VOICE QUALITY AFTER CO₂ LASER CORDECTOMY—WHAT CAN WE REALLY EXPECT?

Isabel Vilaseca, MD,1 Paula Huerta, MD,1 José Luis Blanch, MD,1 Ana María Fernández-Planas, PhD,2 Conchita Jiménez, SLP,1 Manuel Bernal-Sprekelsen, MD1

1 Otolaryngology Department, Hospital Clínic Universitari, Barcelona, Spain. E-mail: ivila@clinic.ub.es
2 Faculty of Arts, Phonetics Laboratory, University of Barcelona, Barcelona, Spain

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Abstract: Background. Endoscopic management of laryngeal carcinoma has gained popularity among laryngologists based on the good oncologic and functional results. We evaluated the voice quality after laser cordectomy for early glottic cancer in a variety of vocal situations and its relation with the extension of resection and the age.

Methods. We conducted a cross-sectional study of voice quality in 42 consecutive male patients treated for T1 glottic carcinoma with laser cordectomy. Patients were compared with 21 controls. Voice quality was self-assessed by the patients. Perceptual analysis was done by a speech pathologist on a running speech sample [GRBAS (grade, roughness, breathiness, asthenicity, strain)]. Acoustic analysis included fundamental frequency (F0), jitter, shimmer, noise to harmonic ratio (N/H), and maximum phonation time (MPT) on the sustained vowels /a/ and /i/, and on various running speech voice samples.

Results. Distribution of the patients included in the study by T classification was as follows: Tis, n = 2 (4.8%); T1a, n = 35 (83.3%); and T1b, n = 5 (11.9%). Cordectomy types were: (I), 14%; (II), 26%; (III), 21%; and (V), 38%. Voice improved in almost 60% of patients, returning to normal in 45%. GRBAS showed significant differences between patients and controls and correlated with type of cordectomy. Acoustic analysis showed significant differences in F0, jitter, and shimmer, with smaller differences in N/H, and MPT.

Conclusion. Voice quality after laser cordectomy differs from controls, but improves in a majority of patients after the surgery, with almost 50% of patients with subjective normal or near normal voice. Voice quality depends on type of cordectomy. ©2007 Wiley Periodicals, Inc. Head Neck 30: 43–49, 2008

Keywords: CO₂ laser cordectomy; quality of voice; acoustic analysis; early glottic cancer

Transoral CO₂ laser cordectomy under microscopic view is 1 of the treatments of choice for patients with early glottic cancer.¹–⁴ Endoscopic cordectomy offers several advantages over radiotherapy and open surgical procedures, such as 1-session therapy, short hospitalization, reduced morbidity, and high cost-effectiveness.⁵,⁶ However, choice of treatment usually considers other factors in addition to survival, such as vocal outcome.

The majority of authors advocate perceptual evaluation of voice, in spite of its subjectivity. Most published studies are based on Hirano’s GRBAS (grade, roughness, breathiness, asthenicity, strain) scale,¹ widely used by speech pathologists. Self-designed scales and quality of life (QOL) questionnaires are also commonly used by untrained staff or for patient self-assessment. Acoustic analysis is an alternative method that provides accurate, objective evaluation of the
sound and physical properties of voice, but not always the ability to communicate.\textsuperscript{7,8} Furthermore, many studies based on acoustic analysis have focused only on sustained vowels, though the isolate use of vowels is rare in daily voice use and in fact the most significant changes and problems are observed when the patients talk, sing, or shout.

In the literature, voice quality after surgery has been directly correlated with the amount of tissue resected.\textsuperscript{2,9–11} The phonomicrosurgical approach to early glottic cancer minimizes vocal sequelae in case of endoscopic resections up to the subgligamental cordectomy and achieves a postoperative conversational voice comparable to that of controls. In fact, at many centers, patients included for laser excision are highly selected to small midcord tumors at 1 vocal cord without impaired mobility. In larger excisions, more vocal difficulties are to be expected after surgery than after radiation therapy.\textsuperscript{4,10,12,13}

From another perspective, life expectancy in developed countries has increased, and the possibility of long-term radiation-induced tumors or even the need to reserve radiation therapy for second malignancies should not be underestimated. For that reason, some authors consider younger patients to be better candidates for laser surgery than for radiation.\textsuperscript{14,15} To our knowledge, a large randomized case-control study comparing laser excision and radiation therapy is still lacking.

