ORIGINAL ARTICLE

VOICE OUTCOMES AFTER RADIOTHERAPY TREATMENT FOR EARLY GLOTTIC CANCER: ASSESSMENT USING MULTIDIMENSIONAL TOOLS

Jessica R. L. Bibby, BSpPath (Hons),1 Susan M. Cotton, MAppSci,2 Alison Perry, PhD,1 June F. Corry, FRANZCR3

1 School of Human Communication Sciences, Faculty of Health Sciences, La Trobe University, Victoria 3086, Australia. E-mail: a.perry@latrobe.edu.au
2 ORYGEN Research Centre, Department of Psychiatry, University of Melbourne, Parkville, Victoria, Australia
3 Division of Radiation Oncology, Head and Neck Cancer Unit, Peter MacCallum Cancer Centre, St. Andrews Place, East Melbourne, Victoria, Australia

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Abstract: Background. This is the first prospective study to use instrumental and both clinician- and client-rated auditory-perceptual measures to examine voice and voice-related quality of life changes in patients after curative radiotherapy for early glottic cancer.

Method. Thirty patients undergoing curative radiotherapy treatment for early glottic cancer completed the following: 3 voice tasks for acoustic, aerodynamic, and auditory-perceptual voice measures (therapist-rated); a patient self-report rating of voice quality; and a voice-related quality of life assessment before and 12 months after radiotherapy.

Results. Patients’ perceptions of their voice quality and their voice-related quality of life significantly improved posttreatment, as did acoustic, aerodynamic, and auditory-perceptual voice measures. Mean speaking fundamental frequency did not change significantly, although breathiness and strain in the voice recordings were demonstrably reduced.

Conclusion. In describing postradiotherapy voices in this study, pertinent measures of voice outcomes have been established, setting the benchmark for comparison in future cohort studies.

Keywords: voice; glottic cancer; radiotherapy; assessment; outcomes

The goals of treatment for early glottic cancer (T1-2, N0) are cure with optimal voice quality.1,2 Radiotherapy or laser surgeries are the current primary treatments for early glottic cancer,3 but there is controversy about which is the better treatment. To date, there are no randomized controlled trials in this area.4 Published reviews suggest comparable local control rates from each treatment modality, but the quality of the published data regarding respective voice outcomes is relatively poor.2,5–10

Voice is a multidimensional construct reliant on, among other things, respiratory support and true vocal fold vibration. When voice quality alters, it often affects self-perception, as well as how the person is perceived by others. An abnormal voice quality, such as the one that occurs with
laryngeal cancer, has the potential to cause social and emotional harm and to decrease quality of life (QOL).1,8,11

Voice assessments should reflect the multidimensional nature of voice and its effect on the individual.12 Measures of voice impairment—respiratory support, vocal fold vibration, auditory-perceptual voice changes—as well as changes to social activity and to voice-related QOL (V-R QOL) may collectively be used to examine treatment outcomes.13

Outcomes of treatment, with either radiotherapy or laser surgery, are important, but there are remarkably few comparative studies, and none using the multidimensional assessment tools we use in this study. Furthermore, very few researchers who have investigated voice changes after radiotherapy for early glottic cancer obtained baseline measures for comparison with posttreatment data.14–17

Voice assessment can be divided into instrumental and perceptual measures. Instrumental measures include acoustic and aerodynamic measures.13 These provide numerical data that give indirect information about vocal fold movement. These assessments are not available in all clinic settings, as they require the use of specialized computer programs.13

Perceptual measures involve the speech pathologist and/or a patient listening to the patient’s voice or a recording of the voice and making subjective judgments about the quality of the voice output.13 Self-report (by the patient) of V-R QOL, using a standardized instrument, can also capture subtle changes to patients’ lives during and after treatment.11,18,19

This study was designed to answer the following questions:

1. Do the voices of patients treated with radiotherapy change perceptually, aerodynamically, and/or acoustically, from pretreatment to 12 months posttreatment?
2. Do patients experience a change in their V-R QOL from pretreatment to 12 months posttreatment?

We hypothesized that there would be positive changes to patients’ voices, as demonstrated by all measures (including QOL). We further hypothesized that patients’ voices would not be normal at 12 months after radiotherapy treatment.

