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Multidimensional assessment of voice and speech after supracricoid laryngectomy with cricohyoidopexy

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Abstract

This study was designed: to evaluate the vocal function in the patients with supracricoid laryngectomy (SCL) compared with normal subjects; to determine the factors affecting voice (such as number of arytenoid(s) preserved and movement of larynx and tongue base); and to determine the correlations between videolaryngostroboscopy, acoustic and perceptual parameters.

Ten patients who underwent SCL with cricohyoidopexy for primary laryngeal squamous cell carcinoma were included into the study. Vocal function was investigated by means or videolaryngostroboscopy. Voice quality was assessed by means of objective acoustic analysis and subjective perceptual ratings by trained raters.

Aberrant, incompetent, and rough mucosal wave was observed in the anterior and superior surfaces of arytenoids(s), the inferior part of tongue base and the lateral walls of the hypopharynx. The acoustic parameters were found to be significantly different from those of normal subjects. The values of perceptual scores were approximately within 50 per cent of normal range. The number of arytenoids spared did not affect acoustic or perceptual measurements. A rough, breathy, unpleasant but intelligible and acceptable voice could be obtained after SCL with cricohyoidopexy.

Key words: Larynx; Carcinoma, Squamous Cell; Surgical Procedures, Operative; Voice; Treatment Outcome

Introduction

Supracricoid laryngectomy (SCL) with cricohyoidopexy (CHP) is described as an alternative technique to total laryngectomy in selected laryngeal cancers, with similar local control and survival rates. In the last two decades, SCL has gained an increasing acceptance around the world.[1–2] Cure rates approaching those of total laryngectomy can be obtained, with preservation of the phonatory function of the larynx. The reconstruction after the resection of the entire epiglottis and pre-epiglottic space is accomplished by a pexis between the cricoid cartilage and the hyoid bone, hence the name 'supracricoid laryngectomy with cricohyoidopexy'. The functional goal of SCL is to preserve speech and swallowing without a permanent tracheostomy.[3] Voice is produced by pulmonary-driven airflow through the reconstructed larynx. Sphincteric action of the neoglottis produces close approximation of the arytenoid cartilages and base of tongue or epiglottis, providing a mucosal source of vibration for phonation.[2] A basic protocol for the functional assessment of voice was accepted by the European Laryngological Society in 2000. This consists of videolaryngostroboscopy, acoustic analysis, perceptual assessment, aerodynamic parameter assessment and subjective rating by the patient.[4]

This present study was designed: to evaluate the vocal function in the patients with SCL compared with normal subjects; to determine the factors affecting voice; and to determine the correlations between videolaryngostroboscopy, acoustic and perceptual parameters.

Materials and methods

Ten consecutive patients who underwent SCL with CHP for primary laryngeal squamous cell carcinoma and who were followed up for at least six months in the Otorhinolaryngology and Head Neck Surgery Department of Celal Bayar University were included into the study. All the patients were alive and well, without recurrence at the primary site or neck after SCL-CHP. All the patients were decannulated and were taking all nutrition by mouth without any limitations for liquids. The control group comprised 13 normal adult volunteer men of similar age. The control subjects had no voice or speech

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complaints. Informed consent was obtained from all subjects. Videolaryngostroboscopy, acoustic analysis and perceptual assessment of voice were performed on all subjects. Vocal function was investigated by videolaryngostroboscopy. Voice quality was assessed by objective acoustic analysis and subjective perceptual ratings by trained raters.

The patients with SCL were recalled for videolaryngostroboscopy and recording of voice samples at least 6 months after surgery. Crevier-Buchman *et al*. have shown that stability of voice and speech parameters occurs at 6 months after SCL-CHP.[5] The age of the patient, time elapsed since surgery, stage of the cancer according to American Joint Committee on Cancer 1997 system, post-operative radiation therapy, neck dissection and the number of arytenoids spared were noted.[6]

The ENT examination and videolaryngo-stroboscopy were performed in both the study and control groups. Videolaryngostroboscopy was recorded on a video tape using a rigid 90° laryngeal telescope. The position(s) and movement(s) of arytenoid(s), vibratory characteristics of the neoglottis, the contact of tongue base to arytenoids during phonation, and vibrating parts of hypopharynx and neolarynx were evaluated.

A digital system was used to record voice samples, and storage was directly performed by the computer. The recordings were made in a quiet room by using a unidirectional microphone. The mouth-to-microphone distance was held constant at 10–15 cm. All subjects were asked to sustain the /a/ vowel at a comfortable pitch and loudness for at least 5 sec. The measurements were made from 3 sec of the mid-portion of the sustained /a/ vowel. The acoustic parameters were fundamental frequency (F0), jitter, percentage jitter, shimmer, signal-to-noise ratio (SNR) and intensity (I0).

