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MAIN ARTICLE

'How does that sound?': objective and subjective voice outcomes following CO_2 laser resection for early glottic cancer

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Abstract

Objective: To investigate the effect of transoral laser microsurgery for early glottic cancer on subjective and objective vocal outcome measures.

Design: Prospective cohort study.

Setting: Tertiary care cancer centre.

Participants: All patients scheduled for transoral laser microsurgery for untreated early primary glottic cancer over a 22-month period and offered voice assessment (31 patients; 19 tumour stage one, 12 tumour stage two).

Main outcome measures: Fundamental frequency, maximum phonation time, calculated jitter, shimmer and subjective voice rating, analysed by tumour stage.

Results: Tumour stage T_1 patients had significantly different fundamental frequencies and maximum phonation times at three months post-operatively, compared with pre-operative values; these differences resolved by 12 months. At 12 months, tumour stage T_2 patients had significantly shorter maximum phonation times, and all patients reported significantly worse subjective voice ratings, compared with pre-operative values.

Conclusion: We found no change in fundamental frequency, jitter and shimmer, one year post-operatively. Maximum phonation time deteriorated but stage one patients appeared to compensate, whereas stage two patients did not. Resection size may be a factor. All patients reported significantly worse subjective voice ratings at one year. Aerodynamic and subjective voice measures appear most sensitive to change in this patient group.

Key words: Laryngeal Neoplasms; Carcinoma; Lasers; Therapeutics

Introduction

Early laryngeal cancer is commonly treated using either primary radiotherapy or transoral laser microsurgery. In our centre, all patients are offered both treatments; however, most opt for transoral laser microsurgery, due to the shorter duration of treatment (with at least similar local control rates).

When signing their written consent form for surgical treatment, patients are required to formally acknowledge the possibility of deterioration in their voice due to the surgery. However, it is difficult to quantify this risk. Therefore, we aimed to prospectively study the voices of patients undergoing transoral laser microsurgery within our institution.

Methods

From January 2002 to November 2007, all patients opting for transoral laser microsurgery for early glottic cancer (i.e. American Joint Committee on Cancer tumour-node-metastasis (TNM) staging of T_1 or T_2, and N_0 and M_0), who had not received other treatment for their cancer, were asked to undertake voice evaluation.

A pre-operative set of voice recordings was made during the same clinic appointment in which patients were booked for surgery. Follow-up recordings were made three and 12 months after surgery. The voice recordings were made in an isolated room away from the clinic, but without formal soundproofing. All recording was performed by a specifically trained speech and language pathologist or clinic nurse. All recordings were made using Computerized Speech Lab (CSL4300) software (Kay Elemetrics, Lincoln Park, NJ, USA). Data were transcribed at the time of recording.

A standardised protocol was used, as previously developed by the speech and language pathologist. The patient was given a short period of instruction on how to use the microphone, and was encouraged to

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TABLE I
SIGNIFICANT ACOUSTIC RESULTS: T_1 CASES

Parameter	Value (mean (range))			Difference*			
	Pre-op	3 mth post-op	12 mth post-op	3 mth post-op		12 mth post-op	
				Diff (95%CI)	*p*	Diff (95%CI)	*p*
F_0(free speech) (Hz)	148.0 (109.9–216.6)	161.9 (122.9–229.0)	159.2 (100.1–255.4)	19.1 (4.2–34.0)	0.02	11.3 (− 2.0 to 24.5)	0.09
F_0(reading) (Hz)	149.8 (103.6–220.7)	161.9 (122.9–229.0)	156.2 (112.1–212.5)	11.7 (1.7–21.7)	0.02	6.0 (− 5.6 to 17.6)	0.29
MPT (sec)	13 (5–24)	11 (6–22)	12 (5–22)	−2.7 (−5.3 to −0.2)	0.04	−1.4 (−4.7 to 2.0)	0.39

*Compared with pre-operative (pre-op) values. T_1=tumour stage one; mth = months; post-op = post-operative; diff = difference; CI = confidence interval; F_0 = fundamental frequency; MPT = maximum phonation time; sec = seconds

keep their mouth at a distance of 30 cm from the microphone, which was mounted on a microphone stand. A period of free speech was recorded, in which the patient described their journey to the clinic. The patient's fundamental frequency in free speech was calculated. The patient was then given the 'rainbow passage' to read, and their fundamental frequency in reading was calculated. The patient's 'jitter' (i.e. frequency perturbation) and 'shimmer' (i.e. amplitude perturbation) were calculated from a recorded segment of the rainbow passage. The patient was instructed to produce the sound 'a' on a full breath of air and to maintain it for as long as possible; the best of three attempts was recorded as the maximum phonation time. Finally, the patient was asked to rate their own voice on a simple ordinal scale of one to five, where one was the worst voice they could imagine having and five was the best.