To test these hypotheses, we audio-recorded patients’ voices and self-perceptions at pretreatment and 12 months postradiotherapy treatment for early glottic cancer. A multidimensional, comprehensive battery of assessments was employed, as described below.

MATERIALS AND METHODS

Study Design. This is a single cohort study, prospectively examining voice outcomes of patients treated with radiotherapy for early glottic cancer. The study protocol is presented in Figure 1.

Sample Characteristics. Forty-one participants at Peter MacCallum Cancer Centre (PMCC), Melbourne, Australia, with confirmed squamous cell cancer (SCC) of the glottis were recruited into this study between July 2002 and September 2004. Of these, 30 people completed the study and were disease-free at 12 months posttreatment.

Attrition (26.8%) in the study was due to various reasons. Of the 11 participants who did not complete the study, 6 were lost to follow-up, 1 had a recurrence of laryngeal cancer postradiotherapy, 1 withdrew from the study, 1 died before final data were collected, 1 underwent a laryngectomy postradiotherapy treatment, and 1 did not have radiotherapy treatment according to the PMCC protocol.

All 30 participants had a laryngeal tumor, staged either as T1N0M0 (n = 21) or as T2N0M0 (n = 9), and received planned curative radiotherapy treatment as per PMCC head and neck cancer unit’s protocol (2002). Participants were more likely to be men and were 45 to 81 years old; only 3 had never smoked (Table 1).

Treatment. All patients were immobilized in a headrest and thermoplastic mask with chin extended. Radiation therapy fields were centered on the true glottis with a 2- to 3-cm margin superiorly–inferiorly, the anterior margin covered patient profile, the posterior edge was 1.5 cm posterior to the arytenoids. Bolus was used for patients with anterior commissure involvement. Radiotherapy planning was performed using 3- to 5-mm CT slices and 3D algorithms; the radiation dose was prescribed to the ICRU 50 point. Participants with T1 lesions received 63 Gy radiation doses, in 28 fractions over 5.5 weeks (n = 21). Participants with T2 lesions received a total 66 Gy, in 35 fractions over 5 weeks, using a concomitant boost regimen consisting of 50 Gy in 2 Gy fractions over 5 weeks, with a second 1.6 Gy fraction.
6 hours later, in the last 10 fractions of treatment ($n = 9$).

**Ethics.** Ethical approval for this study was obtained from both PMCC Ethics' Committee and La Trobe University's Faculty of Health Sciences' Human Ethics Committee. Informed written consent was obtained from all participants before commencing baseline data collection.

**Measures.** At baseline, at 12 weeks and 6 months posttreatment, and again at final follow-up (12 months posttreatment), patients completed 3 voice tasks, from which instrumental (acoustic, aerodynamic) and therapist-rated auditory-perceptual voice measures were taken. A patient self-report rating of voice quality and a V-R QOL were also completed by all patients (Appendix). We report here a comparison of the outcome data collected at baseline (pretreatment) and at endpoint (12 months posttreatment).

Voice tasks undertaken by each patient included a recitation of the days of the week, 3 sustained phonations of “ah” and 1 minute of sustained monolog.

The patient self-report rating of voice quality and the V-R QOL measure were completed prior to the voice samples being taken, to prevent patients’ performance on the voice tasks influencing their responses.

A 100-mm length visual analog scale (VAS) was used to examine the patients’ self-rating of voice quality, with the written descriptors of “no voice” at 0 mm and “excellent voice” at 100 mm. Each patient was required to draw a vertical dash at the point on the line which best represented his (or her) overall voice quality. “No voice” and “excellent voice” were selected for the ends of the
Participants’ voices were audio-recorded on 90-minute TDK digital audiotapes (TDK DA-RXG 90EC) using a TASCAM Digital AudioTape-recorder (model DA-P1) (DAT-corder), connected to a hands-free Optimus Omnidirectional Boundary Microphone (OOMB), in a quiet, carpeted office at PMCC with an ambient noise level of 50 dB. The DAT-corder and OOBM were positioned on a desk approximately 1 m from the participant’s mouth, to allow voice quality to be captured, while limiting recording of the sound of breathy mouth airflow.