Whatever the reasons, the evidence is that laser surgery is progressively becoming the treatment of choice for T1 glottic cancer at many European centers due to its cost-effectiveness. However, in routine practice, a high number of patients present with medium or large T1a tumors affecting the entire vocal cord, or with small tumors so close to the anterior commissure that they have to be treated almost as those with a T1b. What kind of vocal outcome can we expect in these patients? Because voice quality after laser cordectomy is still a controversial issue, we analyzed the perceptual and acoustic vocal outcome of a group of consecutive T1 glottic carcinoma laser-treated patients in a variety of voice production situations, comparing it with healthy controls, and evaluating its relation with the type of cordectomy and age.

**MATERIALS AND METHODS**

Voice quality of 42 consecutive male patients with T1 glottic cancer (Tis, T1a, and T1b) treated with laser surgery in our tertiary referral center was retrospectively studied. Minimum follow-up was set at 6 months. No preoperative or postoperative radiation was administered. One woman treated during that period time was excluded from the analysis to facilitate the comparison with the control group. None of the patients were seen with the evidence of disease at that point, nor had they received specific voice rehabilitation after surgery.

A Sharplan 40C CO\textsubscript{2} laser with an Acuspot 712 micromanipulator with superpulse emission in continuous mode (2–4 W, 270-\textmu m spot size) was used for the excision. Small tumors were removed in monoblock when possible, or otherwise piecemealed. No saline infusion to dissect the muco-ligamentous space was performed. After resection, the specimen was fixed; the deep margin was marked with blue ink and sent for frozen sections. Margins were enlarged until the pathologic report was negative. All patients were classified according to tumor involvement, type of cordectomy, and 2001 TNM classification.\textsuperscript{16} Data were obtained from preoperative examination and from the surgical report. Type of cordectomy was established according to European Laryngological Society classification.\textsuperscript{12}

Subjective voice quality was evaluated by the patients, by a speech therapist, and an otolaryngologist, blind to the characteristics of the tumor, and the type of cordectomy. The otolaryngologist and patients used a specially designed scale to evaluate the degree of dysphonia, ranging from 1 to 3 as follows: 1, normal or almost normal voice (anomalies would only be detected by specially trained staff); 2, moderate dysphonia (voice like persistent laryngitis, no useful). The speech therapist used Hirano’s GRBAS scale,\textsuperscript{1} which comprises 5 domains: grade (G), roughness (R), breathiness (B), asthenicity (A), and strain (S). The domains are rated from 0 to 3, in which 0 is normal, 1 represents a slight voice problem, 2 moderate, and 3 severe. Patients were also asked to compare their voice impairment before and after the surgery. To do that, they answered the question “How is your voice now, and how has it affected your daily life, if you compare to preoperatively?” Three possible answers were considered (worse—same—better), and also the possibility of additional comments was included.

Postoperative voice samples were obtained in a soundproof room using a MARANTZ CP430 re-
corder and the SHURE SM58 microphone (SHURE Inc., Niles, IL). The microphone was placed 20 cm from the patient’s mouth, slightly to the side. The parameters recorded were the sustained Spanish vowels /a/ and /i/ for 3 to 5 seconds, maximum phonation time (MPT), spontaneous speech /ss/ in response to the instruction “tell me about your voice problem,” sentence production /s/ “es hábil un solo día,” and singing voice /sv/ of a popular song “Campana sobre campana.”