Digital recordings for subjective perceptual analysis were collected from each subject during the reading aloud of a standard phonetically balanced Turkish text ("Diyet" passage from Ömer Seyfeddin), equivalent to the "Rainbow Passage", for two min. The recorded voice was assessed by three blinded, skilled raters (a laryngologist, an otolaryngology resident and an audiologist trained in voice rehabilitation). Intra-rater and inter-rater reliability levels were higher than 90 per cent.

The degree of hoarseness was quantified according to the GRBAS (grade, roughness, breathiness, asthenicity, and strain) scale proposed by Hirano.[7] The definition of GRBAS parameters was explained to the raters as: grade, the overall degree of deviance of voice; roughness, the voice quality related to the impression of irregular glottal pulses, of a low-frequency noise component harshness or vocal fry; breathiness, the voice quality related to the audible turbulent noise generated at the glottal level by air leakage; asthenicity, the audible impression of weakness or powerlessness in phonation; and strain, the audible impression of excessive effort, of tension in phonation.[5]

We also included a final judgement on such parameters as intelligibility, pleasantness, and acceptability (IPA). The term 'intelligibility' for the listeners meant the possibility of understanding the extent and quality of a patient's speech. 'Acceptability' and 'pleasantness' referred to the social impact created by each patient's voice for communication in daily life.[8]

The judges used a four-point scoring system to rate each subject for assessing GRBAS and IPA (0 = excellent ability, 1 = good performance, 2 = moderate performance, 3 = poor performance).[4]

Statistical analysis was performed using the Mann Whitney-U test and Spearman's bivariate correlation. The SPSS statistical package was used. Statistical significance was set at the 0.05 level.

Results

The mean age of the patients was 55.1 years (range = 47–69). All of the patients were men. The control group comprised only men with a mean age of 57.7 years (range = 51–69). The median follow-up period was 25 months (range = 6–84). The tumour stages of the patients were two T1, five T2, two T3 and one T4. Adjuvant radiotherapy was performed on only one patient with T4. Ipsilateral modified neck dissection was performed on three patients and bilateral modified neck dissection on seven patients.

Normal mobility of arytenoid(s) was preserved in all patients except for one with slightly impaired arytenoid movement. The arytenoids displaced frontomedially during phonation. Vibrating parts of the neoglottis and hypopharynx were evaluated by videolaryngostroboscopy. Although mucosal wave was observed at the anterior and superior mucosa of the arytenoid(s) and at the inferior part of the tongue base in all patients, the mucosal wave was also detected at the lateral walls of the hypopharynx in some patients. Mucosal wave had high amplitude in all of the patients. The contact of tongue base to arytenoids(s) was observed in six of the patients during phonation via videolaryngostroboscopy.

The parameters of the patient and control groups are compared in Table I. All the parameters were significantly different except intensity. The values of GRBAS and IPA scales were approximately within the 50 per cent of normal range.

Two arytenoids could be spared in three patients and one arytenoid in seven patients. The median and range of the parameters are presented in Table II. No statistical test was performed because the sample sizes were too small; however, the values of the patients with one arytenoid and two arytenoids preserved were found to be similar.

Bivariate correlation was assessed in the patient group. Negative correlations were found between percentage jitter and roughness ($R = -0.63, p = 0.026$) and between jitter and F0 ($R = -0.62, p = 0.027$). Positive correlations were found between percentage jitter and acceptability ($R = 0.64, p = 0.032$), between jitter and stage of tumour ($R = 0.70, p = 0.012$) and between acceptability and stage ($R = 0.65, p = 0.02$).