The voice samples were then copied from the TDK digital audiotapes into the WaveLab Lite/Recording/editing program (version 1.3) on an IBM computer, located in the voice laboratory at the School of Human Communication Sciences, La Trobe University.

Acoustic samples were represented as a voice waveform on the computer screen. A voice-sampling rate of 44.8 KHz was used to gain the highest and clearest quality of voice samples for acoustic analysis. The advanced version 2.5 of the Multi-Dimensional Voice Program (model 5105) (MDVP) on an IBM computer was used for acoustic analysis of the voice waveforms. The MDVP is an optional program of the Kay Elemetrics’ Computerized Speech Lab (CSL) program.²¹

The following were obtained from the voice recordings: (1) measures of perturbation, including jitter and shimmer; (2) harmonic:noise ratio (H:N R); and (3) mean speaking fundamental frequency (MSFF).

Jitter and shimmer represent, respectively, period-to-period irregularities in frequency and in amplitude.²² When either jitter or shimmer measurement is considerably higher than normal, the voice is frequently perceived as rough.²³

H:N R is the ratio of the sound frequencies to the noise energy in the voice. This correlates with a perception of roughness in the voice when this value is lower than normal.¹³ MSFF, as measured in Hertz (Hz), is on average measure of how frequently the vocal folds vibrate in connected speech, and is associated with the perception of pitch, with higher MSFF values correlating with higher perceived pitch.¹³

Jitter, shimmer, and H:N R were obtained from waveforms of 2 seconds of each patient’s vowel prolongations. The first second of recording was excluded, as was any vowel sound produced after the end of the third second, to eliminate the onset and offset of the vowel, which have high degrees of frequency and amplitude perturba-
tion. As the MDVP program is used to analyze noise to harmonic ratio (N:H R), rather than H:N R, a reciprocal calculation (1/N:H R = H:N R) was performed to convert the data for ease of comparison with previous research. The patients’ 30-second monolog waveforms were used for measuring MSFF. Aerodynamic analysis, maximum phonation time (MPT) (seconds) was also performed using the MDVP program. The unedited sustained vowel phonation waveforms and a numerical value corresponding to their length (seconds) were sequentially displayed on the computer screen and were noted by the researcher. The longest waveform of each patient’s 3 vowels was recorded as their MPT.

Auditory-perceptual voice was evaluated by 2 speech pathologists (raters) who were specialists in voice analysis, using Oates and Russell’s Perceptual Voice Profile (PVP) (1998). The PVP is a valid and reliable rating scale, allowing listeners to rate dimensions of a speaker’s voice such as pitch (high/low/monotone), loudness (loud, soft, monoloud), and quality (breathy, strained, rough, glottal fry, pitch breaks, phonation breaks, voice arrests, falsetto, tremor, diplophonia) from recorded monolog.

Raters use a 6-point Likert scale, in which 1 denotes normal voice and 6 is a severe level of vocal impairment. Raters were provided with an instruction sheet, prior to rating the samples, that documented the required procedure. All analyses occurred in quiet, carpeted offices, either at La Trobe University or at the Melbourne Voice Analysis Centre.

Intra- and inter-rater reliability of the 2 raters’ evaluations was examined, using percentage agreement calculations. The intra-rater reliability calculations were performed using the raters’ blinded evaluations of 10 participants’ monologs, which were repeated and randomly distributed on an audio CD used for auditory-perceptual evaluation. Inter-rater reliability percentage agreements were determined from the raters’ evaluations of all the 30 participants’ monologs. Scores within ±1 of each other on the 6-point PVP rating scale were taken as an acceptable level of agreement. Portney and Watkins criteria for judging percentage agreement were used to determine the degree of intra- and inter-agreement for all the rated auditory-perceptual parameters.

Intra-rater reliability was high-to-perfect (80% to 100%) for all of the rated auditory-perceptual parameters. Inter-rater reliability also demonstrated high-to-perfect agreement (83.33% to 100%) for all parameters, except for posttreatment glottal fry, which had a moderate-high (73.33%) satisfactory agreement.

V-R QOL was examined from scores on the standardized V-R QOL questionnaires.