The CSL 4300B (Kay Elemetrics Corp) connected to a PC was used for the acoustic analysis. The parameters evaluated included fundamental frequency (F0), shimmer, jitter, and noise to harmonic ratio (N/H). The vocal range and MPT were also studied. All parameters were compared with a group of 21 healthy subjects specially selected for this study, and matched by age and sex. To analyze the influence of age on voice quality, patients were divided in 2 groups, above and below 65 years old.

Differences between groups were evaluated using the Mann–Whitney U test, chi-square, and analysis of variance (ANOVA) as appropriate. The Pearson test was used to examine the bivariate relations between subjective and objective acoustic parameters. Data were analyzed using SPSS for windows version 11.5. A p value of .05 was defined as statistically significant.

RESULTS
Forty-two men patients were included in the analysis, with a mean age of 66.24 ± 8.26 years (range, 52–86 years) at the moment of surgery. Time since surgery was 18.29 ± 10.5 months (range, 6–48 months). The control group comprised 21 men, mean age 65.67 ± 8.75 years (range, 53–86 years). We found no age-related differences between groups (p = .8).

According to TNM, the sample included 2 Tis (4.8%), 35 T1a (83.3%), and 5 T1b (11.9%). In 26 patients (61.9%), the tumor mainly affected the medial third of the vocal cord; in 4 patients (9.5%), the entire vocal cord; in 7 patients (16.7%), the vocal cord and the anterior commissure, and in 5 patients (11.9%), both vocal cords and the anterior commissure. In 26 patients, the excision was limited to 1 vocal cord; in 11 patients, included 1 vocal cord and the anterior commissure, and in 5 patients, both cords and the anterior commissure. The type of cordectomy is expressed in Table 1.

Perceptual Voice Analysis. Before surgery, 7 patients (16.7%) reported normal or near normal voice compared with 18 patients (42.9%) after the surgery. Twenty-one (50%) were seen with moderate dysphonia preoperatively, compared with 17 patients (40.5%) in the postoperative period, and 14 patients (33.3%) were seen with severe dysphonia before surgery, compared with 7 patients (16.7%) after surgery. Pearson chi-square analysis showed that voice changes were statistically significant after surgery (p = .002). When compared with preoperative voices, 25 patients (59.5%) reported improvement after surgery, 9 patients (21%) reported no change, and 8 patients (19%) reported deterioration. Daily lives did not change because of the voice problem in 35 patients (83.3%); it improved in 4 patients (9.5%) and worsened in 3 patients (7.1%). Voice quality reported by the patients did not correlate with type of cordectomy (p = .121) or TNM classification (p = .291) in our sample.

According to the otolaryngologist, 19 patients (45.2%) had a postoperative normal or near normal voice; 16 patients (38.1%) moderate dysphonia, and 7 patients (16.7%) severe dysphonia. The correlations between voice quality and extension of the tumor (p = .08) and also type of cordectomy (p = .05) showed a tendency toward statistical significance. However, no statistical significant differences were found between voice quality and TNM classification (p = .28). Subjective quality of voice related to type of cordectomy is described in Table 1.

The GRBAS punctuation reported by the speech therapist after the surgery differed significantly between patients and controls (Table 2), and correlated significantly to the voice quality assessed by the patient, the voice assessed by the otolaryngologist, and type of cordectomy (Table 3). Roughness and strength domains correlated to TNM classification (Table 3).

Objective Voice Analysis. The postoperative acoustic analysis showed statistical significant

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**Table 1.** Subjective postoperative voice evaluation by the otolaryngologist and its relation with type of cordectomy.