Data were recorded manually and filed in each patient's individual chart, and a note made on the front sheet about the date of the study. Data were later transcribed into a database (Access 2003; Microsoft, Redmond, Washington, USA) of patients who had undergone laser surgery in our unit. Data were exported initially into a spreadsheet (Excel 2003, Microsoft) and then into a statistical analysis program (PASW version 17; SPSS Inc., Chicago, IL, USA).

Missing data were searched for by retrieving the case notes. We analysed only the data of patients for whom pre-operative and three- and 12-month post-operative voice recordings could be retrieved.

Cases were separated in stage T_1 and T_2 subgroups. Analysis was performed for the total group as well as for the two subgroups.

As the subjective voice rating was a discrete categorical variable, the median was calculated rather than the mean. For other variables, mean pre-operative, three-month post-operative and 12-month post-operative values were calculated. The null hypothesis was that there was a change (in an unspecified direction) between values recorded pre-operatively and those recorded three and 12 months post-operatively, for each variable. A two-tailed, paired Student *t*-test was calculated (using PASW version 17 software) to test the difference between the means of the pre-operative and the three- and 12-month post-operative values; the 95 per cent confidence interval and *p* value were also calculated. The Wilcoxon paired sign rank test was used to analyse the non-parametric subjective voice ratings. A *p* value of less than 0.05 was taken to represent a significant difference between pre- and post-operative recorded values.

Ethical considerations

Our research ethics board granted approval for the study of patient vocal outcomes, prior to patient data collection. Voice outcome data were collected at the time of obtaining consent for surgery; this did not require any additional hospital visits.

Results

Of the 54 patients with at least 24 months follow up, only 41 had undergone pre-operative voice recording. Reasons for lack of voice recording included machine failure, lack of a trained member of staff to make the recording, patient refusal and loss of records.

TABLE II
SIGNIFICANT ACOUSTIC RESULTS: T_2 CASES

Parameter	Value (mean (range))			Difference*			
	Pre-op	3 mth post-op	12 mth post-op	3 mth post-op		12 mth post-op	
				Diff (95%CI)	*p*	Diff (95%CI)	*p*
MPT (sec)	16 (3–36)	10 (3–15)	8 (4–14)	−5.7 (−11.8 to 0.44)	0.07	−7.2 (−12.6 to −1.7)	0.02

*Compared with pre-operative (pre-op) values. T_2=tumour stage two; mth = months; post-op = post-operative; diff = difference; CI = confidence interval; MPT = maximum phonation time; sec = seconds

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TABLE III
SIGNIFICANT ACOUSTIC RESULTS: $T_1 + T_2$ CASES

Parameter	Value (mean (range))			Difference*			
				3 mth post-op		12 mth post-op	
	Pre-op	3 mth post-op	12 mth post-op	Diff (95%CI)	*p*	Diff (95%CI)	*p*
F_0(free speech) (Hz)	151.1 (99.6–240.2)	164.8 (125.3–288.1)	157.1 (83.0–289.7)	13.7 (1.7–250.7)	0.03	6.0 (− 0.7 to 19.2)	0.36
MPT (sec)	16.5 (3–36)	10.3 (3–22)	10.4 (4–22)	−3.3 (−5.6 to −0.9)	0.01	−3.0 (−5.8 to −0.3)	0.03

*Compared with pre-operative (pre-op) values. T_1=tumour stage one; T_2 = tumour stage two; mth = months; post-op = post-operative; CI = confidence interval; F_0 = fundamental frequency; MPT = maximum phonation time; sec = seconds

TABLE IV
SIGNIFICANT VOICE RATING RESULTS

Cases	Value (median (range))			Difference*			
				3 mth post-op		12 mth post-op	
	Pre-op	3 mth post-op	12 mth post-op	Diff (95%CI)	*p*	Diff (95%CI)	*p*
T_1	3 (1–5)	3 (1–5)	2 (1–4)	−0.1 (−1.0 to 0.8)	0.90	−0.7 (−1.3 to −0.1)	0.03
T_2	3.5 (2–5)	3 (2–5)	3 (1–5)	−0.5 (−1.2 to 0.09)	0.08	−0.9 (−1.0 to −0.02)	0.046
T_1+T_2	3.5 (1–5)	3 (1–5)	2.5 (1–5)	−0.3 (−0.8 to 0.3)	0.38	−0.8 (−1.3 to −0.3)	0.02

