

# Voice Outcome in T1a Midcord Glottic Carcinoma

## Laser Surgery vs Radiotherapy

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**Objective:** To compare voice quality after radiotherapy or endoscopic laser surgery in patients with similar T1a midcord glottic carcinomas according to a validated multidimensional protocol.

**Design:** Retrospective cohort study.

**Setting:** University cancer referral center.

**Patients:** Two cohorts of consecutive patients willing to participate after treatment for primary T1a midcord glottic carcinoma with laser surgery (18 of 23 eligible) or radiotherapy (16 of 18 eligible).

**Main Outcome Measures:** Posttreatment voice quality was evaluated according to a multidimensional voice protocol based on validated European Laryngological Society recommendations, including perceptual, acoustic, aerodynamic, and stroboscopic analyses, together with patient self-assessment using the Voice Handicap Index.

**Results:** Approximately half of the patients had mild to

moderate voice dysfunction in the perceptual analysis (53% [8 of 15] in the radiotherapy group and 61% [11 of 18] in the laser surgery group) and on the Voice Handicap Index (44% [7 of 16] in the radiotherapy group and 56% [10 of 18] in the laser surgery group). The voice profile in the laser surgery group was mainly breathy; in the radiotherapy group, it was equally breathy and rough, with a trend for more jitter in the acoustic analysis. There was no statistical difference in the severity of voice dysfunction between the groups in any of the variables.

**Conclusions:** Endoscopic laser surgery offers overall voice quality equivalent to that of radiotherapy for patients with T1a midcord glottic carcinoma, although specific voice profiles may ultimately be different for the 2 modalities. We believe that endoscopic laser surgery is the preferred treatment in these patients because it provides oncologic control similar to that of radiotherapy and the additional benefits of lower costs, shorter treatment time, and the possibility of successive procedures.

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**R**ADIO THERAPY AND CARBON dioxide endoscopic laser surgery (henceforth referred to as laser surgery) are established treatment modalities for T1 glottic carcinoma, although their comparative benefits are debated. The 2 main concerns are disease control and posttreatment voice quality. Both modalities offer a high probability of local control, with a mean 5-year rate of 84% for radiotherapy in 16 large studies.<sup>1-16</sup> For laser surgery, local control has typically been slightly higher, with a mean rate of 92% (range, 88%-94%) for T1a lesions in 10 studies.<sup>17-26</sup> However, these rates apply mainly to studies with selected T1a lesions, excluding lesions invading the anterior commissure or the contralateral vocal cord that are included in radiotherapy studies. In 5 studies<sup>26-30</sup> that included T1b lesions for laser surgery, the

mean 5-year local control was 88% (range, 81%-93%). Although no randomized trial has been performed to our knowledge, local control rates in T1a carcinoma from these retrospective data can be considered at least comparable for the 2 modalities and certainly no worse for laser surgery than for radiotherapy. Therefore, voice quality may have an important role in decisions about treatment strategies.

Although it is clear that both treatment modalities will affect voice quality, it is difficult to compare them because of the limited existing data. The main problem of the few available comparative studies<sup>31-37</sup> on functional outcome is that they are largely affected by selection bias by including only midcord lesions for laser surgery or by not providing details about population characteristics or the selection criteria for laser surgery. Further problems are large variations in follow-up pe-

riods as a consequence of retrospective designs and small sample sizes owing to the relative rarity of the disease and the laborious character of multidimensional voice research. In addition, the voice analysis methods used lack uniformity, reliability, and validity. In most studies, only 1 or 2 aspects of voice quality or function are assessed, whereas the European Laryngological Society (ELS) concluded in 2000 that there is no single voice analysis method that adequately describes voice function and that the assessment of voice pathologic conditions needs to be multidimensional. Therefore, they implemented a validated basic protocol<sup>38</sup> composed of the following: (1) perceptual analysis (grade, roughness, and breathiness); (2) acoustics (jitter, shimmer, fundamental frequency range, and softest intensity); (3) aerodynamics (phonation quotient); (4) videostroboscopy (closure, regularity of vibration, mucosal wave, and symmetry); and (5) subjective rating (Voice Handicap Index [VHI]).

The first aim of this study was to compare voice quality in patients with T1 glottic carcinoma treated with radiotherapy vs laser surgery to determine whether 1 treatment modality is superior to the other with respect to functional outcome. The 2 treatment modalities affect the larynx differently. Therefore, the second aim of this study was to investigate whether the specific voice profile after laser surgery differs from the voice profile after radiotherapy. Although this is not the first article about voice quality after treatment for T1a glottic carcinoma, to our knowledge it is the first study with consecutive and comparable T1a lesions in a laser surgery group and a radiation group and the first using a multidimensional assessment protocol based on ELS recommendations.