<table>
<thead>
<tr>
<th>Type of cordectomy</th>
<th>Normal or near normal voice, n (%)</th>
<th>Moderate dysphonia, n (%)</th>
<th>Severe dysphonia, n (%)</th>
<th>Total n (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>I. Subepithelial</td>
<td>4 (66.7)</td>
<td>2 (33.3)</td>
<td>0</td>
<td>6</td>
</tr>
<tr>
<td>II. Subligamental</td>
<td>6 (54.5)</td>
<td>4 (36.4)</td>
<td>1 (9.1)</td>
<td>11</td>
</tr>
<tr>
<td>III. Transmuscular</td>
<td>5 (55.6)</td>
<td>3 (33.3)</td>
<td>1 (11.1)</td>
<td>9</td>
</tr>
<tr>
<td>V. Extended cordectomy</td>
<td>4 (25)</td>
<td>7 (43.8)</td>
<td>5 (31.3)</td>
<td>16</td>
</tr>
<tr>
<td>All patients</td>
<td>19 (45.2)</td>
<td>16 (38.1)</td>
<td>7 (16.7)</td>
<td>42</td>
</tr>
</tbody>
</table>
differences between patients and controls, with a higher F0 and jitter in all the voice samples, and increased shimmer in sustained vowels. No significant differences were found in MPT and maximum vocal extension in the singing voice (Table 4).

Acoustic parameters were also analyzed according to the type of cordectomy. The larger the resection, the higher the number of parameters presenting significant differences with the control group. Differences in F0, jitter and minimum extension in the singing voice were found in all type of cordectomy, whereas in type V, differences in shimmer and MPT were also common. The characteristics of the acoustic parameters are described in Table 4.

There was a high correlation between postoperative acoustic parameters and perceptual evaluation of voice impairment determined by the GRBAS scale. Grade (G) correlated significantly with /a/ F0, /a/ jitter, /a/ shimmer, /a/ N/H, /i/ N/H, /s/ jitter, /s/ N/H, /ss/ jitter, and MPT. Roughness (R) correlated significantly with /a/ F0, /a/ jitter, /a/ shimmer, /a/ N/H, /i/ N/H, /s/ jitter, /ss/ jitter, and MPT. Breathiness (B) correlated significantly with /s/ F0, /s/ minimum range, and MPT. Asthenicity (A) correlated with /a/ jitter, /a/ N/H, and MPT. Strain (S) correlated significantly with /a/ F0, /a/ jitter, /a/ N/H, /i/ N/H, /s/ jitter, /s/ N/H, /ss/ F0, /ss/ jitter, and /ss/ shimmer.

No voice differences were found between younger and older patients according to type of cordectomy ($p = .69$) or TNM classification ($p = .37$). However, negative changes in daily life were more frequent in younger than older patients ($p = .003$).

**DISCUSSION**

In this study, voice quality in patients after laser cordectomy was worse than in controls and correlated with the extent of resection. Our results suggest that patients treated with laser cordectomy cannot expect to have an objectively normal voice, though in the case of type I cordectomy perceptual analysis may be normal in more than 66% of patients. For more extended excisions, the success rates decrease slightly but more than 55% of patients achieve normal or near normal voices, even when those with transmuscular resection are included. In contrast, excision of a wide part of the vocal muscle or the anterior commissure may lead to a persistent dysphonia in one third of the patients, and only a quarter have subjectively normal or near normal voice. These results agree with previous reports in the literature in which types III–V cordectomies often have a tendency toward permanent dysphonia.2,3,10,11,17 Patients should be warned of this possibility.

The objective data in our study indicate that endoscopic CO2 laser surgery results in an increase of F0, jitter, shimmer, and a moderate decrease of MPT in extended cordectomies when compared with healthy controls. Fundamental frequency rises with increasing tension in the vocal fold (fibrosis), increasing subglottic pressure, and decreasing vibratory mass. In our patients, reduction in vibratory mass (loss of tissue) is probably the most important factor af-

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### Table 2. Perceptual voice evaluation by the speech therapist (GRBAS scale).