**Statistical Analysis.** All data (both pre- and posttreatment) were screened prior to analysis, using visual inspection of graphs and examination of measures of central tendency, variance, skewness, and kurtosis, to detect any errors in data entry, to identify any outliers, and to test for violations to statistical assumptions, such as homogeneity of variance and normality. Standard deviations were quite large in some instances, and data were not normally distributed (as determined by significant skewness). This highlights the heterogeneity of the data, reflecting the range of the pretreatment and posttreatment recordings of voices in this laryngeal cancer population.

To deal with the issue of non-normality, some variables were transformed using the logarithmic algorithm (eg, MSFF [Hz] and jitter [%]), while for other variables (eg, shimmer [dB]), transformation was of no use. For data that were normally distributed, or that became normally distributed after transformation, a series of paired *t* tests were employed to determine whether there was a significant change in voice over the 12-month period. For shimmer, a nonparametric Wilcoxon paired-signed ranks test was used to examine change.

As the percentage agreements for ratings were acceptable, the perceptual voice profile (PVP) scores were averaged, to obtain a single score for each parameter. Auditory-perceptual data (PVP scores) were measured using an ordinal scale, so the Wilcoxon signed-ranks tests was used to determine whether the difference between pretreatment and posttreatment scores for each PVP parameter was statistically significant. For all (ie, parametric and nonparametric) tests, an alpha level (α) of 0.05 was set to determine the significance.

### RESULTS

Table 2 shows the descriptive statistics for the objective voice measures over the 2 time-points.

**Acoustic Outcomes.** Although acoustic measures demonstrated improvement from pretreatment to 12 months posttreatment, only changes in jitter, shimmer, and H:N R were significantly different (*t* (29) = 5.136, *p* < .0001; Z = −2.15, *p* = 0.032; and *t* (29) = −4.44, *p* < .001, respectively) (see Table 2).
In normal voices, jitter does not usually exceed 1% and shimmer does not exceed 0.30 dB.\textsuperscript{13} The mean jitter (\%) and shimmer (dB) of patients’ voices in this study was therefore higher than normal at both time-points.

H:N R normally should be much greater than 1, as values greater than 1 indicate a clearer voice quality.\textsuperscript{13} H:N R of 11.9 dB is typical of the normal population.\textsuperscript{13,24} In this study, the mean H:N R of patients’ voices was greater than 1 both at pretreatment and posttreatment time-points, meaning that there was more harmonic than noise. The patients’ mean H:N R, however, was lower than 11.9 dB, indicating that the level of harmonics was below normal.

Although there were improvements in some scores, there was considerable variability across minimum, maximum MSFF scores, so the range of patient data was compared to normal values, to demonstrate the percentage of participants who remained outside the normal frequency range at 12 months posttreatment. The women participants’ voices were in the normal women range of MSFF (160–260 Hz)\textsuperscript{13} at both pretreatment and posttreatment. Eight (33.34\%) of the men had an MSFF above the men range (80–160 Hz)\textsuperscript{13} at posttreatment, compared to 15 (55.56\%) at pretreatment, demonstrating improvement (in MSFF) posttreatment.

**Aerodynamic Outcomes.** The MPT of the participants with early glottic cancer significantly increased from pretreatment to posttreatment (\(t [29] = -2.48, p = .019\)). The mean MPT of participants in this study at posttreatment may be considered normal when compared to the lowest standard deviation of the normal men and women MPT range (aged men \(M = 14.68 \pm 6.25\) seconds; aged women \(M = 13.55 \pm 5.7\) seconds).\textsuperscript{13} Some patients’ posttreatment MPT scores still fell below the normal range, indicating some patients had less than normally efficient laryngeal and respiratory control, even after radiotherapy treatment.

**Clinician-Rated Auditory-Perceptual Outcomes.** Participants were perceived by the expert raters as having breathy, strained, and rough voices pre-treatment (Table 3).