## METHODS

### PATIENTS

Since October 11, 1996, patients with early glottic cancer (Tis or T1) who had single midcord lesions not extending into the anterior commissure were primarily offered laser surgery in our department, as opposed to the earlier standard treatment of radiotherapy. For the laser surgery group, 41 consecutive T1a lesions treated with laser surgery between July 10, 1999, and March 7, 2005, were reviewed. Deceased patients (n=3), patients with recurrent (n=3) or residual (n=8) disease requiring further treatment, and patients who had undergone additional vocal cord surgery for benign lesions (n=4) were excluded. This left 23 patients eligible for inclusion in the present study. Patients were contacted and were asked to participate in the evaluation of their current voice quality according to the same protocol used in 1998, to which 18 patients agreed.

For the radiotherapy group, we used a historic control group; the data from this group had been gathered during another study in 1999 (E.V.S., M.A.v.R., T.P.M.L., M.S.V., V.A.H.v.d.K., and R.J.B.d.J., unpublished data), also along the lines of ELS recommendations. Because laser surgery was offered in our department from October 11, 1996, onward, from this date irradiated patients with T1 glottic carcinomas must be considered as having selected lesions and cannot serve as an adequate control group for laser surgery-treated patients when evaluating voice outcome. Therefore, the radiotherapy group for the 1999 study had been carefully compiled by reviewing 66 consecutive patients with T1a glottic carcinoma treated between De-

cember 5, 1993, and May 27, 1995, and by selecting only the midcord lesions eligible for laser surgery. After excluding deceased patients (n=6), patients with recurrent disease (n=14) or additional vocal cord surgery (n=3), patients with lesions considered unsuitable for laser surgery (n=17), and patients in whom the exact extent of the tumor could not be retrospectively determined (n=8), 18 eligible patients were identified, 16 of whom were willing to participate in the 1999 study.

All patients were staged by using results of direct laryngoscopy and had biopsy-proved squamous cell carcinoma. Laser surgery was performed only on midcord lesions when it was estimated that at least a 2-mm margin within the affected cord could be obtained by subepithelial or subligamental resection. This is in accord with the Dutch National Guidelines<sup>39</sup> for T1 glottic carcinoma and corresponds to type I or type II chordectomy according to the ELS classification.<sup>40</sup> The final decision to perform laser surgery was based on the results of direct laryngoscopy. The surgical technique consisted of en bloc resection with sampling of margins when deemed necessary.

### VOICE QUALITY AND FUNCTION (MULTIDIMENSIONAL PROTOCOL) STIMULUS MATERIAL AND PROCEDURE

Speech material was recorded on the same equipment for both groups. All speech material was recorded in a sound-treated room using a microphone (Dynamic Røde NT1; Røde, Sydney, Australia), a preamplifier, and a recorder (DTC-ZE 700 DAT [digital audio tape] recorder; Sony Corp, Tokyo, Japan). The mouth-to-microphone distance was kept constant at 20 cm. Running speech, especially read-aloud text, is representative of perceived speech quality and yields stable data. Therefore, speech material for the perceptual analysis consisted of a standard phonetically balanced Dutch text ("80 *dappere fietsers*" [80 brave cyclists]) with a neutral content that was read aloud at a comfortable level by each subject and recorded. Speech material that is generally recommended for acoustic analyses consists of sustained vowels. Subjects produced a vowel (/a/) for as long as possible after maximal inspiration and at spontaneous comfortable pitch and loudness. The better of 2 attempts was used for further analysis. Vital capacity (VC), the volume change at the mouth between the position of full inspiration and complete expiration, was measured using a handheld spirometer.

#### Perceptual Analysis (GRBAS Score)

Perceptual analysis of voice quality was performed using the GRBAS (overall grade of hoarseness, roughness, breathiness, asthenicity, and strain) rating scale based on the work by Ishiki et al.<sup>41</sup> The ELS protocol was adhered to; only grade, roughness, and breathiness were rated.

Running speech samples were presented in random order. Six experienced listeners (E.V.S., M.A.v.R., T.P.M.L., M.S.V., V.A.H.v.d.K., and M.O.W.F.) familiar with the GRBAS system rated the speech samples. The listeners were blinded to the treatment groups. For cases in which the judges rated voice quality differently, consensus was reached through reevaluation and discussion.

