002</td>
<td>.082</td>
<td>.018</td>
</tr>
<tr>
<td>GRBAS scale</td>
<td>&lt;.001</td>
<td>.015</td>
<td>&lt;.001</td>
</tr>
<tr>
<td>Voice Handicap Index–10</td>
<td>.008</td>
<td>.174</td>
<td>&lt;.001</td>
</tr>
</tbody>
</table>

Abbreviations: CD, combined deficit; GD, glottal deficit; MPT, maximum phonation time; MSP, maximum sound pressure; ND, no deficit; RD, respiratory deficit.

aBolded values are statistically significant (Mann-Whitney, P < .017).

Table 4. Multiple Regression Analysis.

<table>
<thead>
<tr>
<th></th>
<th>R²</th>
<th>Equation</th>
</tr>
</thead>
<tbody>
<tr>
<td>MPT /e/</td>
<td></td>
<td>14.927 – 8.605 10⁻²Age + 1.435R + 3.293L</td>
</tr>
<tr>
<td>Males</td>
<td>0.38</td>
<td>12.077 – 7.455 10⁻²Age + 0.712R + 1.035L</td>
</tr>
<tr>
<td>Females</td>
<td>0.13</td>
<td>94.095 – 0.129Age + 3.510R + 5.766L</td>
</tr>
<tr>
<td>MSP</td>
<td></td>
<td>101.539 – 0.282Age + 2.999R + 4.764L</td>
</tr>
<tr>
<td>Males</td>
<td>0.15</td>
<td>94.095 – 0.129Age + 3.510R + 5.766L</td>
</tr>
<tr>
<td>Females</td>
<td>0.23</td>
<td>94.095 – 0.129Age + 3.510R + 5.766L</td>
</tr>
<tr>
<td>GRBAS scale</td>
<td></td>
<td>101.539 – 0.282Age + 2.999R + 4.764L</td>
</tr>
<tr>
<td>VHI–10</td>
<td>0.15</td>
<td>7.203 – 1.135 10⁻³Age – 1.205R – 3.448L</td>
</tr>
</tbody>
</table>

Abbreviations: L, complete glottal closure; MPT, maximum phonation time; MSP, maximum sound pressure; R, normal respiratory function; VHI, Voice Handicap Index.

Aging can affect all organs and systems involved in voice production. Age-related respiratory function decline and glottal gap have a negative impact on voice quality parameters, and patients who suffer from these 2 factors simultaneously are significantly more affected.

The clinical protocol for the evaluation of age-related dysphonia should include respiratory and laryngeal function assessment. The identification of a pathogenic profile in these cases would allow for a specific treatment of each contributing factor that improves the management of this pathology.

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Author Contributions
Miguel Vaca, designed study, collected data, analyzed data, wrote paper; Elena Mora, collected data, analyzed data, revised paper; Ignacio Cobeta, designed study, revised paper.

Disclosures
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References