Ratings for breathiness and strain significantly reduced in severity posttreatment (\(Z = -4.52, p < .0001, Z = -3.14, p < .0001\), respectively), while the ratings for roughness did not significantly change (Table 4). This result could, perhaps, be explained by the presence of outliers in the data. Perception of glottal fry (a creaky, “popping” quality of voice)\textsuperscript{13} changed significantly (\(Z = -2.89, p = .004\)) from normal to slightly impaired from pretreatment to posttreatment. No other parameter of the PVP demonstrated statistically significant change from pretreatment to posttreatment.

**Patient-Rated Auditory-Perceptual Outcomes.** Twenty-eight patients completed the rating at both pretreatment and posttreatment (Table 4). The mean posttreatment VAS score was significantly higher than the mean pretreatment VAS score (\(Z = -4.433, p < .001\)).

**Voice-Related Quality of Life Outcomes.** Twenty-nine patients completed the V-R QOL (Table 4).

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**Table 2.** Means, medians, standard deviations (SD), and ranges for acoustic and aerodynamic measures at pretreatment and 12 months posttreatment.*

<table>
<thead>
<tr>
<th>Variable</th>
<th>Pretreatment</th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th>12 months posttreatment</th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>No.</td>
<td>Mean</td>
<td>Median</td>
<td>SD</td>
<td>Min–Max</td>
<td>No.</td>
<td>Mean</td>
<td>Median</td>
<td>SD</td>
<td>Min–Max</td>
</tr>
<tr>
<td><strong>Acoustic</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>MSFF, Hz</td>
<td>All 30</td>
<td>189.00</td>
<td>170.36</td>
<td>72.72</td>
<td>117.85–408.56</td>
<td>30</td>
<td>157.82</td>
<td>152.06</td>
<td>40.11</td>
<td>100.51–283.34</td>
</tr>
<tr>
<td></td>
<td>Men* 27</td>
<td>189.13</td>
<td>163.45</td>
<td>76.80</td>
<td>117.85–408.56</td>
<td>27</td>
<td>154.63</td>
<td>149.55</td>
<td>40.52</td>
<td>100.51–283.34</td>
</tr>
<tr>
<td></td>
<td>Women* 3</td>
<td>187.87</td>
<td>187.80</td>
<td>3.08</td>
<td>184.83–190.99</td>
<td>3</td>
<td>186.54</td>
<td>193.08</td>
<td>24.58</td>
<td>159.34–207.21</td>
</tr>
<tr>
<td>Jitter, %</td>
<td>30</td>
<td>6.71</td>
<td>5.60</td>
<td>4.16</td>
<td>1.13–16.66</td>
<td>30</td>
<td>3.27</td>
<td>2.17</td>
<td>3.04</td>
<td>0.72–10.29</td>
</tr>
<tr>
<td>Shimmer, dB</td>
<td>30</td>
<td>1.90</td>
<td>1.80</td>
<td>0.82</td>
<td>0.43–3.15</td>
<td>30</td>
<td>3.07</td>
<td>0.90</td>
<td>1.90</td>
<td>0.21–4.26</td>
</tr>
<tr>
<td>H:N R</td>
<td>30</td>
<td>2.77</td>
<td>2.59</td>
<td>1.85</td>
<td>0.37–7.64</td>
<td>30</td>
<td>4.30</td>
<td>4.67</td>
<td>1.65</td>
<td>0.34–6.57</td>
</tr>
<tr>
<td><strong>Aerodynamic</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>MPT</td>
<td>30</td>
<td>9.59</td>
<td>8.22</td>
<td>5.80</td>
<td>1.57–25.00</td>
<td>30</td>
<td>12.16</td>
<td>11.13</td>
<td>6.44</td>
<td>3.43–29.24</td>
</tr>
</tbody>
</table>

*As sex differences in MSFF are likely, men and women data have been separated. However, both sexes were used for the paired t test as, with only 3 women, their data did not impact on the group mean, and group change across time points, not sex, was the focus of interest.
The mean domain scores for social–emotional ($Z = 4.0, p < .001$), physical functioning ($Z = 2.41; p < .001$), and the total V-R QOL ($Z = 2.5; p < .001$) all improved significantly from pretreatment to posttreatment. Normative V-R QOL values and standard deviations (in brackets) are as follows: physical functioning $= 97.3 (5.8)$; social–emotional $= 98.8 (4.2)$; and V-R QOL (total score) $= 98.0 (3.9)$. When the standard deviations of the normal V-R QOL scores are considered, the patients’ mean physical functioning score may be considered normal, while the patients’ mean social–emotional and total V-R QOL scores are below the normal range at 12 months posttreatment.