#### Acoustics and Aerodynamics

Analyses were performed on a stable 2-second midsection of the sustained /a/. The following variables were measured using software for acoustic analyses (Praat; Institute of Phonetic Sciences, Amsterdam, the Netherlands)<sup>42</sup>: the mean fundamental frequency (in hertz), standard deviation of the fundamental frequency (in hertz), percentage jitter, percentage shimmer, mean

intensity (in decibels), and standard deviation of the intensity (in decibels).

Although recommended in the ELS protocol, softest intensity was not analyzed because it had not been included in the recordings from the 1999 radiotherapy group. Aerodynamic measures consisted of the maximum phonation time (MPT) in seconds, VC, and phonation quotient (VC/MPT in milliliters per second).<sup>43,44</sup>

### Videostroboscopy

Different equipment was used with the radiotherapy group (in 1999) than with the laser surgery group (in 2006). Videostroboscopy in the 2006 group was performed using a rigid endoscope (model 4450) and a stroboscope (model 5012) (both manufactured by Richard Wolf GmbH, Knittlingen, Germany) by an experienced laryngologist (E.V.S. and T.P.M.L.). The endoscope was connected to a camera (model DXC-101P; Sony Corp) and a video recorder (NV-L25HQ; Matsushita Electric Industrial Corporation, Kadoma, Japan). Speakers were asked to sustain /i/ at a comfortable pitch and loudness. All audiovisual material from 1999 was reevaluated for the purpose of this study in a random mix with material from 2006. Unfortunately, an experienced rater can often distinguish an irradiated from a surgically treated larynx. Therefore, judges could not be completely blinded to treatment group. Six experienced raters (E.V.S., M.A.v.R., T.P.M.L., M.S.V., V.A.H.v.d.K., and M.O.W.F.) judged the variables advocated by the ELS protocol (glottic closure, mucosal wave, and symmetry). These represent a selection from the variables advocated by Hirano and Bless.<sup>45</sup> Although included in the ELS protocol, regularity or periodicity was not scored because neither had been included in the recordings of the 1999 radiotherapy group.

### Subjective Rating (VHI)

Evaluation of voice impairment experienced by patients was performed using the VHI, Dutch version.<sup>46</sup> The patients completed the questionnaires (unaided by the investigators).

### STATISTICAL ANALYSIS

The Fisher exact test of association was used to test the difference in pattern of voice quality between the 2 groups. It was also used to test for differences in stroboscopic variables. Differences between groups for the VHI and the acoustic analysis were tested by means of the nonparametric Mann-Whitney test because we did not want to use normality assumptions.

## RESULTS

Of 18 irradiated and 23 laser surgery–treated patients who were eligible for the study, 2 in the radiotherapy group and 5 in the laser surgery group declined to participate because of unrelated health or social problems. As a result, 34 patients (16 treated with radiotherapy and 18 treated with laser surgery) who had primary T1a midcord lesions of 1 vocal cord were entered into the study. In all patients treated with laser surgery, tumor removal was possible by subepithelial or subligamental resection (corresponding to type I or type II cordectomy described in the ELS protocol<sup>40</sup>). The patient characteristics for the 2 groups are given in **Table 1**. The groups were similar with respect to age, sex, and smoking habits. The mean follow-up period was calculated in months

**Table 1. Patient Characteristics**

| Characteristic                                            | Radiotherapy Group (n=16) | Laser Surgery Group (n=18) |
|-----------------------------------------------------------|---------------------------|----------------------------|
| Tumor stage                                               | T1a midcord               | T1a midcord                |
| Age, mean (range), y                                      | 69 (52-88)                | 67 (38-81)                 |
| Female sex, No.                                           | 3                         | 4                          |
| Smoker or ex-smoker, No. <sup>a</sup>                     | 15                        | 16                         |
| Follow-up period from date of diagnosis, mean (range), mo | 60 (43-74)                | 45 (15-82)                 |

<sup>a</sup>Ex-smoker defined as a person who quit smoking less than 10 years ago.

from the date of diagnosis and was slightly longer in the radiotherapy group than in the laser surgery group (60 vs 45 months). All patients who entered the study agreed to participate in the self-assessment of voice quality and quality of life. However, 1 patient in the radiotherapy group declined to participate in the acoustic, aerodynamic, and stroboscopic evaluations, and another patient declined to participate in the stroboscopic analysis because of the associated discomfort with the examinations. Therefore, there were 15 patients for the acoustic and aerodynamic analyses and 14 patients for the stroboscopic analysis in the radiotherapy group. One patient in the laser surgery–treated group failed to notice the last page of the VHI questionnaire, resulting in only 17 patients for the evaluation of the emotional subscale and the total score on the VHI in that group.