Discussion

Voice production requires three basic factors: the air

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TABLE I

COMPARISON OF THE PATIENT AND CONTROL GROUPS

	SCL group* [Median (min–max)]		CONTROL group† [Median (min–max)]		*p*
Grade	1.66	(1.00–2.33)	0	(0–0)	<0.001
Roughness	2.00	(1.67–2.33)	0	(0–0.67)	<0.001
Breathiness	2.00	(1.00–2.67)	0	(0–0)	<0.001
Asthenicity	1.00	(0.33–2.33)	0	(0–0.33)	<0.001
Strain	1.33	(0.67–2.00)	0	(0–0)	<0.001
Average of GRBAS	1.60	(1.00–2.13)	0	(0–0.13)	<0.001
Intelligibility	1.17	(0.67–1.67)	0	(0–0.33)	<0.001
Pleasantness	2.00	(1.00–2.67)	0	(0–0.67)	<0.001
Acceptability	1.67	(1.00–2.33)	0	(0–0)	<0.001
Average of GRBAS & IPA	1.58	(0.96–2.08)	0	(0–0.17)	<0.001
Fundamental frequency	94.02	(55.45–188.10)	138.76	(103.00–171.00)	<0.005
Jitter	0.34	(0.15–0.76)	0.01	(0.01–0.05)	<0.001
Percentage jitter	3.46	(1.60–5.88)	0.25	(0.10–0.55)	<0.001
Shimmer	22.39	(10.67–29.96)	4.85	(1.85–7.65)	<0.001
Signal-to-noise ratio	6.78	(2.20–10.10)	16.50	(13.30–21.40)	<0.001
Intensity	77.49	(73.02–82.60)	78.85	(72.79–83.54)	>0.05

GRBAS and IPA scores are the means of the three raters. * = 10. † = 13. GRBAS = Grade, roughness, breathiness, asthenicity, and strain; IPA = Intelligibility, pleasantness, and acceptability

in the lungs, the larynx and the upper respiratory tract. The lungs, supporting muscles, back muscles, diaphragm and abdominal musculature comprise the power source. The larynx serves as the oscillator. The supraglottic vocal tract (supraglottic larynx, pharynx, oral cavity, paranasal sinuses and nasal cavity) serves as resonator.[3] Different parts of the larynx may serve as a vibrating oscillator following partial laryngectomies, however, the vocal folds are the main vibrating part of the larynx in normal subjects. Preservation of one cricoarytenoid unit with an appropriate reconstruction ultimately yields speech and swallowing without a permanent tracheostomy after SCL.[9] We observed that the vibrating parts of the neolarynx were the anterior and superior mucosal surfaces of the arytenoids(s), inferior part of the tongue base, and sometimes the lateral walls of the hypopharynx. Weinstein *et al*. revealed that the mucosal wave occurred on the pliable mucosa of the arytenoid cartilages, including between the arytenoid cartilages, but primarily between the arytenoid cartilages and the rigid surface of the epiglottis, after SCL with CHP.[3] Pastore *et al*. claimed that the voice in patients with SCL seemed to be produced by the vibration of the arytenoid(s), the mucosal layers of the tongue base and the neoglottis.[8] Many parameters, such as glottal closure, regularity, shape, mucosal wave and symmetry, have been used for evaluating videolaryngostroboscopy in the anatomically normal larynx.[4,10] However, most of these could not be used in patients with partial laryngectomy. Weinstein *et al*. developed a new videostroboscopic rating for these patients.[3] We also used different parameters, such as laryngeal closure, site of mucosal wave, type of surgical procedure, number of arytenoids spared and arytenoid movements.

The acoustic parameters used for evaluating voice are F0, intensity, jitter, percentage jitter, shimmer and signal-to-noise ratio.[3–5,11] For acoustic and perceptual analysis, the mid-portion (3 sec) of the

TABLE II

THE EFFECT OF THE NUMBER OF THE ARYTENOIDS PRESERVED ON VOICE AND SPEECH

	One arytenoid preserved* [Median (min–max)]		Two arytenoids preserved† [Median (min–max)]	
Grade	2.00	(1.33–2.33)	1.67	(1.00–1.67)
Roughness	2.00	(1.67–2.33)	2.00	(2.00–2.00)
Breathiness	2.00	(1.67–2.67)	1.67	(1.00–2.00)
Asthenicity	1.00	(0.33–2.33)	1.00	(0.33–1.00)
Strain	1.67	(0.67–2.00)	1.00	(0.67–1.33)
Average of GRBAS	1.67	(1.20–2.13)	1.47	(1.00–1.60)
Intelligibility	1.33	(0.67–1.67)	1.00	(0.67–1.00)
Pleasantness	2.00	(1.67–2.67)	2.00	(1.00–2.00)
Acceptability	1.66	(1.33–2.33)	1.33	(1.00–1.67)
Average of GRBAS &IPA	1.67	(1.21–2.08)	1.46	(0.96–1.58)
Time after surgery	24.00	(2.00–60.00)	72.00	(26.00–84.00)
Fundamental frequency	86.76	(55.45–188.10)	101.70	(100.03–117.30)
Jitter	0.36	(0.18–0.76)	0.24	(0.15–0.35)
Percentage jitter	3.88	(1.60–5.88)	2.42	(2.00–3.49)
Shimmer	23.40	(10.67–29.96)	21.39	(16.19–25.73)
Signal-to-noise ratio	6.90	(2.20–8.80)	6.67	(5.50–10.10)
Intensity	77.25	(73.02–82.60)	77.73	(77.22–77.77)

* = 7. † = 3. GRBAS = Grade, roughness, breathiness, asthenicity, and strain; IPA = Intelligibility, pleasantness, and acceptability.