<table>
<thead>
<tr>
<th>Patients (n = 42)</th>
<th>Controls (n = 21)</th>
<th>I–II–III cordectomies (n = 26)</th>
<th>Extended cordectomy (n = 16)</th>
<th>Patients vs controls</th>
<th>I–II–III vs controls</th>
<th>Extended vs controls</th>
</tr>
</thead>
<tbody>
<tr>
<td>G .67 ± .48</td>
<td>.67 ± .48</td>
<td>.67 ± .48</td>
<td>.67 ± .48</td>
<td>.000</td>
<td>.001</td>
<td>.000</td>
</tr>
<tr>
<td>R .67 ± .51</td>
<td>.67 ± .51</td>
<td>.67 ± .51</td>
<td>.67 ± .51</td>
<td>.000</td>
<td>.031</td>
<td>.000</td>
</tr>
<tr>
<td>B .67 ± .48</td>
<td>.67 ± .48</td>
<td>.67 ± .48</td>
<td>.67 ± .48</td>
<td>.000</td>
<td>.000</td>
<td>.000</td>
</tr>
<tr>
<td>A .67 ± .48</td>
<td>.67 ± .48</td>
<td>.67 ± .48</td>
<td>.67 ± .48</td>
<td>.000</td>
<td>.000</td>
<td>.000</td>
</tr>
<tr>
<td>S .67 ± .48</td>
<td>.67 ± .48</td>
<td>.67 ± .48</td>
<td>.67 ± .48</td>
<td>.000</td>
<td>.007</td>
<td>.000</td>
</tr>
</tbody>
</table>

Abbreviations: G, grade; R, roughness; B, breathiness; A, asthenicity; S, strain.

Note. Data are expressed as mean ± standard deviation.
ter laser surgery and is also reflected in the GRBAS scale, in which the maximum changes are in breathiness and asthenicity.

Although patients with types III–V cordectomies often have a permanent dysphonia, it is rarely an important disability. In fact, 59.5% of patients referred voice improvement after surgery, and 91.5% considered their daily lives to be the same or even better than before surgery. For cases of voice-related disability, the possibility of a second phonemosurgical treatment with reconstruction has been advocated elsewhere.18–20 Restoration of vocal function is usually based on reestablishing aerodynamic glottal competency using a variety of medialization techniques.

The mean follow-up in our sample was 18 months, with a minimum follow-up of 6 months. This period is regarded as sufficient to allow the scarring process to take place and to check the absence of early recurrence.20 In addition, data in the literature suggest that 6 to 24 months after surgery no changes in voice quality are expected.10,21,22

In the present series, the surgically treated patients had the highest values of F0, jitter, shimmer, and N/H. However, only F0 and jitter showed significant differences in all acoustic situations. The lowest values of the acoustic analysis appeared in sustained vowels. However, everyday communication is based not on vowel production but spontaneous speech or oral reading; indeed, the results in connected oral speech are more realistic. As mentioned previously in a group of irradiated patients,21 vowel production is not the only phonetic feature that should be studied.

Most patients did not report deterioration in their lives after surgery, a finding that indicates that laser surgery may be considered appropriate treatment even for unselected T1 glottic tumors. These data are also in accordance with the previous studies,5,11 and correlate with the high percentage of normal or near normal voices reported by patients in the perceptual analysis.

However, in many institutions, the preferential treatment for early glottic cancer is still radiotherapy, because they consider that voice quality is poor after laser surgery.9,23–25 When reviewing the literature, one can conclude that the voice outcome is contradictory. In addition, data are based on relatively small patient samples. Although some studies are in accordance with our results, suggesting that laser surgery is a good treatment for early glottic cancer,2–4,18,26 others seem to demonstrate better voice with radiation compared with laser cordectomy.7,9,23,27 Moreover, when head and neck–specific questionnaires have been included in the analysis, no differences have been