**DISCUSSION**

This study is the first to explore the composite effects of radiotherapy treatment on voice, examining changes in acoustic, aerodynamic, and auditory-perceptual aspects of voice, and in V-R QOL. The use of this multidimensional assessment framework has demonstrated the many positive effects of radiotherapy treatment on voice outcomes, and the pretreatment and posttreatment design of this study allows better attribution of the treatment effects (vs the cancer effects) on voice.

This study has implications for the evaluation of the effectiveness and morbidity associated with glottic cancer treatments. Laser surgery has become a prevalent form of treatment for early glottic cancer and, while there may be advantages, there are no good data on which to advise patients about expected voice outcomes, nor to compare that treatment with radiotherapy. There have been calls for randomized control trials to address this question for over a decade. To date, none have been completed, and those in progress are having difficulty in accrual (Coman, 2005, personal communication). If well conducted, using adequate multidimensional tools for

### Table 3. Means, medians, standard deviations (SD) and ranges for clinician-rated perceptual outcomes (PVP scores*) at pretreatment and 12 months posttreatment.

<table>
<thead>
<tr>
<th>Variable</th>
<th>Pretreatment</th>
<th>Posttreatment</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>No.</td>
<td>Mean</td>
</tr>
<tr>
<td>High pitch</td>
<td>30</td>
<td>1.6</td>
</tr>
<tr>
<td>Low pitch</td>
<td>30</td>
<td>1.1</td>
</tr>
<tr>
<td>Monopitch</td>
<td>30</td>
<td>1.3</td>
</tr>
<tr>
<td>Breathiness</td>
<td>30</td>
<td>3.8</td>
</tr>
<tr>
<td>Strain</td>
<td>30</td>
<td>3.5</td>
</tr>
<tr>
<td>Roughness</td>
<td>30</td>
<td>3.4</td>
</tr>
<tr>
<td>Glottal fry</td>
<td>30</td>
<td>1.2</td>
</tr>
<tr>
<td>Pitch breaks</td>
<td>30</td>
<td>1.3</td>
</tr>
<tr>
<td>Phonation breaks</td>
<td>30</td>
<td>1.4</td>
</tr>
<tr>
<td>Voice arrests</td>
<td>30</td>
<td>1.0</td>
</tr>
<tr>
<td>Diplophonia</td>
<td>30</td>
<td>1.2</td>
</tr>
</tbody>
</table>

*PVP scores: 1 = normal, 2 = slight, 3 = mild, 4 = moderate, 5 = moderate–severe, 6 = severe.

### Table 4. Means, medians, standard deviations (SD) and ranges for participant rated outcomes (VAS and V-R QOL questionnaire) at pretreatment and 12 months posttreatment.

<table>
<thead>
<tr>
<th>Variable</th>
<th>Pretreatment</th>
<th>Posttreatment</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>No.</td>
<td>Mean</td>
</tr>
<tr>
<td>Perceptual VAS</td>
<td>28</td>
<td>41.57</td>
</tr>
<tr>
<td>V-R QOL S-E domain</td>
<td>29</td>
<td>74.00</td>
</tr>
<tr>
<td>P-F domain</td>
<td>29</td>
<td>69.86</td>
</tr>
<tr>
<td>Total V-R QOL</td>
<td>29</td>
<td>70.32</td>
</tr>
</tbody>
</table>

Abbreviations: S-E, social-emotional; P-F, physical functioning.
assessment of voice outcomes, prospective non-randomized comparative cohort studies could give us scientifically useful information about treatment outcomes and allow treatment comparisons to be made. Further, with larger sample sizes, stratification by age would be possible, thereby delineating voice results by age categories, which would be useful.