### VOICE QUALITY (MULTIDIMENSIONAL PROTOCOL) PERCEPTION (GRBAS SCORE)

We distinguished the following 4 patterns of perceptual voice quality (perceptual voice profile): neither rough nor breathy, rough only, breathy only, or both (**Table 2**). All patients in the neither rough nor breathy category were judged to have a normal voice except for 1 patient in the radiotherapy group who was found to have excessive vocal fry. Therefore, for the radiotherapy group, the neither rough nor breathy category contained 8 patients, 7 of whom had normal voices. Approximately half of the voices in both groups were rated as dysfunctional (53% [8 of 15 patients] in the radiotherapy group and 61% [11 of 18] in the laser surgery group). Although the radiotherapy group showed mainly a mixed pattern of roughness and breathiness, voice quality in the laser surgery group was characterized as predominantly breathy. In statistical analysis, the distribution of the perceptual voice profiles in the voices classified as deviant (7 patients in the radiotherapy group and 11 patients in the laser surgery group) did not differ significantly between the groups ( $P=.27$ , Fischer exact test).

Table 2 gives the severity of voice pathologic conditions (mild, moderate, or severe) in the 2 treatment groups. Voice dysfunction in the laser surgery group tended to be mild (73% [8 of 11]) rather than moderate or severe (27% [3 of 11]), whereas voice dysfunction in the radiotherapy group was equally moderate (50% [4 of 8]) and mild (50% [4 of 8]).

**Table 2. Voice Quality**

| Variable                                                | No. (%)            |                     |
|---------------------------------------------------------|--------------------|---------------------|
|                                                         | Radiotherapy Group | Laser Surgery Group |
| Perceptual voice profile, No. of patients               | 15 <sup>a</sup>    | 18                  |
| Neither rough nor breathy, normal <sup>b</sup>          | 8 (53)             | 7 (39)              |
| Rough only                                              | 1 (7)              | 1 (6)               |
| Breathy only                                            | 2 (13)             | 7 (39)              |
| Both <sup>c</sup>                                       | 4 (27)             | 3 (17)              |
| Severity of voice pathologic condition, No. of patients | 8                  | 11                  |
| Overall                                                 |                    |                     |
| Mild                                                    | 4 (50)             | 8 (73)              |
| Moderate                                                | 4 (50)             | 2 (18)              |
| Severe                                                  | 0                  | 1 (9)               |
| Roughness                                               |                    |                     |
| Mild                                                    | 3 (38)             | 4 (36)              |
| Moderate                                                | 2 (25)             | 0                   |
| Severe                                                  | 0                  | 0                   |
| Breathiness                                             |                    |                     |
| Mild                                                    | 2 (25)             | 7 (64)              |
| Moderate                                                | 4 (50)             | 2 (18)              |
| Severe                                                  | 0                  | 1 (9)               |

<sup>a</sup>One patient declined to participate in the perceptual analysis.

<sup>b</sup>All patients in this category were judged to have normal voices except for 1 patient in the radiotherapy group who was found to have excessive vocal fry.

<sup>c</sup> $P=.27$ , Fisher exact test for difference in deviant voice profiles.

**Table 3. Acoustic and Aerodynamic Analysis**

| Variable                    | Mean                                   |                            | P Value <sup>b</sup> |
|-----------------------------|----------------------------------------|----------------------------|----------------------|
|                             | Radiotherapy Group (n=15) <sup>a</sup> | Laser Surgery Group (n=18) |                      |
| VC, mL                      | 2886                                   | 2649                       | .34                  |
| MPT, s                      | 14.50                                  | 16.17                      | .38                  |
| VC/MPT, mL/s                | 254                                    | 181                        | .11                  |
| Fundamental frequency       | 145                                    | 156                        | .61                  |
| SD of fundamental frequency | 2.74                                   | 1.83                       | .14                  |
| Jitter, %                   | 1.00                                   | 0.45                       | .06                  |
| Shimmer, %                  | 5.17                                   | 4.36                       | .61                  |
| Mean intensity              | 60.53                                  | 0.80                       | .56                  |
| SD of mean intensity        | 0.81                                   | 0.86                       | .82                  |

Abbreviations: MPT, mean phonation time; VC, vital capacity; VC/MPT, phonation quotient.

<sup>a</sup>One patient declined to participate in the acoustic analysis.

<sup>b</sup>Mann-Whitney test for difference in acoustic and aerodynamic variables.