Data represent subjective voice rating scores unless otherwise indicated. *Compared with pre-operative (pre-op) values. Mth = months; post-op = post-operative; CI = confidence interval; T_1 = tumour stage one; T_2 = tumour stage two

Of these 41 patients, 31 had all three sets of complete recordings available for analysis. These 31 patients comprised five women and 26 men, with a mean age of 67 years (range, 30–84 years). Nineteen patients had stage T_1 tumours and 12 had stage T_2 tumours. Table I summarises the significant results for the stage T_1 patients, Table II summarises results for the stage T_2 patients, and Table III summarises results for stage T_1 and T_2 patients combined.

As patients' subjective voice ratings were non-parametric variables, these are summarised separately in Table IV and Figure 1.

At three months post-operatively, there was a statistically significant change in fundamental frequency (both free speech and reading) and maximum phonation time in the stage T_1 group, compared with pre-operative values. At this same time point, we also observed a significant difference in the free speech fundamental frequency and maximum phonation time for the whole patient group, compared with pre-operative values. However, at this time point there were no significant differences in jitter or shimmer in either subgroup, compared with pre-operative values.

At 12 months post-operatively, there were no statistically significant differences in fundamental frequency (free speech or reading), jitter or shimmer, either for the whole group or for the T_1 or T_2 subgroups, compared with pre-operative values. At this same time point, we also observed no significant difference in the maximum phonation time for the T_1 subgroup, compared with pre-operative values. However, at this time point the maximum phonation time of the T_2 subgroup and the whole group was significantly shorter, compared with pre-operative values.

Three months after surgery, there was no statistically significant difference in subjective vocal rating for any of the groups, compared with pre-operative values.

However, a statistically significant difference was noted for subjective vocal rating in the whole group and in the T_1 and T_2 subgroups, comparing pre-operative and 12-month post-operative values. For subjective vocal ratings, the median pre-operative result, median 12-month post-operative result and median change were respectively 3.5, 2.5 and −1.0 for the whole

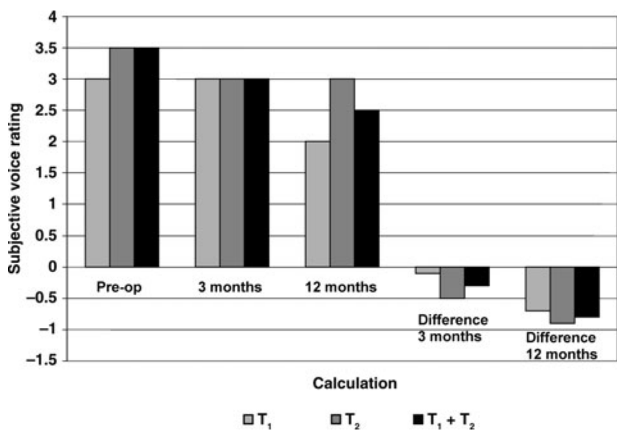

FIG. 1
Median subjective vocal ratings over time, and differences over time (compared with pre-operative values). Pre-op = pre-operative; T_1 = tumour stage one; T_2 = tumour stage two

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group, 3.0, 2.0 and −1.0 for the T_1 subgroup, and 3.5, 3.0 and −0.5 for the T_2 subgroup.

Discussion

In the treatment of early glottic cancer, it has become accepted that radiotherapy, open partial surgery and transoral laser microsurgery provide similar cure rates. Therefore, vocal outcome should be a high priority when assessing the success of these treatments.[1,2]

In this group of patients, it is usually not possible to conduct a pre-disease vocal assessment, as by the time of presentation the patient's voice is potentially altered by their vocal fold pathology. It has been suggested that patients with risk factors for glottic cancer (i.e. heavy smokers and drinkers, and those with pre-existing dysplasia) are also at risk of dysphonia due to these same factors.[1] Therefore, the concept of normative values for objective vocal assessment may not be relevant to these patients.[3,4]

Patients who present with dysphonia due to glottic cancer are often concerned about how the treatment will affect their voice. Although we have no pre-disease 'normal' baseline for such patients, we can assess the vocal effects of surgery using patients' pre-operative status as a baseline.[2] We can also assess patient's perception of their voice, while accepting the subjective, multifactorial nature of such self-evaluation.

This paper only reports our patients' vocal outcomes. Our patients' survival outcomes (published elsewhere) were comparable with published results when matched for stage. Therefore, we were keen to investigate how transoral laser microsurgery, in our hands, affected vocal outcomes, and thus to prospectively collect vocal data on all of these patients where possible.