In this study, the voices of the 30 participants, on average, showed significant improvement in acoustic and aerodynamic measures (particularly jitter, shimmer, H:N R, and MPT) at 12 months postradiotherapy treatment. Further, 2 independent expert speech pathologists rated the patients’ voices at that end-point as being significantly less breathy and strained than they were at pretreatment but, nevertheless, still rough with slight glottal fry. Participants themselves reported their voices to be better at posttreatment than they had been at pretreatment and, on average, they felt that this had resulted in an improved V-R QOL.

Improvement in acoustic voice measures, from pretreatment to posttreatment, may be attributed to removal of the cancer from the vocal folds. When cancer is present on 1 or both vocal folds, they typically vibrate irregularly and asymmetrically, not achieving full closure, causing excessive air to escape through the vocal folds. Consequently, the voice signal has high amounts of jitter and shimmer and spectral noise, making it sound rough. People with early glottic cancer may develop hyperfunctional vocal behaviors, such as increasing laryngeal tension, to compensate for their rough-sounding voice. If tension in the cricothyroid and/or vocalis muscle (extrinsic and intrinsic muscles of the larynx) is increased during phonation, MSFF may, in turn, increase, which may explain these participants’ high MSFF values at pretreatment.

It is also possible that, subsequent to an increased attempt to adduct the vocal folds, the supra-laryngeal muscles are recruited, thereby elevating the larynx—which may also increase the patients’ MSFF, as occurs with muscle tension dysphonia. The presence of the high MSFF value (408.56 Hz) at pretreatment may also be an indication of the limitation of the Multi-Dimensional Voice Program when being used to analyze a “noisy” voice.

Vocal function may not normalize completely after radiotherapy, due to the side effects of treatment and/or the continual use of learned compensatory behaviors. At 12 months posttreatment, side effects of treatment may include vocal fold scarring, atrophy, and/or fibrosis. The presence of any of these sequelae can negatively affect the voice in ways similar to the effects of cancer itself.

Visualizing the vocal tract in future studies may assist with determining the physical cause(s) of these acoustic findings in the pretreatment and posttreatment voice.

**Aerodynamic Outcomes.** Patients’ improvement in MPT at 12 months posttreatment indicated greater respiratory and laryngeal control after treatment, which is consistent with other researchers’ findings. MPT may have increased posttreatment secondary to greater vocal fold closure, and thus decreased air escape. Vocal fold closure may not, however, return to normal in some patients; hence, their lowered MPT range, due to radiotherapy-induced vocal fold scarring, atrophy, and/or fibrosis. As participants in this study did not have documented videostroboscopic examination of vocal fold movement(s), this hypothesis needs further examination in future studies.

In this study, 18 (60%) participants were 70 years and older, and many had a significant history of smoking, which may also contribute to their MPT results. There is evidence to suggest that MPT decreases with the physiological changes associated with older age and with smoking, as these factors can reduce vital lung capacity and, consequently, vocal power.

**Auditory-Perceptual Outcomes.** Participants’ voices recorded prior to treatment were rated as mildly-moderately strained, moderately breathy, and mildly rough, by expert speech pathologists who were unaware of the status of the patient. Post-treatment, voices were perceived as being slightly breathy, slight-mildly strained, and mildly rough. It is likely that these may be qualities that distinguish the voices of someone who has had radiotherapy from a normal voice. The effects of age and smoking may be confounding these results, however, as these factors may also contribute to voice quality. The lack of significant improvement in the perception roughness in the voice was consistent with the high amounts of jitter and shimmer and the participants’ low H:N R posttreatment. The increase in glottal fry may be attributed to the fibrotic or atrophic effects of radiotherapy occurring mostly on the edges of the vocal folds and/or air being released through the vocal folds in more irregular bursts, posttreatment.
Participants' self perceptions of voice quality were significantly better at 12 months posttreatment, with 4 participants rating their voice as excellent (highest rating possible) on the VAS, in line with improvement in the acoustic and clinician-rated auditory-perceptual voice characteristics of their voices. However, although there was an average increase in their self-perceptual ratings, the ranges of pretreatment and posttreatment VAS scores overlapped (pretreatment: min = 10, max = 90; posttreatment: min = 25, max = 100), indicating a degree of variability across these participants’ perceptions.

Other researchers have also found (using questionnaires) that irradiated participants with early glottic cancer perceived their voices to be superior posttreatment when compared with pretreatment.