### ACOUSTIC AND AERODYNAMIC ANALYSIS

The mean values for the different acoustic and aerodynamic variables (see the "Methods" section) are given in **Table 3**. The percentage of jitter in voices was higher in the radiotherapy group (1.00%) than in the laser surgery group (0.45%). The difference was of borderline significance ( $P=.06$ , Mann-Whitney test). Although not significant, other perturbation measures such as shimmer and the standard deviation of fundamental frequency were elevated in the radiotherapy group. There were no sig-

**Table 4. Structural Analysis (Stroboscopy)**

| Variable                                         | No. (%)                                |                            | P Value <sup>b</sup> |
|--------------------------------------------------|----------------------------------------|----------------------------|----------------------|
|                                                  | Radiotherapy Group (n=14) <sup>a</sup> | Laser Surgery Group (n=18) |                      |
| Closure                                          |                                        |                            |                      |
| Complete                                         | 6 (43)                                 | 8 (44)                     | .93                  |
| Incomplete                                       | 8 (57)                                 | 10 (56)                    |                      |
| Symmetry <sup>c</sup>                            |                                        |                            |                      |
| Symmetric                                        | 1 (7)                                  | 1 (6)                      | .81                  |
| Asymmetric                                       | 12 (86)                                | 17 (94)                    |                      |
| Not assessable                                   | 1 (7)                                  | 0                          |                      |
| Mucosal wave                                     |                                        |                            |                      |
| Normal both sides                                | 1 (7)                                  | 1 (6)                      | .24                  |
| Not normal both sides                            | 9 (64)                                 | 17 (94)                    |                      |
| One or both sides not assessable                 | 4 (29)                                 | 0                          |                      |
| Reduced or absent 1 side <sup>c</sup>            | 5 (36)                                 | 13 (72)                    |                      |
| Reduced or absent both sides <sup>c</sup>        | 4 (29)                                 | 4 (22)                     | .31                  |
| Nonvibrating parts <sup>c</sup>                  |                                        |                            |                      |
| Yes                                              | 4 (29)                                 | 14 (78)                    | .08                  |
| No                                               | 5 (36)                                 | 4 (22)                     |                      |
| Not assessable                                   | 5 (36)                                 | 0                          |                      |
| Ventricular activity or supraglottic involvement |                                        |                            |                      |
| Yes                                              | 4 (29)                                 | 9 (50)                     | .40                  |
| No                                               | 10 (71)                                | 9 (50)                     |                      |

<sup>a</sup>Two patients declined to participate in the stroboscopic analysis.

<sup>b</sup>Fisher exact test for difference in stroboscopic variables.

<sup>c</sup>Patients whose data were not assessable are excluded from these categories.

nificant differences in the aerodynamic measures, and these were within normal limits for both groups.

### VIDEOSTROBOSCOPY

Videostroboscopy showed abnormal patterns in almost all patients (**Table 4**). More than half of the patients in each group had incomplete closure of the vocal cords (57% [8 of 14 patients] in the radiotherapy group and 56% [10 of 18] in the laser surgery group). The symmetry and vibratory pattern of the mucosal wave were normal in only 1 patient in each group (7% in the radiotherapy group and 6% in the laser surgery group). Unfortunately, 4 videostroboscopic recordings in the radiotherapy group were considered not assessable. In 2 of these patients, one of the vocal cords showed a normal vibratory pattern, but the other could not be assessed because of ventricular activity impeding the view. In the other 2 patients, anatomic and participation factors prevented full-quality stroboscopic recordings. Statistical analysis (Fisher exact test) showed no significant difference between the 2 groups, although the large quantity of missing data prevents a meaningful comparison between groups.

### SUBJECTIVE RATING (VHI)

Results of the VHI are given in **Table 5**. The VHI was normal for 56% (9 of 16) of irradiated patients and for

**Table 5. Voice Handicap Index (VHI)**

| Variable                                 | Mean (Median)               |                                           | P Value <sup>b</sup> |
|------------------------------------------|-----------------------------|-------------------------------------------|----------------------|
|                                          | Radiotherapy Group (n = 16) | Laser Surgery Group (n = 18) <sup>a</sup> |                      |
| Physical score                           | 8.7 (4.5)                   | 7.9 (6.0)                                 | .85                  |
| Functional score                         | 5.0 (2.0)                   | 6.2 (4.5)                                 | .21                  |
| Emotional score                          | 3.9 (0.0)                   | 4.9 (1.0)                                 | .49                  |
| Total score                              | 17.6 (8.0)                  | 19.2 (11.0)                               | .48                  |
| No. with normal total score <sup>c</sup> | 9                           | 8                                         | ... <sup>d</sup>     |

<sup>a</sup>Seventeen patients provided data for the emotional score and for the total score because 1 patient failed to completed the questionnaire.