### Table 4. Comparison of postoperative acoustic parameters in different vocal situations.

<table>
<thead>
<tr>
<th></th>
<th>LC (all)</th>
<th>LC (I–III)</th>
<th>LC (V)</th>
<th>Control group</th>
<th>LC vs control</th>
<th>LC (I–II–III) vs control</th>
<th>LC (V) vs control</th>
</tr>
</thead>
<tbody>
<tr>
<td>F0</td>
<td>169.6 ± 35.6</td>
<td>168.2 ± 35.7</td>
<td>172.0 ± 36.4</td>
<td>119.7 ± 19.8</td>
<td>.000</td>
<td>.000</td>
<td>.000</td>
</tr>
<tr>
<td>N/H</td>
<td>2.7 ± 1.5</td>
<td>2.5 ± 1.5</td>
<td>3.1 ± 1.5</td>
<td>1.5 ± 0.6</td>
<td>.001</td>
<td>.007</td>
<td>.001</td>
</tr>
<tr>
<td>Jitter</td>
<td>2.6 ± 3.5</td>
<td>2.8 ± 2.7</td>
<td>2.3 ± 1.5</td>
<td>1.1 ± 0.4</td>
<td>.002</td>
<td>.032</td>
<td>.001</td>
</tr>
<tr>
<td>Shimmer</td>
<td>1.4 ± 1.3</td>
<td>1.3 ± 1.2</td>
<td>1.6 ± 1.1</td>
<td>.8 ± 0.6</td>
<td>.008</td>
<td>.129</td>
<td>.001</td>
</tr>
<tr>
<td>MaxF0</td>
<td>250.1 ± 45.9</td>
<td>251.9 ± 43.5</td>
<td>247.1 ± 50.7</td>
<td>223.7 ± 61.4</td>
<td>.088</td>
<td>.111</td>
<td>.192</td>
</tr>
<tr>
<td>MinF0</td>
<td>113.1 ± 23.1</td>
<td>109.4 ± 19.7</td>
<td>119.1 ± 27.3</td>
<td>93.8 ± 17.5</td>
<td>.001</td>
<td>.006</td>
<td>.002</td>
</tr>
<tr>
<td>Vocal range</td>
<td>137 ± 48.5</td>
<td>142.5 ± 46.9</td>
<td>128 ± 51.2</td>
<td>129.9 ± 50.6</td>
<td>.636</td>
<td>.422</td>
<td>.892</td>
</tr>
<tr>
<td>MPT</td>
<td>10.22 ± 6.9</td>
<td>12.00</td>
<td>6.67</td>
<td>12.45</td>
<td>.109</td>
<td>.527</td>
<td>.006</td>
</tr>
</tbody>
</table>

Abbreviations: LC, laser cordectomy; F0, fundamental frequency; N/H, noise-harmonic ratio; MaxF0, maximum F0 at singing voice; MinF0, minimum F0 at singing voice; MPT, maximum phonation time.
found. In fact, a recent study conducted in the Netherlands concluded that patients selected for endoscopic laser surgery reported fewer voice-related problems than those who underwent radiotherapy.

The primary endpoint of our study was not to address the controversy between radiation or laser cordectomy for early glottic tumors. Instead, we mainly focused on the analysis of perceptual and objective voice outcome after laser cordectomy in a wide range of glottic lesions, and compared them with a control group without voice impairment.

Age was not determinant of voice quality after surgery in our study, though it does seem to have a different impact on daily life. For a majority of patients, life remained unchanged, but the subjects with bigger changes had a tendency to be younger. Probably, the impact of any grade of dysphonia in older patients is easier to cope with, because they have reduced professional and social voice requirements than younger patients. In addition, there were no professional voice users in our series, but in the hypothetical case of a group of patients with higher level of voice expectancy, the impact on daily lives would probably have been different. From this point of view, not only high professional voice demands but also age should be considered when deciding the best treatment for patients with large T1 tumors.

In conclusion, our results indicate that the objective quality of voice after laser surgery in a group of consecutive men treated for T1 glottic cancer differs from that found in controls. There is an improvement of perceptual voice evaluation in 59% of the patients after the surgery, being normal or near normal in almost 50% of the patients, and it is directly related to the extension of the resection. The involvement of the anterior commissure correlates negatively with voice quality; only 1 of 4 patients with this condition have normal perceptual voice. There are no differences in voice quality according to age, but the impact on daily life is higher in young people.

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