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sustained /a/ vowel was used, as this method was reported to be the most appropriate.[5] Perturbation measures (in period and amplitude) and harmonics-to-noise computations have emerged as the most robust measures.[4]

- **Aspects of the perceptual and acoustic characteristics of voice after supracricoid laryngectomy with cricohyoidopexy have been studied previously (*Acta Otolaryngol (Stock)* 1998;118:597-599**
- **In this paper the quality of the voice in 10 patients undergoing such partial surgery for laryngeal cancer was analysed using videostroboscopy, acoustic analysis and by using a subjective perceptual grading**
- **Stroboscopic alterations and altered acoustic analysis were found but the perceptual scores were within 50 per cent of the normal range**
- **The quality of the resultant speech was found to be satisfactory for communication and was acceptable to the patients studied**

The averages of F0 for patients with SCL have been reported to be between 108 and 117 Hz. In our study, we found the average F0 in patients with SCL was 100 Hz. This rate was significantly lower than the average F0 in control subjects (138.76 Hz). Pastore *et al*. claimed that F0 and intensity did not primarily affect the quality and perception of voice and speech.[8] We postulate that the lower F0 values in SCL patients are a result of the larger mass of the vibrating arytenoids(s) and tongue base.[8]

We observed that all of the acoustic parameters except intensity were significantly different in the patient group (Table I). The F0 and signal-to-noise ratio were found to be decreased; jitter, percentage jitter and shimmer were found to be increased. All other studies that included acoustic analysis of patients undergoing SCL, that we could identify, were performed without age-matched controls.[2,3,5,8,11] Most of the investigators reported that F0 decreased in patients with SCL, as we observed,[2,3,5,8] while some authors noted increased F0 values.[12] The values of shimmer and jitter in our study group were found to be increased, similar to the literature.[2,5] Perturbation measures (jitter and shimmer) allow for the analysis of the vibratory activity of the glottis.[3] The low fundamental frequency and high jitter, shimmer and harmonics-to-noise values that characterized the acoustic abnormalities of these patients were attributable to the slower than normal, unstable and incompetent mucosal vibratory patterns of the reconstructed laryngeal valving mechanism.[2] A rough mucosal wave in the neoglottis occurs following SCL; this results in increasing perturbation measures. In a similar way, it was reported that voice and speech parameters correlated with stroboscopic findings.[3] One of the findings of our study is that the number of arytenoids spared does not affect voice and speech parameters (Table II). This result might be related to the incomplete neoglottal closure that is always present in SCL, no matter whether one or both arytenoids are preserved.

The vocal folds are not necessary for voice, but they are necessary for high quality of voice.[3] It was reported that the voice was present after SCL but was generally quite hoarse and rough, as we have observed.[3,8] A rough, breathy, unpleasant but intelligible and acceptable voice could be obtained after SCL with CHP. The values of perceptual scores were approximately within 50 per cent of the normal range (Table I). Similar results were reported in perceptual analysis in the literature.[2,5,8,13] The perceptual effects of the biomechanical disturbances, such as incompetent mucosal vibratory pattern, were evidenced by the moderate-to-severe breathy–hoarse vocal quality ratings rendered for all of the patients.[2] Breathiness was due to the free passage of escaping air through the arytenoids. Laryngeal closure correlated with breathiness of voice quality.[3] Positive correlation was reported between acoustic and perceptual parameters.[5] It was noted that laryngeal videostroboscopic examinations of SCL patients demonstrated aberrant mucosal vibratory patterns and morphological features that helped to explain the aforementioned acoustic, aerodynamic and perceptual voice abnormalities obtained.[2]

Conclusion

In our study of 10 patients who underwent SCL with cricohyoidopexy for primary laryngeal squamous cell carcinoma, aberrant, incompetent and rough mucosal waves were observed on the anterior and superior surfaces of the arytenoids(s), the inferior part of the tongue base, and the lateral walls of the hypopharynx. The acoustic parameters were found to be significantly different from normal control subjects. A rough, breathy, unpleasant but acceptable voice could be obtained after SCL with CHP. The quality and perception of speech were found to be satisfactory for communication and social acceptance of the patient.

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