Synopsis of key findings

In our patients, aside from some initial changes in fundamental frequency for both free speech and reading in the T_1 subgroup, the main changes noted were in maximum phonation time and subjective voice rating.

The fall in maximum phonation time seems logical, as this parameter is directly related to glottic competence. Resective surgery is likely to cause greater air loss through a persistent gap in the glottis, thus shortening the maximum phonation time. In the T_1 subgroup, the maximum phonation time initially shortened by a mean of 2.7 seconds at three-month post-operative testing, compared with pre-operative baseline measurements. At 12 months post-operatively, the change from baseline was less, at only 1.4 seconds shorter. The opposite was seen in the T_2 subgroup, in which the maximum phonation time deteriorated with time. There was a mean decrease of 5.7 seconds at three months post-surgery and of 7.2 seconds at 12 months post-surgery, compared with baseline. As T_1 disease generally requires a smaller volume resection than T_2 disease, it may be that patients compensate better following T_1 resections.[5] This conclusion would be in keeping with other published findings indicating that voices tend towards breathiness following transoral laser microsurgery.[4,6–8]

Comparison with other studies

Our findings for objective voice measures are in keeping with published data, which indicate that transoral laser microsurgery for T_1 glottic tumours leaves patients with a grossly normal voice in many cases.[4–9] The published information generally does not include voice results for larger tumours.

One problem with the published data is the lack of standardisation of vocal outcomes assessed. There have been attempts to provide a suggested minimum dataset for assessing dysphonias.[10] However, due to time and resource limitations it is probably more sensible to use those characteristics that have been shown to measure change in a given condition.

In our study, objective acoustic measures showed no significant change. One other study found an improvement in these measures, while others found a deterioration, or no change.[4,5,8,11]

It is not clear how these values relate to everyday speech, and, as previously discussed, it is not possible to compare them with normative values.

Of the objective measures assessed in the current study, the maximum phonation time showed the most change. There are many factors that can affect maximum phonation time, including underlying lung pathology, patient effort and compliance, and glottic competence. These confounding factors must be considered when assessing any change in this measure. However, other papers have also noted a fall in maximum phonation time following transoral laser microsurgery.[8,11]

Importantly, leakage of air through an incompetent glottis is treatable by various vocal fold medialisation techniques. Zeitels *et al.* reported normalisation in sound pressure level in nine patients who underwent vocal fold medialisation following transoral laser microsurgery.[1] This suggests that some of the voice abnormalities caused by transoral laser microsurgery may be treatable. Speech therapy has also been shown to improve outcomes following transoral laser microsurgery. Van Gogh *et al.* conducted a randomised, controlled trial of 23 patients (treated both with transoral laser microsurgery and with radiotherapy), and demonstrated improvements in both subjective and objective measures of vocal performance following speech therapy.[12]

The present study showed a significant deterioration in subjective voice rating at 12 months, for the whole group and both subgroups, compared with pre-operative values. Interestingly, there was no significant difference at the three-month assessment, compared with pre-operative values. This may be due in part to the complex relationship between patients perception of their voice and other psychological factors.

The subjective scale used was a very basic one to five scale, and as such was not very sensitive. No attempt was made to undertake expert-rated subjective voice assessment, due to resource constraints. A visual analogue scale would have provided more information. The scale used had limitations, including lack of standardisation, reliance on past recall to measure the patient's 'best ever voice', and lack of normal values.

There are several validated scales in existence which have been used for self-assessment of vocal function. The most common is the Vocal Handicap Index, developed and validated by Jacobson *et al.* in 1997 to quantify the psychosocial consequences of voice disorders.[13] The use of such a scale in the future would provide a more sensitive indicator of patients' voice disorder severity, and would facilitate the assessment of intervention outcomes.

Clinical application of study findings

Transoral Laser Microsurgery achieves excellent local control in early glottic cancer. We believe that vocal outcomes are a significant factor when assisting patient choice of treatment. Our study will help clinicians inform patients fully about the quality of their voice after treatment with transoral laser microsurgery.

- **Patients suitable for transoral laser microsurgery of the larynx are often dysphonic at presentation**
- **Acoustic measures may not be sensitive assessors of the effect of laser surgery for early laryngeal cancer**
- **This study assessed voice effects of transoral laser microsurgery for early glottic cancer**
- **Three months post-operatively, maximum phonation time was worse in both tumour stage T_1 and T_2 patients; the latter were unable to compensate for this at 12 months**
- **All patients reported a subjective voice change, still present one year after surgery**

Conclusion

In the present study, we found acoustic objective measures to be unhelpful in this assessment. We noted a significant change in maximum phonation time at three months post-surgery, probably due to incompetent glottic closure. Patients with T_1 tumours seemed to have compensated for this effect by the end of the first post-operative year. However, the effect became greater with time in T_2 patients.