<sup>b</sup>Mann-Whitney test for difference in VHI score.

<sup>c</sup>Normal score is 10 or less of 120.

<sup>d</sup>A P value was not determined.

44% (8 of 18) of laser surgery–treated patients. A total score of 10 or less of a possible 120 on the VHI is considered normal. Both groups showed slight elevations in the mean total VHI scores (17.6 in the radiotherapy group and 19.2 in the laser surgery group). However, the distribution of scores in both groups was skewed because the median scores were normal in the radiotherapy group and close to normal in the laser surgery–treated group (8.0 in the radiotherapy group and 11.0 in the laser surgery group). This indicates that the voice handicap for most patients is minimal, with few severely affected patients in both groups. There was no significant difference in the total score ( $P=.48$ , Mann-Whitney test) or in any of the subclass scores on the VHI between irradiated and laser surgery–treated patients.

#### AGREEMENT BETWEEN VOICE HANDICAP AND GRBAS GRADE

We also investigated the measure of agreement between the patients' perception of their voice quality and that of the experienced listeners (E.V.S., M.A.v.R., T.P.M.L., M.S.V., V.A.H.v.d.K., and M.O.W.F.) (**Table 6**). Among patients who rated their voices as normal, 56% (5 of 9) in the radiotherapy group and 38% (3 of 8) in the laser surgery group were rated as having normal voices by expert listeners. One of these patients in the laser surgery group was rated as having a severely deviant voice by expert listeners. In contrast, among patients who were rated as having normal voices by the expert listeners, 71% (5 of 7) in the radiotherapy group and 43% (3 of 7) in the laser surgery group had normal scores on the VHI. The  $\kappa$  statistic calculated for agreement between the score of the VHI ( $\leq 10$  or  $> 10$ ) and the overall grade of the GRBAS (0 or  $> 0$ ) was 0.125. This indicates poor agreement according to the rating system by Fleiss<sup>47</sup> and slight agreement according to that by Landis and Koch.<sup>48</sup>

#### COMMENT

In this study, we compared voice quality and function in consecutive patients with T1a midcord glottic carcinoma treated with radiotherapy or laser surgery using a validated multidimensional assessment protocol based on

**Table 6. Agreement Between VHI and GRBAS**

| Variable                                                               | No. (%)            |                     |
|------------------------------------------------------------------------|--------------------|---------------------|
|                                                                        | Radiotherapy Group | Laser Surgery Group |
| GRBAS grade in patients with normal VHI of $\leq 10$ , No. of patients | 9 <sup>a</sup>     | 8                   |
| 0                                                                      | 5 (56)             | 3 (38)              |
| 1                                                                      | 1 (11)             | 4 (50)              |
| 2                                                                      | 2 (22)             | 0                   |
| 3                                                                      | 0                  | 1 (13)              |
| VHI score in patients with normal GRBAS grade of 0, No. of patients    | 7                  | 7                   |
| $\leq 10$                                                              | 5 (71)             | 3 (43)              |
| 11-30                                                                  | 1 (14)             | 1 (14)              |
| 31-55                                                                  | 1 (14)             | 3 (43)              |

Abbreviations: GRBAS, overall grade of hoarseness, roughness, breathiness, asthenicity, and strain; VHI, Voice Handicap Index.

<sup>a</sup>The data for 1 patient who did not complete the GRBAS are missing from this analysis.

that recommended by the ELS. In all patients treated with laser surgery, tumor removal was possible by subepithelial or subligamental resection. Therefore, the selection criteria for laser surgery, based on the limited horizontal extent of the lesion (midcord), seem to have correlated well with limited invasion of the deeper layers of the vocal fold. In perceptual analysis, roughly half of the patients in both groups had mild to moderate voice dysfunction (53% [8 of 15] in the radiotherapy group and 61% [11 of 18] in the laser surgery group). There was a tendency toward differing voice profiles in the 2 treatment groups. Voices in the laser surgery group were mainly breathy, whereas voices in the radiotherapy group were equally breathy and rough, although this difference was not statistically significant. Breathiness as a main abnormality in laser surgery–treated patients is not unexpected because of the removal of tissue leading to a deficit, albeit small. Lymphedema is a long-term complication after radiotherapy, developing 3 to 12 months after treatment, and this may have compensated for the deficit left where the carcinoma had destroyed mucosa in some patients, explaining why breathiness was less predominant in the radiotherapy group than in the laser surgery group. In acoustic analysis, there was a trend for more jitter in the radiotherapy group. This indicates more frequency perturbations in these voices. Perturbation measures such as jitter are more often correlated with perceptual roughness.<sup>49-51</sup> Therefore, these acoustic results correspond to the tentative perceptual profiles (Table 2) that showed more roughness in the radiotherapy group. However, none of these trends reached statistical significance.