Voice-Related Quality of Life. Participants’ perceptions of their QOL in voice-related activities improved over the 12-month period. The patients’ normal Physical Functioning score at 12 months posttreatment indicates that despite acoustic and perceptual irregularities, their voices at 12 months posttreatment were serviceable for their everyday needs. Nevertheless, the patients’ lower than normal social–emotional score and total score highlights that the participants may still have had emotional issues related to the use of their voice in social situations. Stewart et al demonstrated similar results using the Voice Handicap Index, although their patients also had a mild physical handicap in relation to their QOL, 1 or more years posttreatment.

In summary, this study demonstrates the value of using multidimensional assessment of voice to fully document pretreatment and posttreatment changes.

CONCLUSIONS

In this study, acoustic and auditory-perceptual improvement in patients’ voices following radiotherapy treatment for early glottic cancer has been demonstrated. We would recommend that the multidimensional tools for voice assessment used in this study be used for future comparative cohort studies, or for randomized control trials of treatment outcomes of early glottic cancer. In this way, evidence-based practice will be promoted, and treatment choices may be made from objective outcome data.

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APPENDIX: V-RQOL (HOGIKYAN AND Sethuraman, 1999) AND VISUAL ANALOG SCALE QUESTIONNAIRE

The Visual Analog Scale was incorporated into the V-R QOL questionnaire to obtain a subjective assessment of voice quality by the patient.

We are trying to learn more about how a voice problem can interfere with your day-to-day activities. On this paper, you will find a list of possible voice problems. Please answer all of the questions based on what your voice is like. There are no “right” or “wrong” answers.

Considering both how severe the problem is when you get it, and how frequently it happens, please rate each item below on how “bad” it is (that is, the amount of each problem that you have). Use the following rating scale for rating the amount of the problem:

1 = None—not a problem
2 = A small amount
3 = A moderate problem
4 = A lot
5 = Problem is as “bad as it can be”
<table>
<thead>
<tr>
<th>Because of my voice</th>
<th>How much of a problem is this?</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. I have trouble speaking loudly or in noisy situations.</td>
<td>2</td>
</tr>
<tr>
<td>2. I run out of air and need to take frequent breaths when talking.</td>
<td>2</td>
</tr>
<tr>
<td>3. I sometimes do not know what will come out when I begin speaking.</td>
<td>2</td>
</tr>
<tr>
<td>4. I am sometimes anxious or frustrated (because of my voice).</td>
<td>2</td>
</tr>
<tr>
<td>5. I sometimes get depressed (because of my voice).</td>
<td>2</td>
</tr>
<tr>
<td>6. I have trouble using the telephone (because of my voice).</td>
<td>2</td>
</tr>
<tr>
<td>7. I have trouble doing my job or practicing my profession (because of my voice).</td>
<td>2</td>
</tr>
<tr>
<td>8. I avoid going out socially (because of my voice).</td>
<td>2</td>
</tr>
<tr>
<td>9. I have to repeat myself to be understood.</td>
<td>2</td>
</tr>
<tr>
<td>10. I have become less outgoing (because of my voice).</td>
<td>2</td>
</tr>
<tr>
<td>11. How do you rate the quality of your voice now?</td>
<td>2</td>
</tr>
</tbody>
</table>

Please indicate how you rate the quality of your voice at the present time by placing a small vertical mark on the horizontal line below—the better you think your voice quality is, the farther to the right you should make your mark.

<table>
<thead>
<tr>
<th>No Voice</th>
<th>Excellent</th>
</tr>
</thead>
</table>

The following question was asked only at the baseline assessment:

12. What will the quality of your voice be like 12 months after treatment?

Having discussed with your doctor how your voice might be affected by your cancer and its treatment, please indicate how you think the quality of your voice will be 12 months after you have finished treatment for your cancer. Again, indicate this by marking the horizontal line below.

<table>
<thead>
<tr>
<th>No Voice</th>
<th>Excellent</th>
</tr>
</thead>
</table>

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REFERENCES

28. Coman W. Personal communication to the Australian and New Zealand Head and Neck Society (ANZHNS) meeting, Sydney, Australia, November 2005.