Patients' subjective vocal rating decreased in a statistically significant manner 12 months after transoral laser microsurgery, compared with pre-operative values. We consider this to be an important finding, consistent with the literature, which will help inform our future patient management. We found few previous reports of vocal outcomes for patients with T_2 glottic cancer treated with transoral laser microsurgery; the present study provides evidence that these patients do almost as well as those with T_1 cancers.

References

1 Zeitels SM, Hillman RE, Franco RA, Bunting GW. Voice and treatment outcome from phonosurgical management of early glottic cancer. *Ann Otol Rhinol Laryngol Suppl* 2002;**190**:3–20
2 Peretti G, Piazza C, Balzanelli C, Mensi MC, Rossini M, Antonelli AR. Preoperative and postoperative voice in Tis-Tl glottic cancer treated by endoscopic cordectomy: an additional issue for patient counseling. *Ann Otol Rhinol Laryngol* 2003; **112**:759–63
3 Van Gogh CD, Mahieu HF, Kuik DJ, Rinkel RN, Langendijk JA, Verdonck-de Leeuw IM. Voice in early glottic cancer compared to benign voice pathology. *Eur Arch Otorhinolaryngol* 2007;**264**:1033–8
4 Tamura E, Itahara S, Ogura M, Kohno N. Voice quality after laser surgery or radiotherapy for T1a glottic carcinoma. *Laryngoscope* 2003;**113**:910–14
5 Jong-Lyel R, Dong-Hyun K, Sang Yoon K, II Park C. Quality of life and voice in patients after laser cordectomy for Tis and T1 glottic carcinomas. *Head Neck* 2007;**29**:1010–16
6 Sjögren EV, van Rossum MA, Langeveld TP, Voerman MS, van de Kamp VA, Friebel MO *et al.* Voice outcome in T1a midcord glottic carcinoma laser surgery vs radiotherapy. *Arch Otolaryngol Head Neck Surg* 2008;**134**:965–72
7 Rosier JF, Grégoire V, Counoy H, Octave-Prignot M, Rombaut P, Scalliet P *et al.* Comparison of external radiotherapy, laser microsurgery and partial laryngectomy for the treatment of T1N0M0 glottic carcinomas: a retrospective evaluation. *Radiother Oncol* 1998;**48**:175–83
8 Vilaseca I, Huerta P, Blanch JL, Fernandez-Planas AM, Jimeinez C, Bernal-Sprekelsen M. Voice quality after CO_2 laser cordectomy — what can we really expect? *Head Neck* 2008;**30**:43–9
9 Cohen SM, Garrett CG, Dupont WD, Ossoff RH, Courey MS. Voice-related quality of life in T1 glottic cancer: irradiation versus endoscopic excision. *Ann Otol Rhinol Laryngol* 2006; **115**:581–6
10 Dejonckere PH, Bradley P, Clemente P, Cornut G, Crevier-Buchman L, Friedrich G *et al.* Committee on Phoniatrics of the European Laryngological Society (ELS). A basic protocol for functional assessment of voice pathology, especially for investigating the efficacy of (phonosurgical) treatments and evaluating new assessment techniques: guideline elaborated by the Committee on Phoniatrics of the European Laryngological Society (ELS). *Eur Arch Otorhinolaryngol* 2001;**258**:77–82
11 Núñez Batalla F, Caminero Cueva MJ, Señaris González B, Llorente Pendás JL, Gorriz Gil C, López Llames A *et al.* Voice quality after endoscopic laser surgery and radiotherapy for early glottic cancer: objective measurements emphasizing the Voice Handicap Index. *Eur Arch Otorhinolaryngol* 2008; **265**:543–8
12 van Gogh CD, Verdonck-de Leeuw IM, Boon-Kamma BA, Rinkel RN, de Bruin MD, Langendijk JA *et al.* The efficacy of voice therapy in patients after treatment for early glottic carcinoma. *Cancer* 2006;**106**:95–105
13 Jacobson BH, Johnson A, Grywalski C, Silbergleit A, Jacobson G, Benninger MS. The Voice Handicap Index (VHI): development and validation. *Am J Speech Lang Pathol* 1997;**6**:66–70

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