Despite approximately half of the voices being normal, videostroboscopy showed dysfunction in almost all patients, with incomplete closure in more than half of the patients in both groups (57% [8 of 14] in the radiotherapy group and 56% [10 of 18] in the laser surgery group) and reduced mucosal wave in all assessable patients except 1 in each group. This illustrates that not all structural anomalies have a clinical effect.

**Table 7. Summary of Current Literature About Voice Outcome in T1 Glottic Carcinoma Laser Surgery vs Radiotherapy**

| Source                                       | Patients                                                                  | Follow-up                                                | Outcome Measures                                                       |
|----------------------------------------------|---------------------------------------------------------------------------|----------------------------------------------------------|------------------------------------------------------------------------|
| Cohen et al, <sup>31</sup> 2006 <sup>a</sup> | 202 T1a and 6 T1b for laser surgery,<br>85 T1a and 8 T1b for radiotherapy | >3 mo                                                    | Self-assessment (VHI)                                                  |
| Loughran et al, <sup>32</sup> 2005           | 36 T1a (18 laser surgery,<br>18 radiotherapy)                             | 28 mo for laser surgery,<br>31 mo for radiotherapy       | Perceptual (GRBAS), self-assessment<br>(VHI, VPQ, Voice Symptom Score) |
| Peeters et al, <sup>34</sup> 2004            | 92 T1a (52 laser surgery,<br>40 radiotherapy)                             | ≥12 mo                                                   | Self-assessment (VHI)                                                  |
| Tamura et al, <sup>36</sup> 2003             | 15 T1a (10 laser surgery,<br>5 radiotherapy)                              | 12-53 mo for laser surgery,<br>14-34 mo for radiotherapy | Acoustics, aerodynamics                                                |
| Wedman et al, <sup>37</sup> 2002             | 24 T1a (15 laser surgery,<br>9 radiotherapy)                              | 2-15 y                                                   | Acoustics, aerodynamics, perceptual,<br>self-assessment (VAS)          |
| Rydell et al, <sup>35</sup> 1995             | 36 T1a (18 laser surgery,<br>18 radiotherapy)                             | 3 mo to 2 y                                              | Acoustics, aerodynamics, perceptual<br>(GRBAS)                         |
| McGuirt et al, <sup>33</sup> 1994            | 24 T1a (11 laser surgery,<br>13 radiotherapy)                             | ≥6 mo                                                    | Acoustics, aerodynamics, stroboscopy                                   |

Abbreviations: GRBAS, overall grade of hoarseness, roughness, breathiness, asthenicity, and strain; VAS, visual analog scale; VHI, Voice Handicap Index; VPQ, Vocal Performance Questionnaire.

<sup>a</sup>Meta-analysis of 6 studies. All others are retrospective cohort studies.

As for self-assessment, patients in both groups rated their voices as mildly deviant on the VHI (mean total score, 17.6 in the radiotherapy group and 19.2 in the laser surgery group). Again, the difference was not statistically significant. The poor agreement between the perceptual assessment (GRBAS) and the VHI ( $\kappa$  statistic, 0.125), widely used and validated modalities, indicates that patients' perception of voice quality in both groups does not always correspond to expert opinion. We believe that this reflects the fact that a patient's perception of voice handicap is influenced not only by anatomic functioning but also by several environmental factors. It may be that the substantial period of time since treatment causes speakers to become accustomed to their voice, shifting their perception of "normal." These findings may indicate a role for posttreatment voice therapy not only in optimizing voice function but also in detecting and aiding patients experiencing more-than-expected handicaps after treatment.<sup>52</sup> This again highlights the fact that voice research needs to be multidimensional and standardized to properly characterize voice quality and patient perception, particularly because patient perception may be the most important variable in determining treatment choice. This is especially relevant because the limits of laser surgery for glottic carcinoma excisions are slowly being stretched beyond the T1a midcord lesions to involve the anterior commissure and deep resections down to the thyroid cartilage.<sup>26,29,53,54</sup> In many countries, voice quality is the key issue in the advancement of the limits of laser surgery. Therefore, optimal documentation and characterization of posttreatment voice function and quality are essential.

When we compared our results with the current literature, we identified 1 meta-analysis<sup>31</sup> and 6 retrospective studies<sup>32-37</sup> (listed in **Table 7**) evaluating functional outcome in T1 glottic carcinoma treated with radiotherapy or laser surgery. Four of these studies<sup>32,33,36,37</sup> found no (or almost no) difference in voice quality between the 2 treatment modalities. Tamura et al<sup>36</sup> studied acoustic and aerodynamic variables in 15 patients with T1a carcinoma and found only increased fun-

damental frequency and air flow rate in laser surgery-treated patients compared with healthy control subjects, but the difference in irradiated patients was not significant. Wedman et al<sup>37</sup> studied acoustic, structural, and self-assessment variables in 24 patients with T1a carcinoma. The only difference found was a better mucosal wave in the laser surgery group compared with the radiotherapy group, although the statistical reporting is incomplete. McGuirt et al<sup>33</sup> studied acoustic, aerodynamic, and structural variables in 24 patients with T1a carcinoma and found no difference between the 2 treatment modalities. These 3 studies do not contain descriptions of the selection of patient populations. Loughran et al<sup>32</sup> studied perceptive and self-assessment variables in 36 patients with T1a carcinomas (18 treated with laser surgery and 18 treated with radiotherapy) and found a significantly better score for irradiated patients on the emotional subscale of the Voice Symptom Score voice assessment questionnaire. However, the overall score did not differ significantly, along with any other variables. The authors do not describe the selection criteria for laser surgery.

Two studies<sup>34,35</sup> identify significant differences between the 2 treatment modalities. Peeters et al<sup>34</sup> compared VHI scores among 92 patients with T1a glottic carcinoma (52 treated with laser surgery and 40 treated with radiotherapy) and found that the VHI total score was significantly better in the laser surgery group (mean total scores, 12 in the laser surgery group and 18 in the radiotherapy group). However, results were biased by the fact that the radiotherapy group consisted of all patients not considered suitable for laser surgery. Also, the difference found is small, possibly insufficient to be clinically significant. Rydell et al<sup>35</sup> studied acoustic and perceptual variables in 36 patients with T1a glottic carcinomas (18 treated with laser surgery and 18 treated with radiotherapy) and found significantly better voice quality in irradiated patients, with less jitter, breathiness, asthenia, and strain, as well as lower fundamental frequency, despite the possibility of larger lesions in this group because of selection bias.

Finally, Cohen et al<sup>31</sup> performed a meta-analysis of the VHI results for T1a (and a few T1b) carcinomas in the current literature, from which 6 studies were selected with a total of 299 patients (208 treated with laser surgery and 91 treated with radiotherapy). Mean total scores of 12.9 for laser surgery–treated patients and 18.5 for irradiated patients were found, but the difference was not statistically significant. The meta-analysis by Cohen et al incorporates the same bias as the studies entered.

As discussed in the introduction, insufficient methodological quality (mainly owing to selection bias but also because of incomplete reporting on treatment selection criteria and patient populations, differing voice-measuring instruments, and small sample size) is a problem in the current literature. However, accepting these limitations, the evidence in our article supports our finding that there is little or no difference in overall voice quality between the 2 treatment modalities of radiotherapy vs laser surgery. Although the differences found by Peeters et al<sup>34</sup> and Rydell et al<sup>35</sup> are statistically significant, it is uncertain whether they would be clinically relevant. Although this issue is outside the scope of this study, it is another topic in voice research to be addressed. Despite the removal of selection bias, the problem of small sample size remains in the present study. As stated earlier, this is a general problem resulting from the relative rarity of the disease and the laborious character of multidimensional voice research. Our study (n=34) together with the studies by Loughran et al<sup>32</sup> and Rydell et al<sup>35</sup> (n=36 for both) constitute the largest studies in the literature to date.

In summary, among patients with unselected T1a mid-cord lesions, which in the laser surgery group were treatable by subepithelial or subligamental resection, roughly half of the patients will have mild to moderate voice dysfunction regardless of treatment modality. There is no statistical difference in the severity and type of voice dysfunction between patients undergoing radiotherapy vs laser surgery as assessed by a multidimensional protocol, although voice dysfunction profiles may ultimately be different, with voices of irradiated patients showing more roughness and the voices of laser surgery–treated patients being mainly breathy. Supported by the modest trend found in the literature, our results lead us to conclude that laser surgery offers overall voice quality equivalent to that of radiotherapy for patients with T1a mid-cord glottic carcinoma. We believe that laser surgery is the preferred treatment for T1a midcord glottic carcinoma because it provides oncologic control similar to that of radiotherapy and the additional benefits of lower costs, shorter treatment time, and the possibility of successive procedures.

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